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

Environmental radioactivity in the Netherlands

Results in 2011

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Colophon

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Abstract

Environmental radioactivity in the Netherlands
Results in 2011

In 2011 the Netherlands fulfilled the European obligation to annually measure radioactivity in the environment and in food. According to the Euratom Treaty of 1957, all Member States of the European Union are obliged to perform these measurements each year. In addition the Netherlands complies with the guidelines established in 2000 for performing the measurements uniformly.

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

Radioactivity during two radiological incidents
In 2011 two radiological incidents occurred which could be detected in the Netherlands. Radionuclides originating from the incident at the nuclear site at Fukushima (Japan) were detected from 18 March until 10 June and radionuclides originating from an incident at an institute for medical isotopes in Budapest (Hungary) were detected from 3 until 11 November. The levels of radionuclides measured in the Netherlands as a result of these incidents were very low and do not pose a threat to public health.

Radioactivity in air, food and milk
Except for the measurements during these two radiological incidents, measurements in the air and environment showed normal levels, which are within the range of previous years. The deposition of polonium-210 showed the highest level since 1993, but this level does not pose a threat to public health. Radioactivity levels in food and milk were well below the export and consumption limits set by the European Union, except for one sample. Of 231 samples game and poultry one sample of boar (originating from the Netherlands in January 2011) contained 1.4 times more cesium-137 than the set limit.

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

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

Rapport in het kort

Radioactiviteit in het Nederlandse milieu
Resultaten in 2011

In 2011 voldeed Nederland aan de Europese verplichting om jaarlijks de hoeveelheid radioactiviteit in het milieu en in voeding te meten. Volgens het Euratom-verdrag uit 1957 zijn alle lidstaten van de Europese Unie verplicht deze metingen jaarlijks te verrichten. Nederland voert daarbij de aanbevelingen uit die in 2000 zijn opgesteld om de metingen volgens een bepaald stramien uit te voeren. De metingen leveren achtergrondwaarden op, oftewel radioactiviteits-niveaus die onder normale omstandigheden aanwezig zijn. Deze waarden kunnen bijvoorbeeld bij calamiteiten of rampen als referentie dienen. Het RIVM rapporteert namens Nederland over radioactiviteit in het milieu aan de Europese Unie.

Radioactiviteit gedurende twee radiologische incidenten
In 2011 vonden twee radiologische incidenten plaats waarna in Nederland radionucliden te meten waren. Van 18 maart tot en met 10 juni zijn radionucliden aangetroffen die afkomstig waren van het incident met de nucleaire installatie bij Fukushima (Japan), en van 3 tot 11 november afkomstig van een incident bij een instituut voor medische isotopen in Budapest (Hongarije). De niveaus van radionucliden die in Nederland als gevolg van deze incidenten zijn aangetoond, waren zeer laag en vormen geen risico voor de volksgezondheid.

Radioactiviteit in lucht, voedsel en melk
De metingen in lucht en omgeving lieten een normaal beeld zien, dat niet verschilde van voorgaande jaren. De depositie van polonium-210 is het hoogst sinds 1993, de aangetroffen radioactiviteitsniveaus zijn echter niet schadelijk voor de volksgezondheid. De radioactiviteitsniveaus in voedsel en melk liggen net als in voorgaande jaren duidelijk onder de Europese limieten die zijn opgesteld voor consumptie en export, op één monster na. Van de 231 monsters wild en gevogelte bevatte één monster wild zwijn (van januari 2011) 1,4 keer meer cesium-137 dan de gestelde limiet.

Radioactiviteit in oppervlaktewater
In het oppervlaktewater liggen de radioactiviteitsniveaus op een aantal locaties boven de streefwaarden die in de Vierde Nota waterhuishouding (1998) zijn bepaald. De overschrijdingen zijn echter zodanig dat ze niet schadelijk zijn voor de volksgezondheid. Voor oppervlaktewater bestaan er geen limieten voor radioactieve stoffen, waarop wordt toegezien en gehandhaafd. Wel zijn er streefwaarden, die bij voorkeur niet overschreden mogen worden.

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

Preface

The following institutes contributed to the report:

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

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

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

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

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

Contents

Summary

The Dutch government is obliged to measure radioactivity in air, water and soil under the terms of the Euratom Treaty of 1957. In 2000, the European Union specified this treaty by means of recommendations describing the matrices to be measured (air dust, ambient dose, surface water, drinking water, milk and food) and the frequency of the measurements. The results should be published yearly. This report presents the results of radioactivity measurements made in the Dutch environment in 2011. The measurements were carried out by RIVM, RWS, RIKILT, NVWA and (tasked by N.V. EPZ) NRG.

In 2011 two radiological incidents occurred which could be detected in the Netherlands. In the weeks (from 18 March until 10 June) following the incident at the nuclear site at Fukushima (Japan) radionuclides originating from the incident (^{129}Te, ^{129m}Te, ^{132}Te, ^{131}I, ^{132}I, ^{134}Cs, ^{136}Cs and ^{137}Cs) were measured in air, air dust and deposition. During week 45 (from 3 until 11 November) ^{131}I could be measured in air dust most probably as a result of an incident at the Institute of Isotopes, Budapest.

The levels of radionuclides measured following the Fukushima and Budapest incidents do not pose a threat to the public health. The absorbed dose as a result of inhalation of ^{131}I following the Fukushima incident is less than 0.00001 mSv. To put this into perspective, the dose which a resident of the Netherlands receives annually is 2.4 mSv on average. The dose from other paths of exposure and from the other radionuclides measured following the Fukushima incident is much lower than the dose as a result of inhalation of ^{131}I, and is therefore insignificant, as is the dose as a result of ^{131}I following the Budapest incident.

During the Fukushima incident 23–41% of ^{131}I in air was aerosol bound, 10-31% was elementary I_2 and 41–57% was organically bound (e.g. CH_3I).

Yearly averaged activity concentrations in air dust were determined for gross α, gross β, ^{7}Be, ^{137}Cs and ^{210}Pb.

The yearly total activity in deposition was determined for gross α, gross β, ^{3}H, ^{7}Be, ^{137}Cs, ^{210}Pb and ^{210}Po. Gross α and gross β is the total activity of nuclides emitting α and β radiation, respectively. The results are presented in Table S1 and are within the range of those in previous years, except for the yearly total activity in deposition from ^{210}Po (61.4 Bq·m^{-2}), which was the highest since 1993, although this level does not pose a threat to public health.

The National Radioactivity Monitoring Network (NMR) was used to determine the activity concentrations of gross α and artificial β (β radiation emitted by man-made nuclides) in air dust. The difference between the NMR data and those mentioned above is due to the contribution of short-lived natural radionuclides (radon daughters). The yearly averaged gross α activity concentration in air dust was 4.1 Bq·m^{-3}. The yearly average of the artificial β activity concentration did not deviate significantly from zero. The NMR was also used to determine the ambient dose equivalent rate: the yearly averaged measured value was 73.1 nSv·h^{-1}.

In surface water, the yearly averaged activity concentrations of gross α, residual β (gross β minus naturally occurring ^{40}K), ^{3}H, ^{90}Sr and ^{226}Ra were determined. The

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

The gross α activity concentrations in the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse exceeded the target value (100 mBq·L^{-1}) in 1 out of the 12, 9 out of the 12, 10 out of the 13, 1 out of the 13, 13 out of the 13 and 1 out of the 13 samples taken, respectively. The yearly averaged gross α activity concentrations in the Noordzeekanaal, Nieuwe Waterweg and Scheldt (165, 180 and 290 mBq·L^{-1}, respectively) were above the target value, but within the range of those in previous years.

The residual β activity and ^{90}Sr activity concentrations (both individual samples and yearly average) were below the target value (200 mBq·L^{-1} and 10 mBq·L^{-1}, respectively).

The ^{3}H activity concentrations in the Rhine, Scheldt and Meuse exceeded the target value (10 Bq·L^{-1}) in 2 out of the 13, 5 out of the 7 and 10 out of the 13 samples taken, respectively. The yearly averaged ^{3}H activity concentrations in the Scheldt and Meuse (14.0 and 28.0 Bq·L^{-1}, respectively) were above the target value, but within the range of those in previous years.

The ^{226}Ra activity concentrations in the Nieuwe Waterweg and Scheldt exceeded the target value (5 mBq·L^{-1}) in 1 out of the 7 and 5 out of the 7 samples taken, respectively. The yearly averaged ^{226}Ra activity concentration in the Scheldt (7.3 mBq·L^{-1}) was above the target value, but within the range of those in previous years.

The ^{60}Co activity concentration in suspended solids in the Meuse exceeded the target value (10 Bq·kg^{-1}) in 3 out of the 52 samples taken, but the yearly averaged ^{60}Co activity concentration was below the target value.

The ^{131}I activity concentrations in suspended solids in the Noordzeekanaal and Meuse exceeded the target value (20 Bq·kg^{-1}) in 6 out of the 6 and 16 out of the 52 samples taken, respectively. The yearly averaged ^{131}I activity concentration in the Meuse was below the target value. The yearly averaged ^{131}I activity concentration in the Noordzeekanaal (54 Bq·kg^{-1}) was higher than those in previous years and exceeded the target value. The contribution of the Fukushima incident to the ^{131}I activity concentration in suspended solids is insignificant.

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

The ^{210}Pb activity concentrations in the Nieuwe Waterweg, Rhine, Scheldt and Meuse exceeded the target value (100 Bq·kg^{-1}) in 3 out of the 7, 4 out of the 6, 2 out of the 7 and 6 out of the 6 samples taken, respectively. The yearly averaged ^{210}Pb activity concentrations in the Rhine and Meuse (104 and 165 Bq·kg^{-1}, respectively) were above the target value, but within the range of those in previous years.

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

^{137}Cs and ^{210}Pb activity concentrations in suspended solids in seawater were within the range of those in previous years.

Typical activities found in raw input water for drinking water production are presented in Table S1. There is little potassium (and thus ^{40}K) present in this water. The gross α activity concentrations were equal or below 0.1 Bq·L^{-1}. The gross β activity concentrations were below 1.0 Bq·L^{-1} and the ^{3}H activity concentrations were below 100 Bq·L^{-1}.

The results of the monitoring program for milk and mixed diet are presented in Table S1. Radioactivity was measured in well over 1,500 food products, of which 26 samples contained ^{137}Cs. Eight samples of honey and eighteen samples of game contained ^{137}Cs. Only one sample was above the set limit of 600 Bq·kg^{1}. A sample of boar (originating from the Netherlands in January 2011) contained 830 ± 26 Bq·kg^{-1} ^{137}Cs.

In addition to measurements on milk and food, RIKILT Wageningen UR performed measurements on grass samples on two separate occasions in 2011. None of the grass samples taken during either campaign contained artificial radionuclides above the detection limits. Naturally occurring ^{40}K was detected in 111 out of the 130 samples taken; the activity varied from 5 to 300 Bq·m^{-2}.

Data on environmental samples taken around the nuclear power plant at Borssele are presented in Table S2. The levels of ^{131}I detected in air and grass (as an equivalent of deposition) on 6 April are in range with the levels found by RIVM in air and deposition in the weeks following the Fukushima incident.

In 2011, the Netherlands complied with the Euratom recommendations on annually measuring radioactivity in the environment and in food.

Samenvatting

In het kader van het Euratom Verdrag uit 1957 is de Nederlandse overheid verplicht om radioactiviteitsgehalten te meten in de compartimenten lucht, water en bodem. In 2000 heeft de Europese Unie dit nauwkeuriger gespecificeerd middels aanbevelingen. Hierin wordt in detail beschreven wat moet worden gemeten (luchtstof, de omgevingsdosis, oppervlaktewater, drinkwater, melk en voedsel) en met welke frequentie. De resultaten dienen jaarlijks te worden gerapporteerd. In dit rapport worden de resultaten gegeven van radioactiviteitsmetingen in het Nederlandse milieu in 2011. De metingen zijn verricht door RIVM, RWS, RIKILT, NVWA en (in opdracht van N.V. EPZ) NRG.

In 2011 vonden twee radiologische incidenten plaats die in Nederland te meten waren. In de weken (van 18 maart tot en met 10 juni) na het incident bij de nucleaire installatie bij Fukushima (Japan) zijn in lucht, luchtstof en depositie radionucliden aangetroffen die afkomstig zijn van het incident (^{129}Te, ^{129m}Te, ^{132}Te, ^{131}I, ^{132}I, ^{134}Cs, ^{136}Cs en ^{137}Cs). In week 45 (3 tot en met 11 november) werd ^{131}I aangetroffen in luchtstof dat zeer waarschijnlijk afkomstig is van een incident bij het Institute of Isotopes in Budapest.

De aangetoonde niveaus van radionucliden als gevolg van de incidenten te Fukushima en Budapest vormen geen risico voor de volksgezondheid. De opgelopen dosis van inhalatie van ^{131}I als gevolg van het incident te Fukushima is minder dan 0,00001 mSv. Om dit in perspectief te plaatsen: de dosis die een persoon in Nederland jaarlijks oploopt is 2,4 mSv. De doses als gevolg van andere blootstellingroutes en andere radionucliden zijn nog veel lager dan die als gevolg van inhalatie van ^{131}I, en daarmee insignificant. Hetzelfde kan gezegd worden voor de dosis van ^{131}I als gevolg van het incident te Budapest.

Gedurende het incident te Fukushima was 23-41% van het ^{131}I in lucht aerosol gebonden, 10-31% was elementair I_2 en 41-57% was organisch gebonden (CH_3I).

In luchtstof werd de jaargemiddelde activiteitsconcentratie bepaald van totaal-α, totaal-β, ^{7}Be, ^{137}Cs en ^{210}Pb.

In depositie werd de totale jaarlijkse activiteit bepaald van totaal-α, totaal-β, ^{3}H, ^{7}Be, ^{137}Cs, ^{210}Pb en ^{210}Po. Totaal-α respectievelijk totaal-β is de totale activiteit aan α- dan wel β-straling uitzendende nucliden. De resultaten zijn weergegeven in Tabel S1 en vallen binnen het bereik van voorgaande jaren, met uitzondering van de depositie van ^{210}Po (61,4 Bq·m^{-2}) die het hoogst sinds 1993 is. Dit niveau vormt geen gevaar voor de volksgezondheid.

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 4,1 Bq·m^{-3}. Het jaargemiddelde voor de kunstmatige β-activiteitsconcentratie in luchtstof week niet significant af van nul. Met het NMR werd daarnaast het omgevingsdosisequivalenttempo bepaald, de jaargemiddelde meetwaarde was 73,1 nSv h^{-1}.

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

De totaal α-activiteitsconcentratie in het IJsselmeer, het Noordzeekanaal, de Nieuwe Waterweg, de Rijn, de Schelde en de Maas overschrijdt de streefwaarde (100 mBq·L^{-1}) in respectievelijk 1 van de 12, 9 van de 12, 10 van de 13, 1 van de 13, 13 van de 13 en 1 van de 13 genomen monsters. De jaargemiddelde totaal α-activiteitsconcentraties in het Noordzeekanaal, de Nieuwe Waterweg en de Schelde (respectievelijk 165, 180 en 290 mBq·L^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De rest β-activiteitsconcentraties en de ^{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 Rijn, de Schelde en de Maas overschrijdt de streefwaarde (10 Bq·L^{-1}) in respectievelijk 2 van de 13, 5 van de 7 en 10 van de 13 genomen monsters. De jaargemiddelde ^{3}H-activiteitsconcentraties in de Schelde en de Maas (respectievelijk 14,0 en 28,0 Bq·L^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De ^{226}Ra-activiteitsconcentratie in de Nieuwe Waterweg en de Schelde overschrijdt de streefwaarde (5 mBq·L^{-1}) in respectievelijk 1 van de 7 en 5 van de 7 genomen monsters. De jaargemiddelde ^{226}Ra-activiteitsconcentratie in de Schelde (7,3 mBq·L^{-1}) is boven de streefwaarde, maar valt binnen het bereik van voorgaande jaren.

De ^{60}Co-activiteitsconcentratie in zwevend stof in de Maas overschrijdt de streefwaarde (10 Bq·kg^{-1}) in 3 van de 52 genomen monsters. De jaargemiddelde ^{60}Co-activiteitsconcentratie is echter beneden de streefwaarde.

De ^{131}I-activiteitsconcentratie in zwevend stof in het Noordzeekanaal en de Maas overschrijdt de streefwaarde (20 Bq·kg^{-1}) in respectievelijk 6 van de 6 en 16 van de 52 genomen monsters. De jaargemiddelde ^{131}I-activiteitsconcentratie in de Maas is echter beneden de streefwaarde. De jaargemiddelde ^{131}I-activiteitsconcentratie in het Noordzeekanaal (54 Bq·kg^{-1}) is hoger dan in voorgaande jaren en overschrijdt de streefwaarde. De bijdrage van het incident in Fukushima aan de ^{131}I-activiteitsconcentratie in zwevend stof is niet significant.

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, de Schelde en de Maas overschrijdt de streefwaarde (100 Bq·kg^{-1}) in respectievelijk 3 van de 7, 4 van de 6, 2 van de 7 en 6 van de 6 genomen monsters.
De jaargemiddelde ^{210}Pb-activiteitsconcentraties in de Rijn en de Maas (respectievelijk 104 en 165 Bq·kg^{-1}) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

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

Gangbare activiteitsconcentraties die in ruw water voor de drinkwaterproductie gevonden worden, zijn weergegeven in Tabel S1. In dit water is weinig kalium, en dus ^{40}K, aanwezig. In 2011 waren de totaal α-activiteitsconcentraties gelijk aan of lager dan 0,1 $Bq \cdot L^{-1}$. De totaal β-activiteitsconcentraties waren lager dan 1,0 $Bq \cdot L^{-1}$ en de ^{3}H-activiteitsconcentraties waren lager dan 100 $Bq \cdot L^{-1}$.

De resultaten van het meetprogramma voor melk en voedsel zijn weergegeven in Tabel S1. Radioactiviteit werd geanalyseerd in meer dan 1500 voedselprodukten waarvan 26 monsters ^{137}Cs bevatte. Acht monsters honing en 18 monsters wild bevatte ^{137}Cs. Slechts één monster was boven de limiet van 600 $Bq \cdot kg^{-1}$. Een monster wild zwijn (afkomstig uit Nederland van januari 2011) bevatte 830 ± 26 $Bq \cdot kg^{-1}$ ^{137}Cs.

Naast metingen in melk en voedsel heeft RIKILT Wageningen UR in 2011 metingen in gras uitgevoerd in twee aparte campagnes. In de grasmonsters genomen tijdens beide campagnes werden geen kunstmatige radionucliden boven de detectielimieten aangetroffen. Natuurlijk voorkomend ^{40}K werd aan getroffen in 111 van de 130 grasmonsters, waarbij de activiteit varieerde van 5 tot 300 $Bq \cdot m^{-2}$.

Gegevens betreffende milieumonsters genomen rondom de kerncentrale Borssele zijn weergegeven in Tabel S2. De gemeten niveaus ^{131}I in lucht en gras (als een equivalent van depositie) op 6 april vallen binnen het bereik van de niveaus in lucht en depositie gemeten door het RIVM in de weken na het Fukushima incident.

Nederland voldeed in 2011 aan alle Europese aanbevelingen ten aanzien van de jaarlijkse radioactiviteitsmetingen in het milieu en in voedsel.

Table S1: Summary of the results of the Dutch monitoring program in 2011

Matrix	Parameter	Locations	Values	Frequency (per year)
Air dust [1]	Gross α	1	0.029 mBq·m^{-3}	52
	Gross β	1	0.494 mBq·m^{-3}	52
	^{7}Be	1	3.820 mBq·m^{-3}	52
	^{137}Cs	1	0.00472 mBq·m^{-3} [2]	52
	^{210}Pb	1	0.496 mBq·m^{-3}	52
Deposition [2]	Gross α	1	45.0 Bq·m^{-2}	12
	Gross β	1	123 Bq·m^{-2}	12
	^{3}H	1	332–1,540 Bq·m^{-2} [3]	12
	^{7}Be	1	1,320 Bq·m^{-2}	52
	^{137}Cs	1	0.5–1.5 Bq·m^{-2} [3]	52
	^{210}Pb	1	104 Bq·m^{-2}	52
	^{210}Po	1	61.4 Bq·m^{-2}	12
Surface water [1]	Gross α	6	12–514 mBq·L^{-1}	12–13 [4]
	Residual β	6	< 1–192 mBq·L^{-1}	12–13 [4]
	^{3}H	6	784 – 55,100 mBq·L^{-1}	6–13 [4]
	^{90}Sr	3	< 1–6 mBq·L^{-1}	6–7 [4]
	^{226}Ra	4	1–13.6 mBq·L^{-1}	6–7 [4]
Suspended solids in surface water [1]	^{60}Co	6	< 1–23.7 Bq·kg^{-1}	6–52 [4]
	^{131}I	6	< 1–114 Bq·kg^{-1}	6–52 [4]
	^{137}Cs	6	1–16.1 Bq·kg^{-1}	6–52 [4]
	^{210}Pb	4	60.1–253 Bq·kg^{-1}	6–7 [4]
Seawater [1]	Gross α	8	70–1,080 mBq·L^{-1}	4–13 [4]
	Residual β	8	47–226 mBq·L^{-1}	4–13 [4]
	^{3}H	8	108–5,870 mBq·L^{-1}	4–13 [4]
	^{90}Sr	4	< 1–7 mBq·L^{-1}	4–13 [4]
Suspended solids in seawater [1]	^{137}Cs	4	< 1–8.41 Bq·kg^{-1}	3–4 [4]
	^{210}Pb	4	56.3–127 Bq·kg^{-1}	3–4 [4]
Drinking water [1]	Gross α	185	< 0.1 Bq·L^{-1}	355 [5]
	Gross β	191	< 0.1 Bq·L^{-1}	414 [5]
	Residual β	174	< 0.2 Bq·L^{-1}	377 [5]
	^{3}H	188	< 4.2 Bq·L^{-1}	400 [5]
Milk [1]	^{40}K	24	59.3 Bq·L^{-1}	891 [5]
	^{60}Co	24	< 1.4 Bq·L^{-1}	891 [5]
	^{90}Sr	24	< 0.6 Bq·L^{-1}	50 [5]
	^{131}I	24	< 0.6 Bq·L^{-1}	891 [5]
	^{134}Cs	24	< 0.6 Bq·L^{-1}	891 [5]
	^{137}Cs	24	< 0.5 Bq·L^{-1}	891 [5]

Continued on the next page

Table S1: Continued

Matrix	Parameter	Locations	Values	Frequency (per year)
Food [6, 7, 8]				
Grain and grain products	^{137}Cs	-	< 10 Bq·kg^{-1}	70 (0) [9]
Vegetables	^{137}Cs	-	< 10 Bq·kg^{-1}	130 (0) [9]
Fruit and fruit products	^{137}Cs	-	< 10 Bq·kg^{-1}	57 (0) [9]
Milk and dairy products	^{137}Cs	-	< 10 Bq·kg^{-1}	44 (0) [9]
Meat and meat products	^{137}Cs	-	< 10 Bq·kg^{-1}	61 (0) [9]
Game and poultry	^{137}Cs	-	< 10 Bq·kg^{-1}	35 (0) [9]
Salads	^{137}Cs	-	< 10 Bq·kg^{-1}	30 (0) [9]
Oil and butter	^{137}Cs	-	< 10 Bq·kg^{-1}	36 (0) [9]
Honey	^{137}Cs	-	15–209 Bq·kg^{-1}	91 (8) [9]
Food [6, 7, 10]				
Vegetables	^{137}Cs	-	< 0.5 Bq·kg^{-1}	50 (0) [9]
Meat and meat products	^{137}Cs	-	< 0.5 Bq·kg^{-1}	667 (0) [9]
Game and poultry	^{137}Cs	-	3.3–830 Bq·kg^{-1}	196 (18) [9]
Eggs	^{137}Cs	-	< 0.5 Bq·kg^{-1}	125 (0) [9]
Fish and seafood products	^{137}Cs	-	< 0.5 Bq·kg^{-1}	151 (0) [9]
Mixed diet	^{90}Sr	-	< 5 Bq·kg^{-1}	41 (0) [9]

[1] Yearly average.

[2] Excluding the Fukushima period (18 March until 10 June 2011) the yearly average for 2011 was 0.000445 mBq·m^{-3}.

[2] Yearly total.

[3] A 68% confidence range.

[4] Frequency depends on location.

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

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

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

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

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

[10] As measured by RIKILT Wageningen UR.

Table S2: Summary of the results of the monitoring program in the vicinity of the nuclear power plant at Borssele in 2011

Matrix	Parameter	Locations	Values [1]	Frequency (per year)
Air dust	Gross α	5	0.001–0.295 mBq·m^{-3}	12
	Gross β	5	0.131–0.98 mBq·m^{-3}	12
	^{60}Co	5 [2]	< 0.016–< 0.08 mBq·m^{-3}	12
	$^{131}I_{el}$ [3]	5 [2]	< 0.1–0.172 mBq·m^{-3}	12
	$^{131}I_{or}$ [3]	5 [2]	< 0.2–0.42 mBq·m^{-3}	12
	^{137}Cs	5 [2]	< 0.014–< 0.06 mBq·m^{-3}	12
	Nat. [4]	5 [2]	0.9–2.3 mBq·m^{-3}	12
Grass	^{60}Co	5 [2]	< 1–< 5 Bq·kg^{-1}	12
	^{131}I	5 [2]	< 0.9–10.5 Bq·kg^{-1}	12
	^{137}Cs	5 [2]	< 0.9–< 4 Bq·kg^{-1}	12
Soil	^{54}Mn	4	< 0.2 Bq·kg^{-1}	1
	^{60}Co	4	< 0.2 Bq·kg^{-1}	1
	^{134}Cs	4	< 0.2 Bq·kg^{-1}	1
	^{137}Cs	4	0.72–1.95 Bq·kg^{-1}	1
Water	Residual β	4	0.036–0.141 Bq·L^{-1}	12
	^{3}H	4	7.1–9.9 Bq·L^{-1}	12
Suspended solids	Gross β	4	0.3–1.64 kBq·kg^{-1}	12
Seaweed	^{60}Co	4 [2]	< 2–< 4 Bq·kg^{-1}	12
	^{131}I	4 [2]	0.9–< 3 Bq·kg^{-1}	12
	^{137}Cs	4 [2]	< 2–< 3 Bq·kg^{-1}	12
Sediment	^{60}Co	4 [2]	< 0.3–< 0.4 Bq·kg^{-1}	12
	^{131}I	4 [2]	< 0.2–< 0.4 Bq·kg^{-1}	12
	^{137}Cs	4 [2]	0.34–2.28 Bq·kg^{-1}	12

[1] Given range represents values of individual samples.

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

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

[4] Naturally occurring γ-emitters.

1 Introduction

Levels of radioactive nuclides of natural origin, such as ^{40}K and daughters from the uranium and thorium series may be enhanced as a result of human activities (e.g. emissions from factories processing ores). Man-made radionuclides are found in the environment as a result of, for example, nuclear weapons tests or discharges from nuclear installations. Monitoring radiation in the environment provides knowledge about radiation levels under normal circumstances and enables the confirmation of abnormal levels. This report presents the results of radioactivity measurements made in the environment in the Netherlands. The aims of this report are threefold: 1) to present a survey of radioactivity measurements made in the Dutch environment under normal circumstances (in 2011 it was extended with measurements following two radiological incidents abroad); 2) to determine the compliance of monitoring programs in the Netherlands with the EU recommendation and to report possible omissions; 3) to constitute the Dutch national report on radioactivity in the environment to the EU and to other Member States.

In the chapters, the results will be presented in graphs and tables. More detailed tables are presented in Appendix A. Chapters 2 to 8 are subdivided according to the structure of the Recommendation on the Application of Article 36 of the Euratom Treaty [1] and give the results of measurements for various environmental compartments. Chapter 9 is an additional chapter for 2011 and contains data on measurements on grass samples. Chapter 10 contains data on environmental samples taken around the nuclear power plant at Borssele. General conclusions from Chapters 1 to 10 are presented in Chapter 11.

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

2 Airborne particles

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

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

The collection efficiency of the filter type G-3 was determined to be 96 ± 1% with a flow rate of approximately 760 $Nm^3 \cdot h^{-1}$ based on ^{7}Be and ^{210}Pb results [4]. The results presented in this chapter are corrected for this collection efficiency.

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

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

The data from 1991 to 2004 were reanalysed to determine the yearly averages by the method described in Appendix B [7]. This can lead to small differences between the data presented in this report and the data reported prior to 2005.

Table 2.1: Monitoring program for the determination of radioactive nuclides in air dust; differences between the sampling procedures until 2011 and from 2011 onwards

Matrix	Location	Parameter	Sample period	Sample volume	Analysis frequency
Sampling with former HVS on a glass fibre filter (Schleicher & Schuell GF10) until 2011					
Air dust	Bilthoven	gross α, gross β	week	500 m^3 (1)	weekly
	Bilthoven	γ-emitters (2)	week	50,000 m^3	weekly
Sampling with Snow White HVS on a polypropylene filter (G-3) from 2011 onwards					
Air dust	Bilthoven	gross α, gross β	week	925 m^3 (3)	weekly
	Bilthoven	γ-emitters (2)	week	125,000 m^3	weekly

(1) A sub-sample of 1% from the filter through which about 50,000 m^3 is sampled.

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

(1) A sub-sample of 0.74% from the filter through which about 125,000 m^3 was sampled.

Paragraphs 2.1 and 2.2 present data on radioactive nuclides measured regularly. Data on additional radioactive nuclides measured following the incidents at Fukushima (Japan) and Budapest (Hungary) are presented in paragraph 2.3.

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 [5]. The period between sampling and analysis was five to ten days, which is long compared with the decay time of the short-lived decay products of ^{222}Rn and ^{220}Rn. This is done to ensure that these naturally occurring decay products do not contribute to the measured α and β activity concentrations. The frequency distributions of gross α activity and gross β activity concentrations in air dust are given in Figures 2.2 and 2.3, respectively.

The yearly averages of the gross α and β activity concentrations of long-lived nuclides in 2011 were within the range of the results from the period 1992-2010, as illustrated in Figure 2.4. Since 2007, a new (more realistic) calibration for gross α has been implemented. The new calibration factor is 1.4 times higher than the one used in previous years, which results in lower reported gross α activities.

A change in equipment with a coinciding change in filter type resulted in a change in the reported gross α (-24%) and gross β (-15%) results for which no correction is applied [4]. A possible explanation is a deeper permeation of the air dust in the filter type G-3 than in the filter type GF10. This results in a difference in self-absorption of the α and β particles measured, i.e. lower gross α and gross β results.

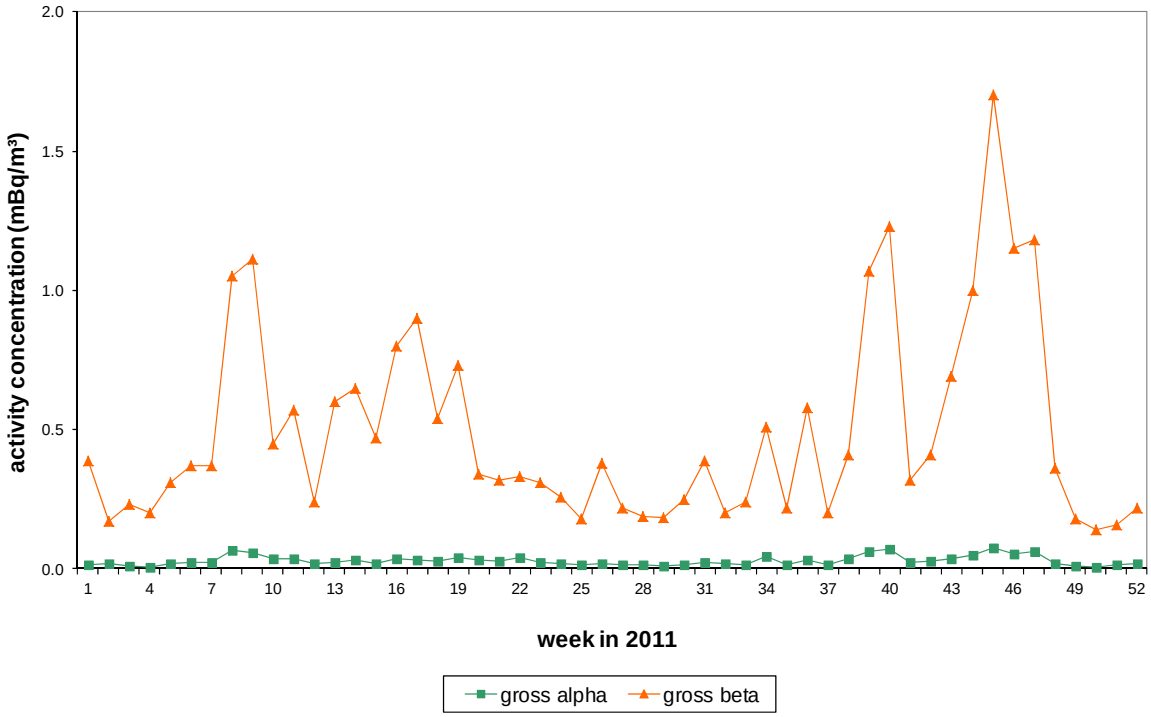


Figure 2.1: Weekly averaged gross α and β activity concentrations of long-lived nuclides in air dust sampled at RIVM

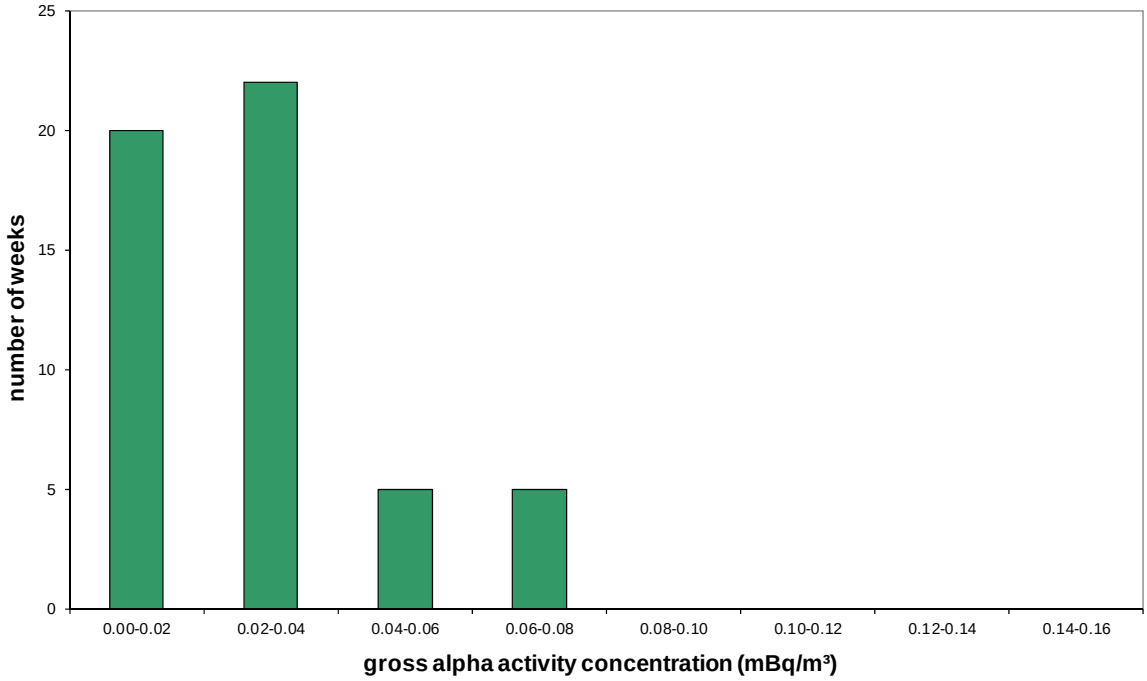


Figure 2.2: Frequency distribution of gross α activity concentration of long-lived nuclides in air dust collected weekly in 2011

The yearly average was 0.029 (SD=0.017) mBq·m^{-3}. SD is the standard deviation and illustrates the variation in weekly averages during the year.

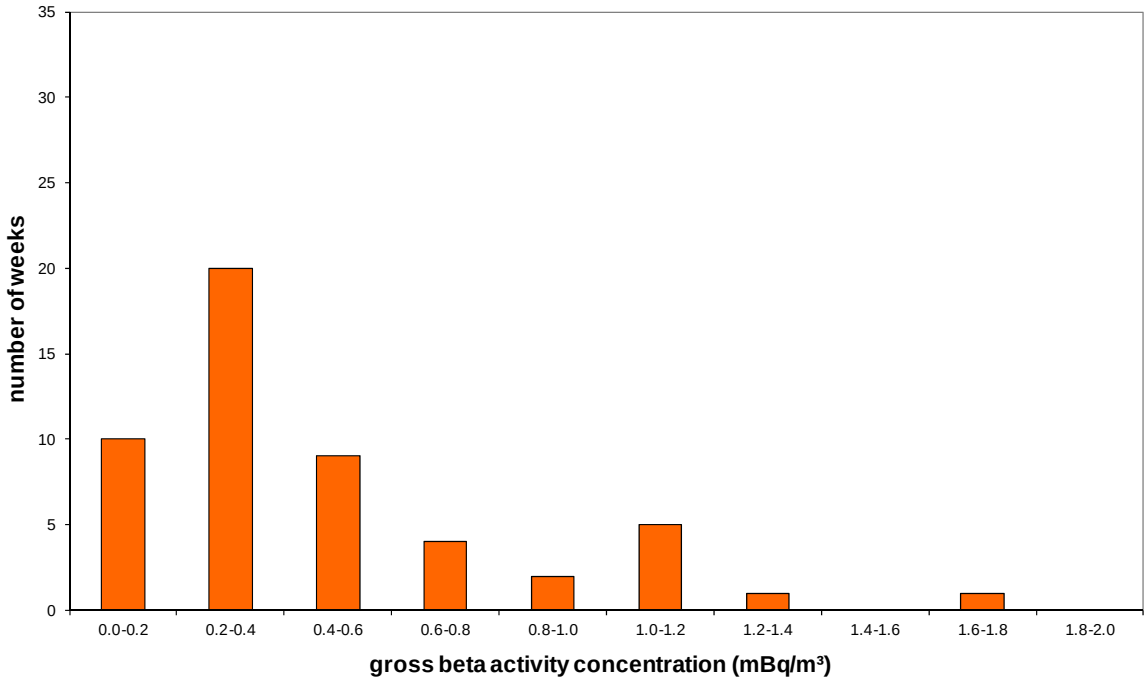


Figure 2.3: Frequency distribution of gross β activity concentration of long-lived nuclides in air dust collected weekly in 2011
The yearly average was 0.494 ± 0.008 (SD=0.4) mBq·m^{-3}.

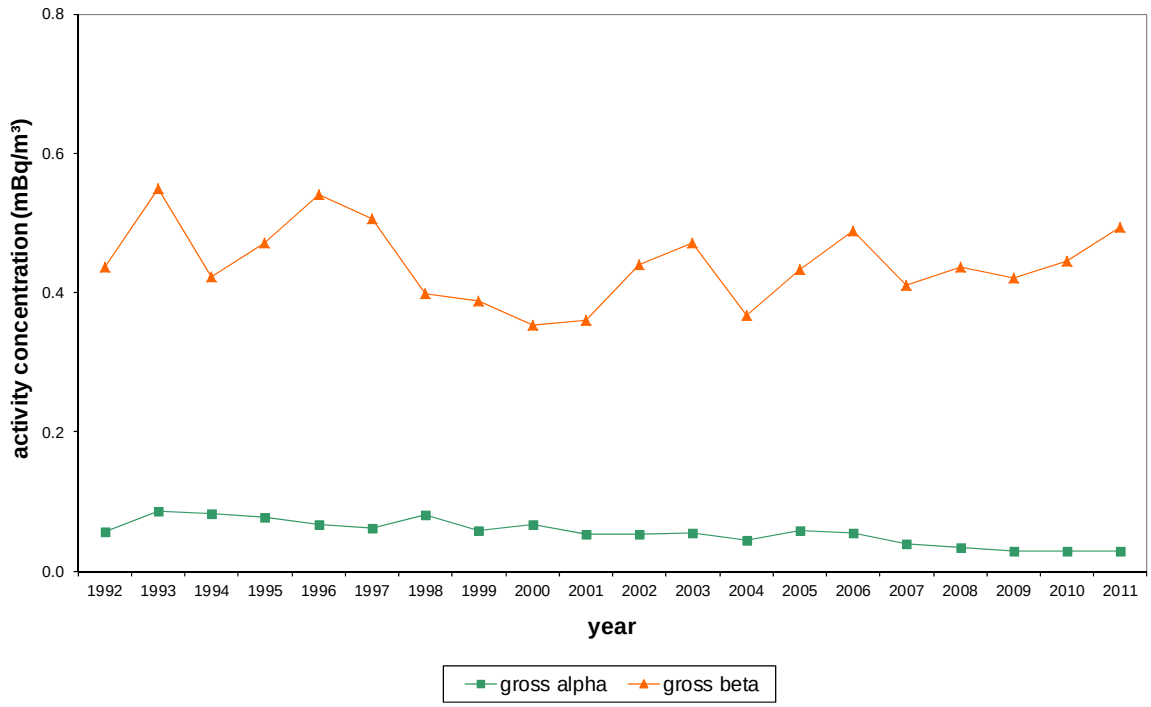


Figure 2.4: Yearly averaged gross α and gross β activity concentrations of long-lived nuclides in air dust at RIVM in 1992–2011

2.2 γ-emitting nuclides

Several nuclides were detected regularly, ^{7}Be (52 times), ^{210}Pb (52 times) and ^{137}Cs (43 times). The results are presented in Table A3 and Figures 2.5, 2.6 and 2.7. The detection limits for the nuclides considered in the gammaspectroscopic analysis of the HVS samples are given in Table A2. Between 2000 and the middle of 2009, the detection limit of ^{137}Cs was higher than from 1991 to 1999 due to a different detector set-up. Since July 2009, a new detector set-up has been used, which results in lower detection limits.

The behaviour of ^{7}Be in the atmosphere has been studied worldwide [8, 9, 10, 11, 12, 13, 14]. Natural ^{7}Be (half-life of 53.3 days) is formed by spallation reactions of cosmogenic radiation with atmospheric nuclei such as carbon, nitrogen and oxygen resulting in the formation of BeO or $Be(OH)_2$ molecules. Approximately 70% of ^{7}Be is produced in the stratosphere and the remaining 30% is produced in the troposphere. It has an estimated residence time of about one year in the stratosphere and about six weeks in the troposphere. Most of the ^{7}Be produced in the stratosphere does not reach the troposphere, except during spring when seasonal thinning of the tropopause takes place at mid-latitudes, resulting in air exchange between the stratosphere and the troposphere.

In the troposphere, ^{7}Be rapidly associates mainly with submicron-sized aerosol particles. Gravitational settling and precipitation processes accomplish transfer to the earth's surface. Seasonal variations in the concentration of ^{7}Be in surface air are influenced by the following main atmospheric processes: wet and dry deposition, mass exchange between stratosphere and troposphere, vertical transport in the troposphere and horizontal transport of air masses from the subtropics and mid-latitudes to the tropics and polar regions.
The red line in Figure 2.5 shows the seasonal variation of the ^{7}Be activity concentration, with peaks during the spring and summer periods, reflecting the seasonal variations in the transport rate of air from stratosphere to troposphere. Figure 2.5 further shows the influence of the solar cycle. The maxima at 1997 and 2007–2009 and the minimum at 2000–2002 are consistent with the solar minima (measured by radio flux and sunspot count) of 1996–1997 and 2008-2009 and the solar maximum of 2000–2002 [15]. In the summer of 1991 two severe geomagnetic storms caused a significant worldwide disturbance of the earth's geomagnetic field. This resulted in a considerable decrease in cosmogenic radiation, 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 2010 fit into the pattern described above.

The nuclide ^{137}Cs (half-life of 30.2 years) is of anthropogenic origin. Until 2011 the two main sources of ^{137}Cs in the environment were nuclear weapons tests and the Chernobyl accident, and resuspension of previously deposited activity was the main source of airborne ^{137}Cs activity.

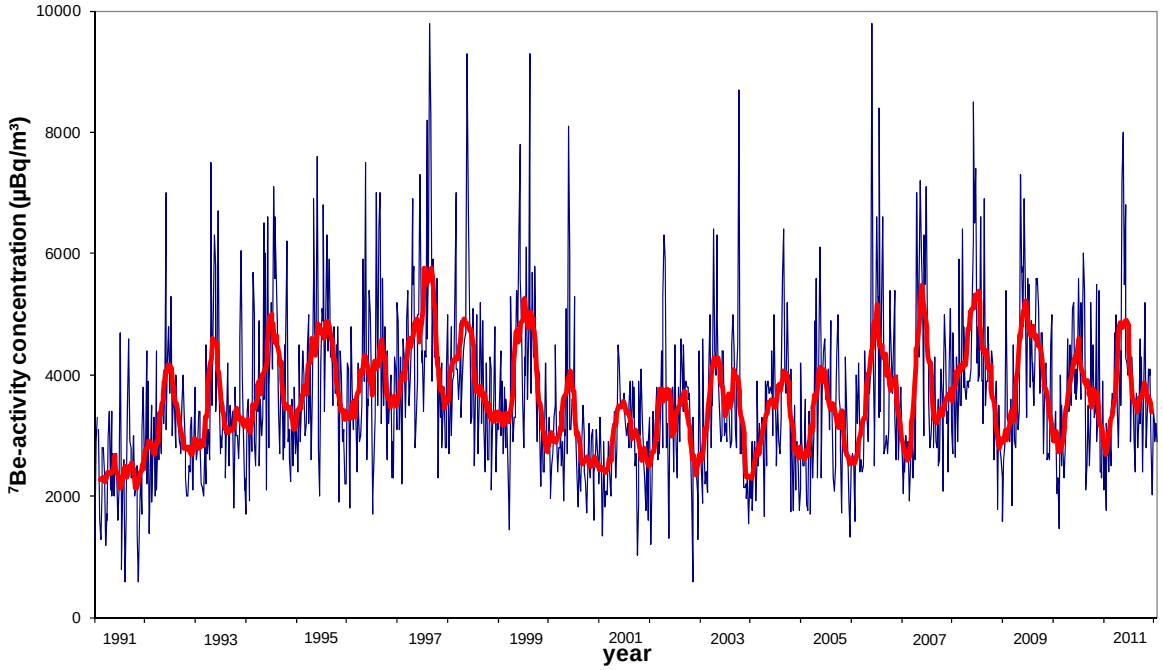


Figure 2.5: Weekly averaged ^{7}Be activity concentrations (blue) in air dust at RIVM in 1991–2011

The red line is a moving average of 13 weeks. The yearly average for 2011 was 3820 ± 50 (SD=1200) µBq·m^{-3}.

Figure 2.6 shows a peak during May 1992. During the same period several wildfires occurred near the Chernobyl area [17] and the level of airborne ^{137}Cs activity increased ten times in the 30 km exclusion zone around Chernobyl. It is plausible that the airborne ^{137}Cs was transported to Western Europe by the weather conditions in the same period (dry with a strong easterly wind [18]). On 29 May 1998, an incident occurred at Algeciras (Spain): an iron foundry melted a ^{137}Cs source concealed in scrap metal [19]. As a result, elevated levels of airborne ^{137}Cs activity were measured in France, Germany, Italy and Switzerland during late May and early June. Figure 2.6 shows a slightly elevated level of ^{137}Cs activity (second peak) around the same period (29 May until 5 June 1998). Such slightly elevated levels are not uncommon, as can be seen in Figure 2.6. These elevations may be related to resuspension of previously deposited dust, especially during a strong wind from the continent [19]. From 18 March until 10June 2011, elevated levels of ^{137}Cs activity were measured as a result of the incident at Fukushima (Japan). More detailed results on ^{137}Cs during that period are presented in paragraph 2.3.

The primary source of atmospheric ^{210}Pb (half-life of 22.3 years) is the decay of ^{222}Rn exhaled from continental surfaces. Therefore, the atmospheric concentration of ^{210}Pb over continental areas is generally higher than that over oceanic areas (^{222}Rn exhalation from the ocean is 1,000 times less than that from the continents). The reported reference value of ^{210}Pb in air dust is 500 µBq·m^{-3} [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].

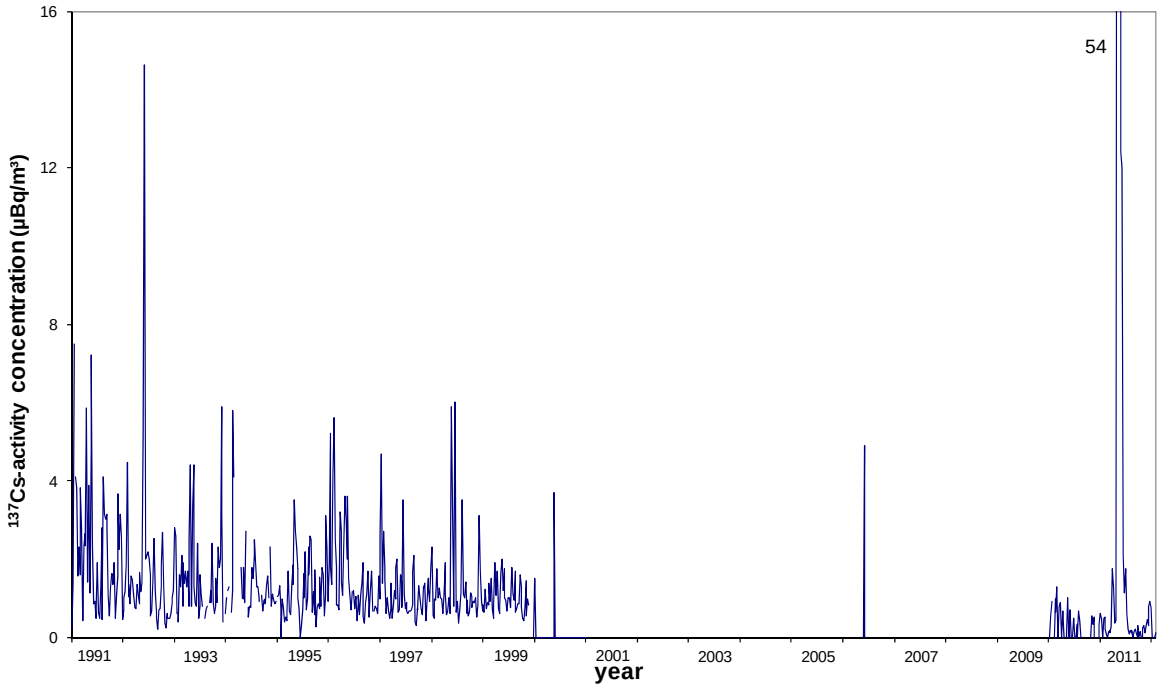


Figure 2.6: Weekly averaged ^{137}Cs activity concentrations in air dust at RIVM in 1991–2011

Nine out of the 52 measurements were below the detection limit in 2011. The yearly average for 2011 was 4.72 ± 0.18 (SD=12) µBq·m^{-3}, including the period following the Fukushima incident. Excluding the Fukushima period (18 March until 10 June 2011) the yearly average for 2011 was 0.445 ± 0.011(SD=0.5) µBq·m^{-3}. Between 2000 and the middle of 2009, the detection limit was higher than during 1991–1999, due to a different detector set-up. Since July 2009, a new detector set-up has been used, which results in lower detection limits (see Table A2).

Other sources of ^{210}Pb in air dust are volcanic activity and industrial emissions [24, 25, 26, 27, 28, 29]. Examples of industrial emissions are discharges from power plants using fossil fuels, discharges from fertiliser and phosphorus industries, and exhaust gases from traffic. In the Netherlands, emissions by power plants are only of local importance regarding ^{210}Pb deposition. Emissions by the phosphorus industry contribute a negligible part of the yearly total ^{210}Pb deposition [29]. Volcanic eruptions bring uranium decay products into the atmosphere, such as ^{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 were evenly distributed worldwide, the contribution to the yearly total ^{210}Pb deposition would be negligible.

Unusual ^{210}Pb values might be explained by natural phenomena such as an explosive volcanic eruption, Saharan dust [30, 31, 32] or resuspension of (local) dust. Normally there is a good correlation between ^{210}Pb and gross β activity concentrations, as was the case in 2011 (Figure 2.8). The weekly averaged ^{210}Pb activity concentrations in 2011 were within the range of those found in previous years (Figure 2.7).

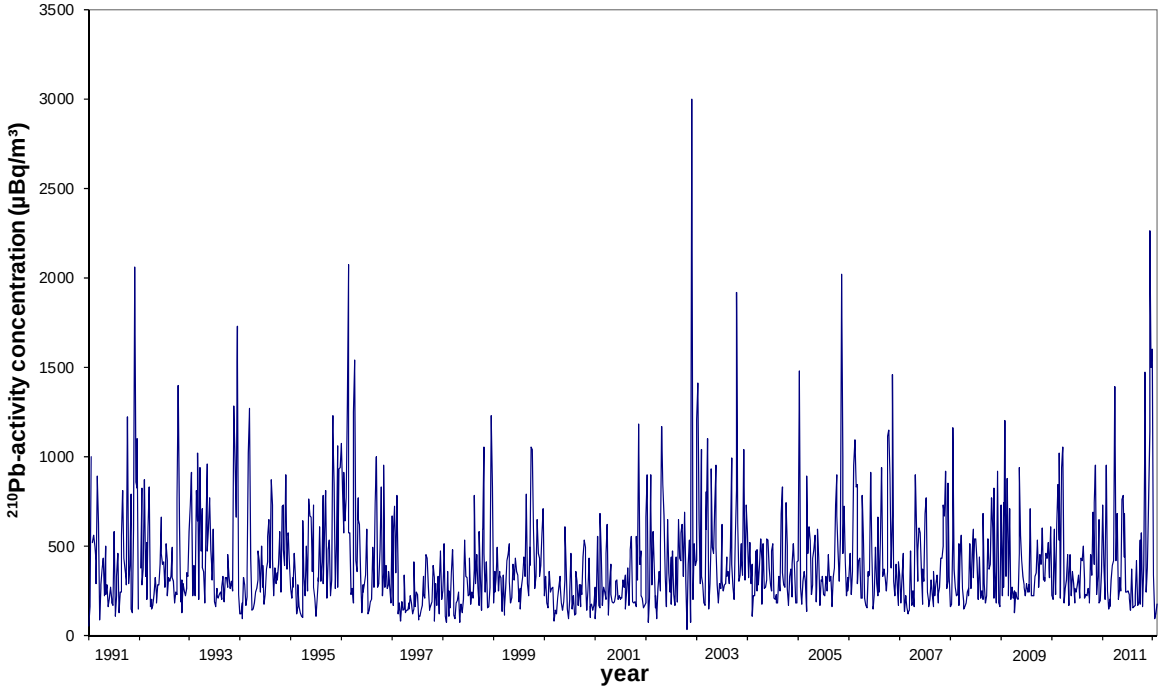


Figure 2.7: Weekly averaged ^{210}Pb activity concentrations in air dust at RIVM in 1991–2011

The yearly average for 2011 was 496 ± 9 (SD=500) µBq·m^{-3}.

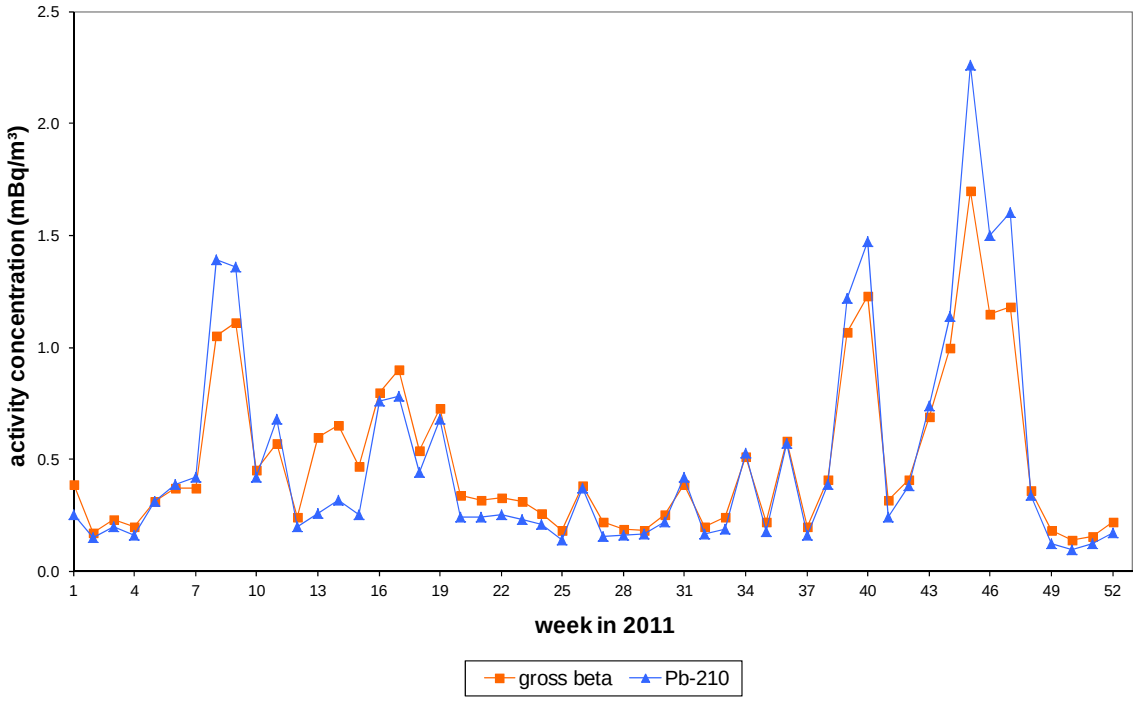


Figure 2.8: Figure illustrating the correlation between weekly averaged gross β and ^{210}Pb activity concentrations in air dust at RIVM

2.3 Additional results following the incidents at Fukushima (Japan) and Budapest (Hungary)

In the weeks (from 18 March until 10 June) following the incident at the nuclear site at Fukushima (Japan), sampling was carried out with the Snow White highvolume sampler with a sampling period of 3 days to 1 week. In addition, sampling was carried out with the former high volume sampler [2] with a sampling period of 24 hours (when possible) and in a measuring vehicle with a three-stage sampler (glass fibre filter, carbon filter and carbon filter cartridge) with a sampling period of 3 days and a flow rate of 4.5 $m^3 \cdot h^{-1}$. A more detailed description of the measurements following the incident at Fukushima is given elsewhere [33].

During week 45 (from 3 until 11 November) ^{131}I was measured in air dust sampled with the Snow White high-volume sampler. According to the Hungarian Atomic Energy Authority (HAEA), the source of the ^{131}I detected in Europe was probably a release to the atmosphere from the Institute of Isotopes, Budapest. The Institute of Isotopes produces radioisotopes for healthcare, research and industrial applications. According to the HAEA, the release occurred from 8 September to 16 November 2011 [34].

The additional results of both incidents (other than those presented in paragraph 2.2) are presented in Tables A4 to A7 and in case of the Fukushima incident also in Figures 2.9 to 2.12. The results presented in this report can differ from those presented in [33]. The results presented here are corrected for coincidence and collection efficiency (necessary only for the Snow White high volume sampler), unlike those presented in [33]. In addition, the results of extra samples and extra measurements (using a well-type detector) are presented in this report in comparison with those presented in [33].

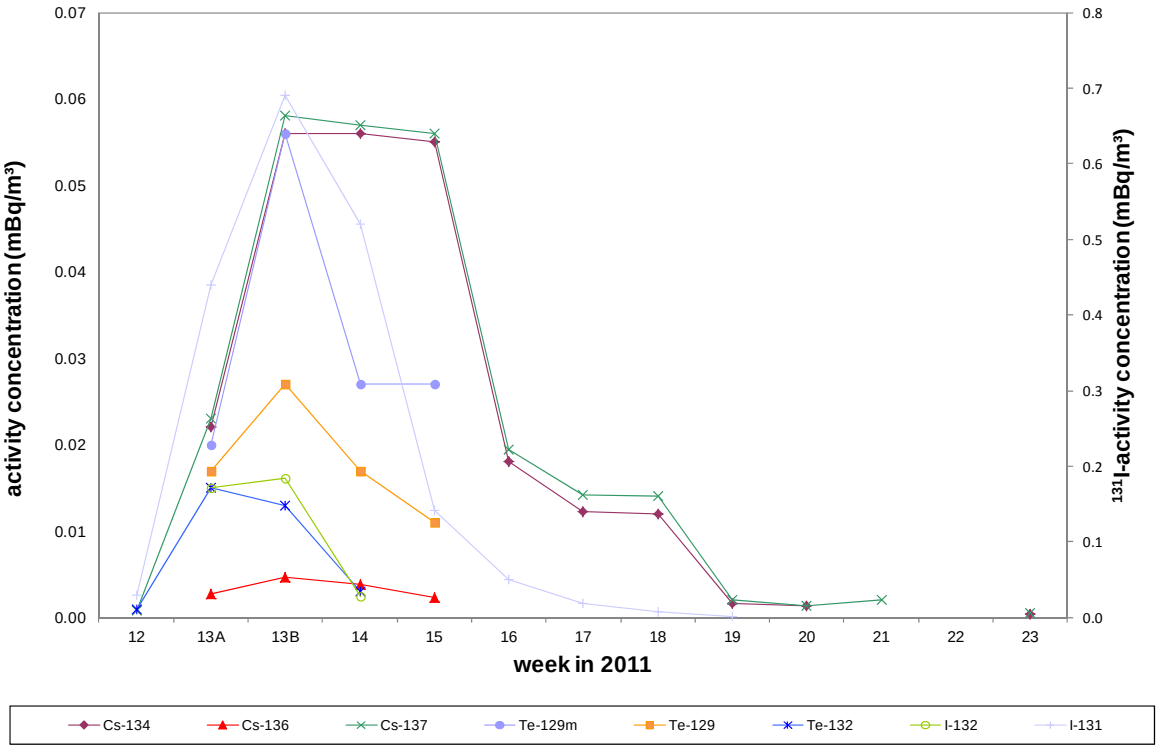


Figure 2.9: Activity concentrations of γ-emitters in air dust sampled with the Snow White high volume sampler and measured directly as a folded filter on a coaxial Ge detector

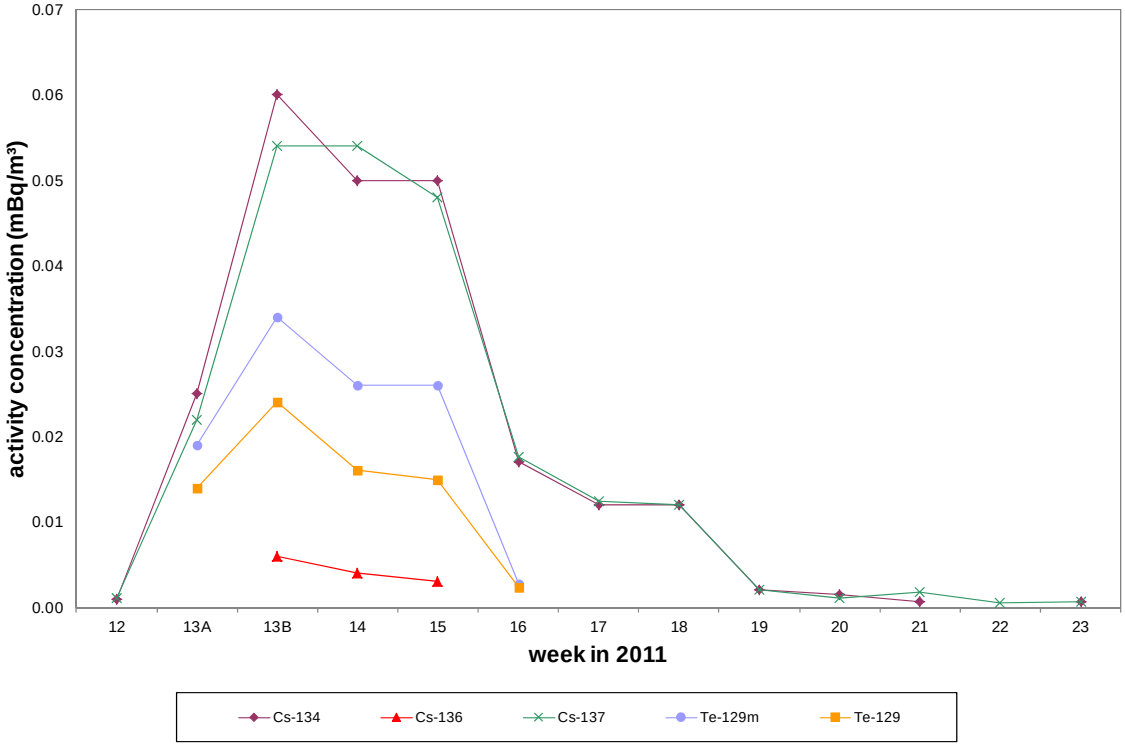


Figure 2.10: Activity concentrations of γ-emitters in air dust sampled with the Snow White high volume sampler and measured after several days as ash residue on a well-type Ge detector

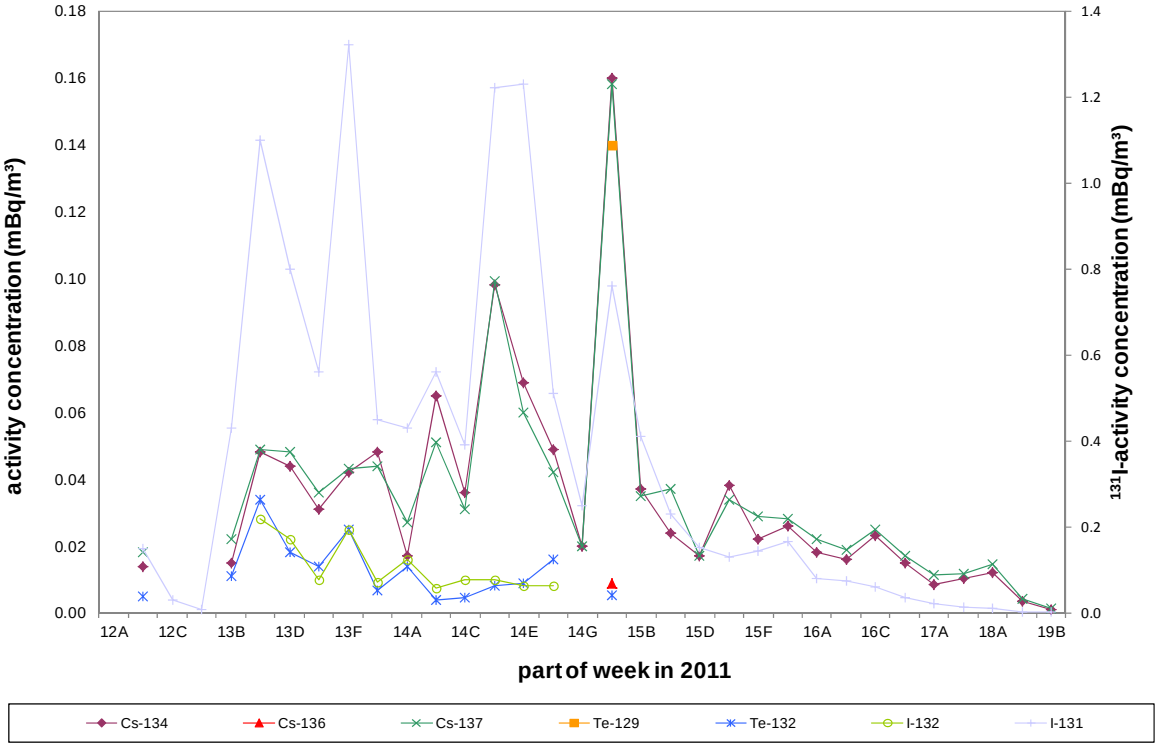


Figure 2.11: Activity concentrations of γ-emitters in air dust sampled with the former high volume sampler and measured directly as a folded filter on a coaxial Ge detector

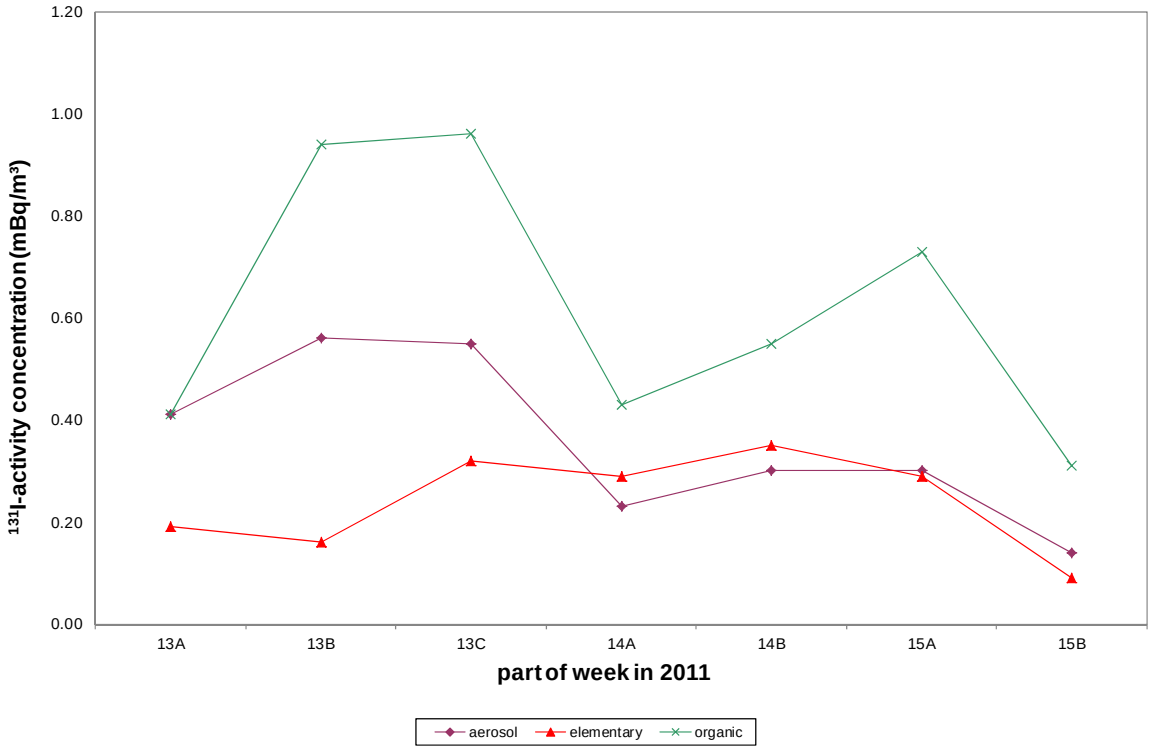


Figure 2.12: ^{131}I activity concentrations in air sampled with a three-stage sampler and measured on a coaxial Ge detector
^{131}I is either aerosol bound, elementary I_2 or organically bound.

The segmentation of the different forms of ^{131}I can be deduced from Figure 2.12 and Table A6. The levels of radionuclides measured following the Fukushima incident do not pose a threat to public health, as can be seen by the following calculation.

The most relevant path of exposure during the Fukushima incident was the inhalation of ^{131}I. Tables A4 and A7 show that ^{131}I was measured from 23 March to 13 May. As shown in Table A7, the average daily ^{131}I activity concentration in air dust is 240 $\mu Bq \cdot m^{-3}$ during that period. Table A6 shows that on average 29% of ^{131}I was aerosol bound; thus the combined (for all iodine fractions) average daily ^{131}I activity concentration inhaled during that period was 820 $\mu Bq \cdot m^{-3}$. Assuming that an average person inhales air at a rate of 1.2 $m^3 \cdot h^{-1}$ and the inhaled ^{131}I is totally absorbed by the lungs, during the period of 51 days (from 23 March to 13 May) that person will have absorbed 1 Bq of ^{131}I. To convert this into the absorbed dose one must use dose conversion factors [35]. By applying the relevant dose conversion factor for ^{131}I, the absorbed dose is less than 0.00001 mSv. To put this into perspective, the dose which a resident of the Netherlands receives annually is 2.4 mSv on average [36]. The dose from other paths of exposure and from the other radionuclides measured following the Fukushima incident are much lower than the dose as a result of inhalation of ^{131}I, and is therefore insignificant.

The measured level of ^{131}I following the incident at Budapest is even lower than the level following the Fukushima incident and therefore does not pose a threat to public health.

3 Deposition

Table 3.1 describes the monitoring program for determining radioactive nuclides in deposition. Sampling was done on the RIVM premises in Bilthoven. Samples were collected weekly for γ-emitters and monthly for gross α, gross β, ^{3}H and ^{210}Po according to a standard procedure [37].

The weekly samples for γ-emitters and monthly samples for gross α and gross β were acidified with sulphuric acid and evaporated. The resulting sulphate residue was analysed according to standard procedures [6, 38, 39].

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

The monthly samples for ^{210}Po were reduced in volume by evaporation. The resulting solution was analysed according to a standard procedure [40], with a minor difference. The ingrowth of ^{210}Po from ^{210}Pb was derived from the ^{210}Pb results from the weekly samples for γ-emitters instead of the procedure described in [40].

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

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

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

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

3.1 Long-lived α and β activity

The monthly deposited gross α and gross β activities of long-lived nuclides are given in Figure 3.1, Figure 3.3 and Table A8. The yearly total deposition of gross α and gross β were 45.0 ± 1.5 and 123 ± 3 $Bq \cdot m^{-2}$, respectively. These values are within the range of those from previous years, as illustrated in Figure 3.2, Figure 3.4 and Table A9.

The monthly deposition of ^{3}H is given in Table A8. In 2010, the yearly total deposition of ^{3}H ranged between 332 and 1,540 $Bq \cdot m^{-2}$ (68% confidence level). The yearly total consisted of 12 samples, and 8 of the 12 measurements were below the detection limit. Therefore, detection limits were used for the contribution to the yearly total. The range in 2011 did not differ significantly from those measured since 1993, as illustrated in Figure 3.5 and Table A9. Until 1998, samples were electrolytically enriched before counting, which resulted in a much lower detection limit than after 1997.

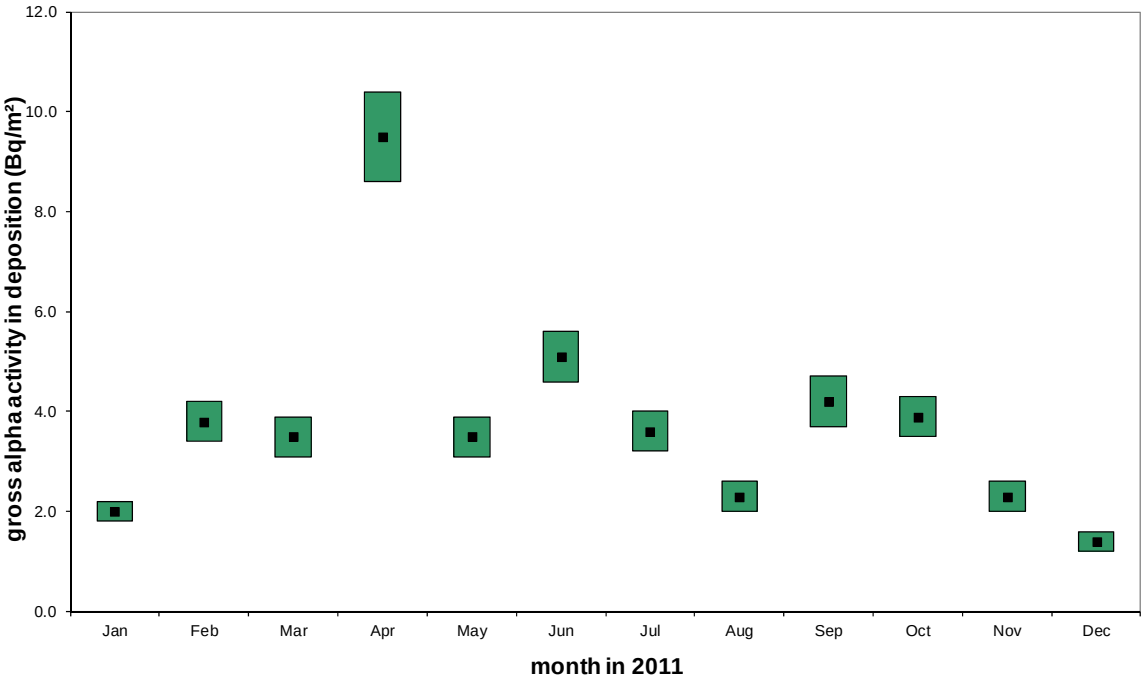


Figure 3.1: Monthly deposited gross α activity of long-lived nuclides at RIVM
Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

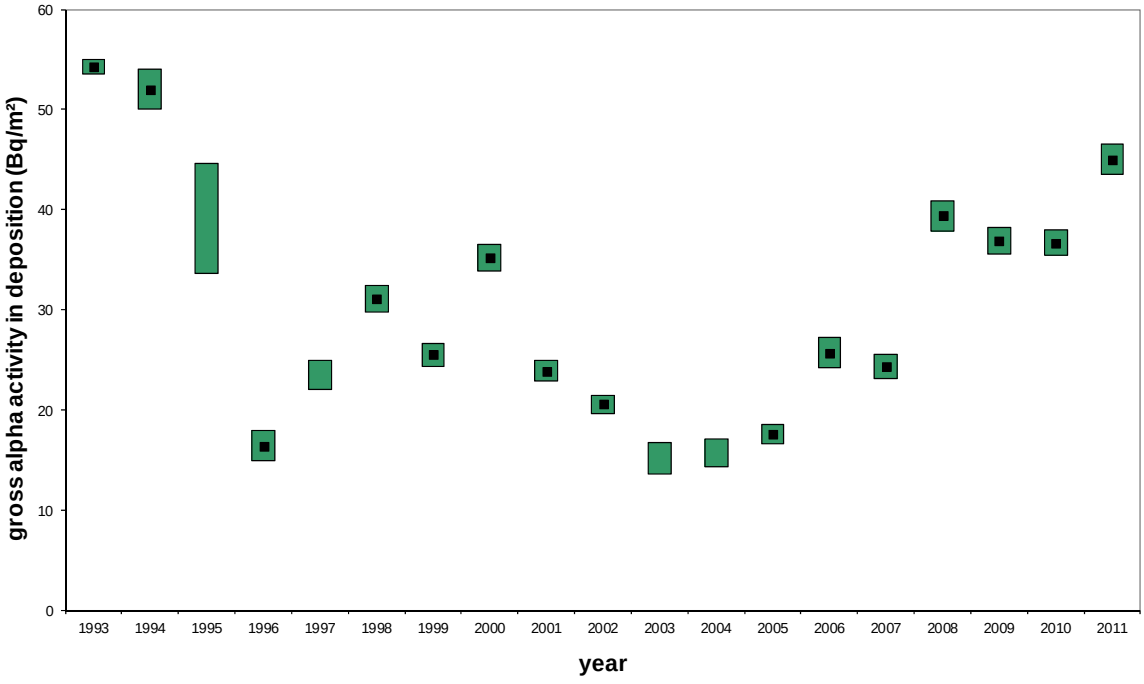


Figure 3.2: Yearly gross α activity of long-lived nuclides deposited at RIVM from 1993 to 2011
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

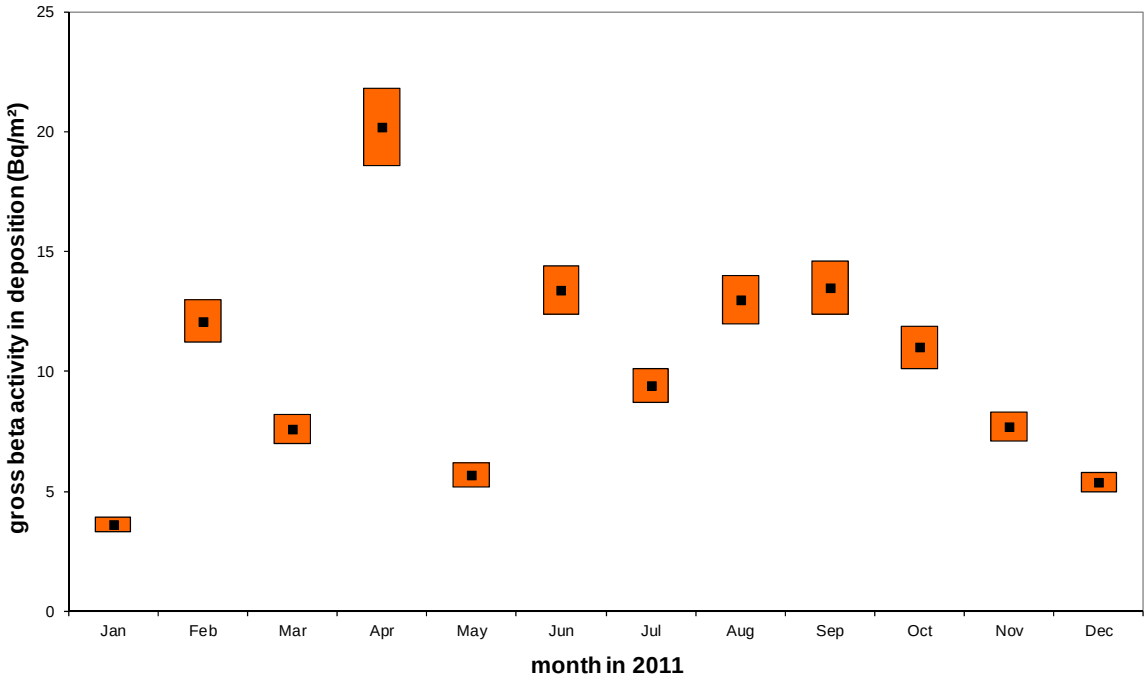


Figure 3.3: Monthly deposited gross β activity of long-lived nuclides at RIVM
Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

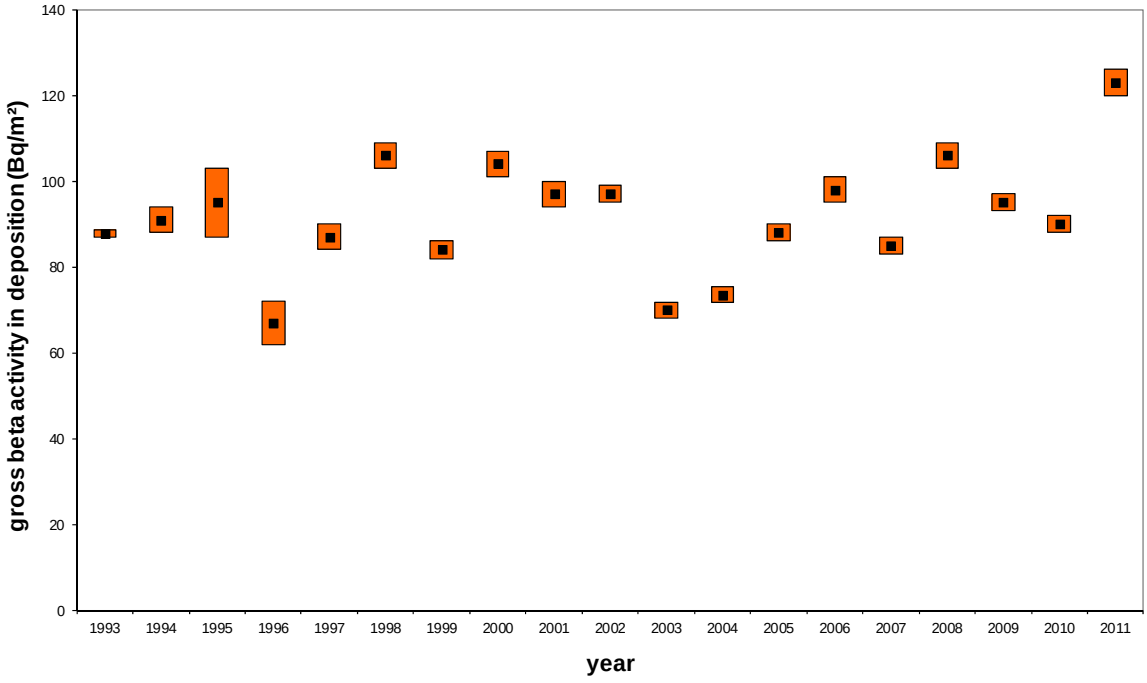


Figure 3.4: Yearly gross β activity of long-lived nuclides deposited at RIVM from 1993 to 2011
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars).

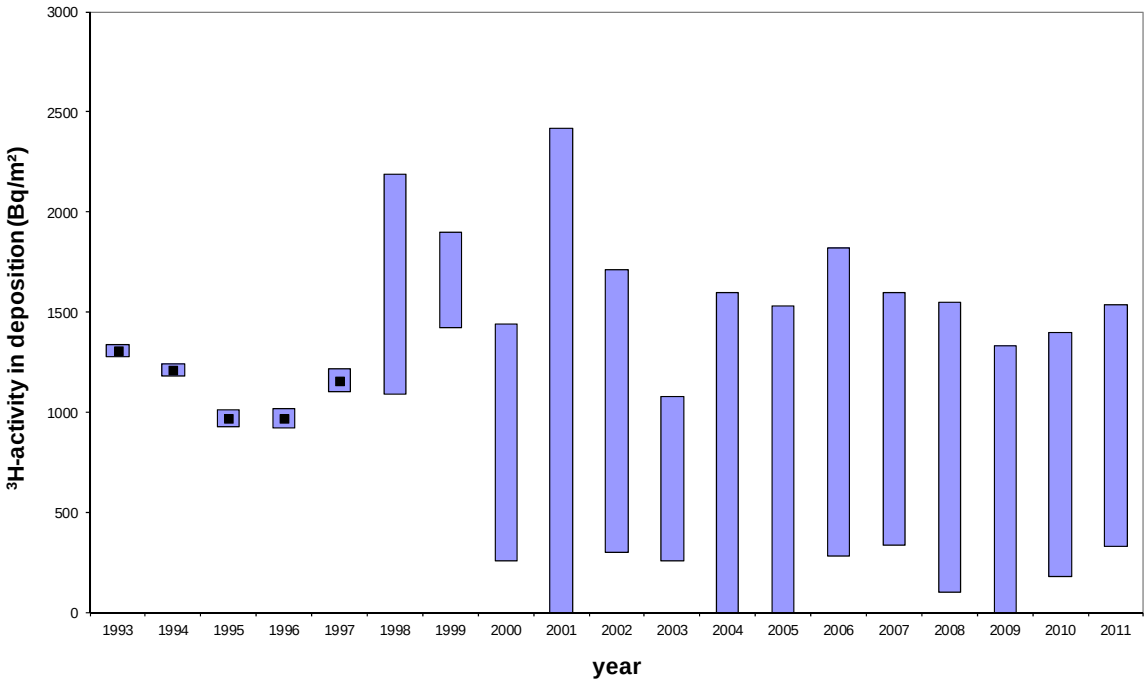


Figure 3.5: Yearly deposition of ^{3}H at RIVM from 1993 to 2011
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

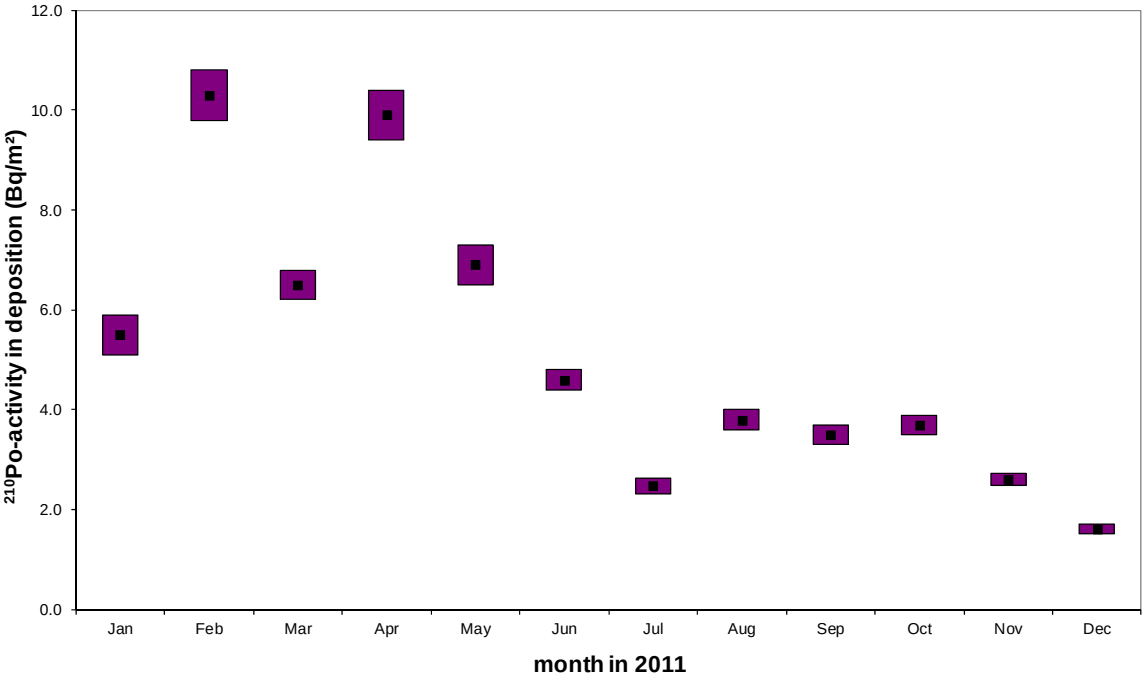


Figure 3.6: Monthly deposited ^{210}Po activity at RIVM
Monthly totals (black dots) are shown with a 68% confidence range (coloured bars).

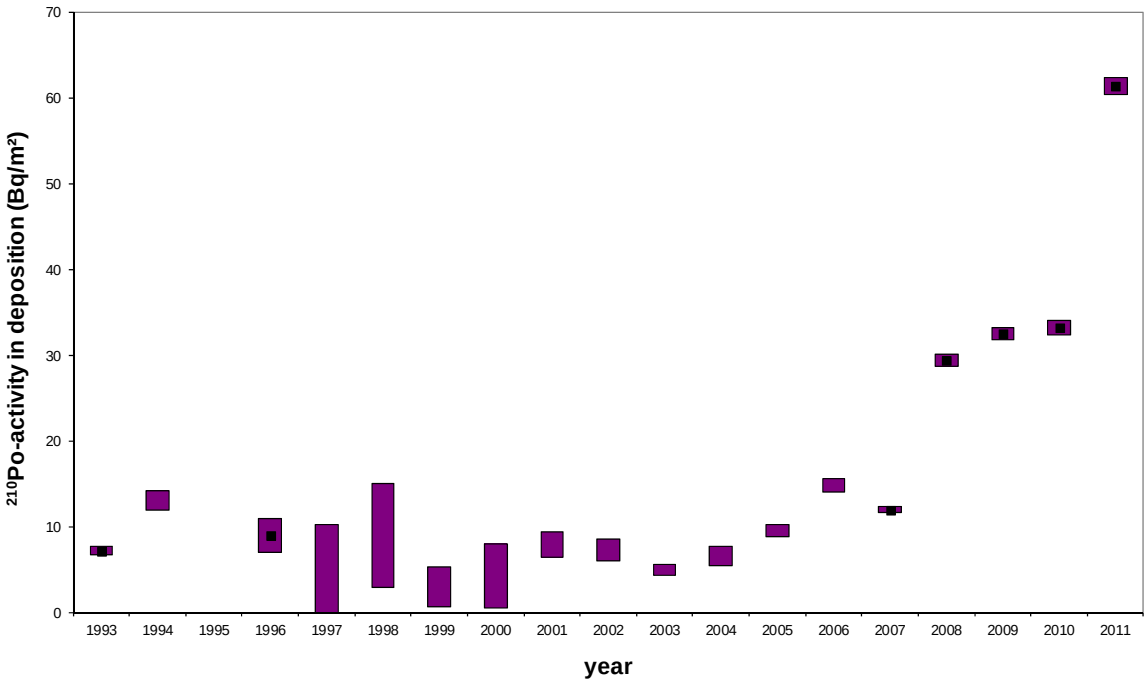


Figure 3.7: Yearly ^{210}Po activity deposited at RIVM from 1993 to 2011
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

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

The monthly α spectroscopy results for ^{210}Po are given in Figure 3.6 and Table A10. The results for previous years are given in Figure 3.7 and Table A11. The yearly total deposition of ^{210}Po in 2011 was 61.4 ± 1.0 Bq·m^{-2} (68% confidence level). This is the highest yearly total since 1993, but this level does not pose a threat to public health. Contrary to expectation, the correlation between the level of ^{210}Po and the level of gross α is less evident in January to March and May 2011, as can be seen in Figure 3.8.

3.2 γ-emitting nuclides

Detectable quantities of the naturally occurring nuclides ^{7}Be and ^{210}Pb were found in all 52 weekly samples. The yearly total deposition of ^{7}Be was 1,320 ± 30 Bq·m^{-2} and the yearly total deposition of ^{210}Pb was 104 ± 2 Bq·m^{-2}. The nuclide ^{137}Cs was detected in 8 of the 52 weekly samples (the detection limit for ^{137}Cs is 0.02 Bq·m^{-2}). The yearly total deposition of ^{137}Cs ranged between 0.5 and 1.5 Bq·m^{-2} (68% confidence level). The weekly results for deposition of ^{7}Be, ^{137}Cs and ^{210}Pb are given in Table A12 and Figures 3.9 and 3.12. The results for previous years are given in Table A11 and Figures 3.10, 3.11 and 3.13.

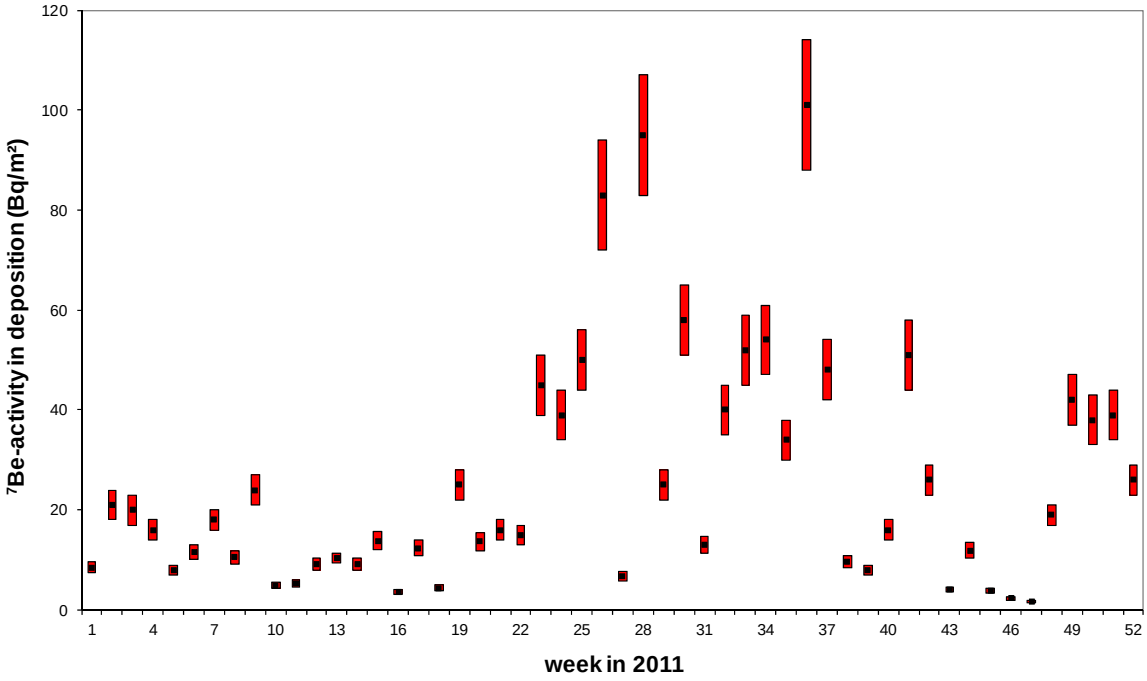


Figure 3.9: Weekly deposited ^{7}Be activity at RIVM
Weekly totals (black dots) are shown with a 68% confidence range (coloured bars).

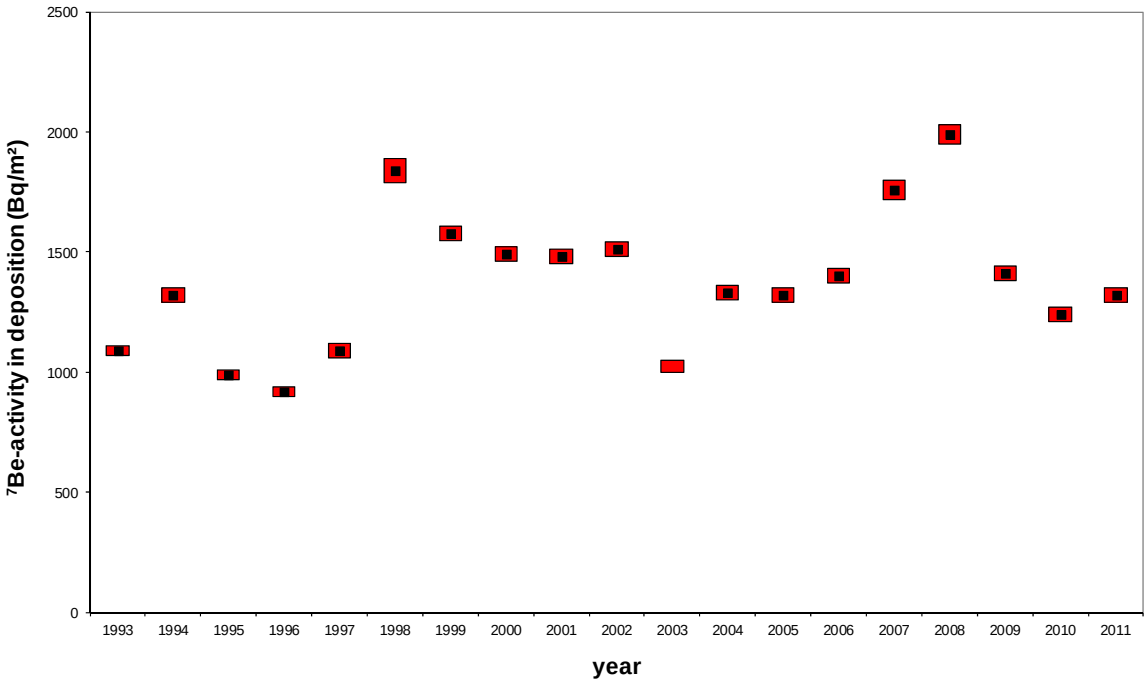


Figure 3.10: Yearly ^{7}Be activity deposited at RIVM from 1993 to 2011
Yearly totals (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

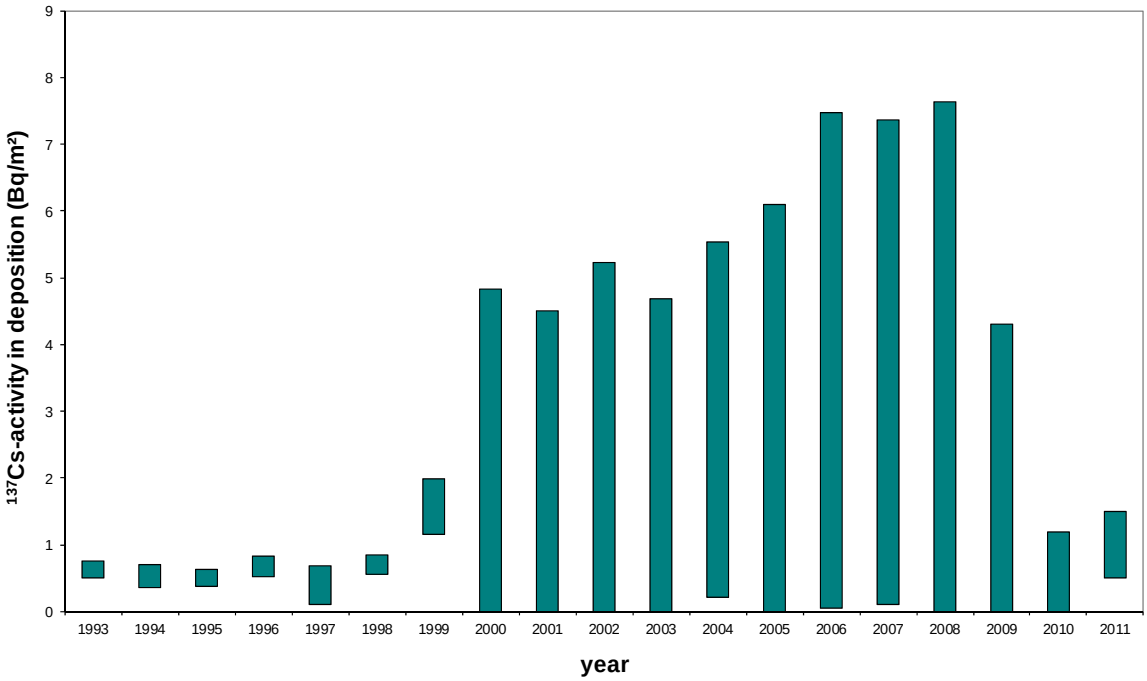


Figure 3.11: Yearly ^{137}Cs activity deposited at RIVM from 1993 to 2011
Yearly averages are shown solely as a 68% confidence range since the yearly result is made up of at least one detection limit. From 2000 to June 2009, the detection limit was higher than during 1993–1999, due to a different detector set-up. Since July 2009, a new detector set-up has been used, which results in lower detection limits.

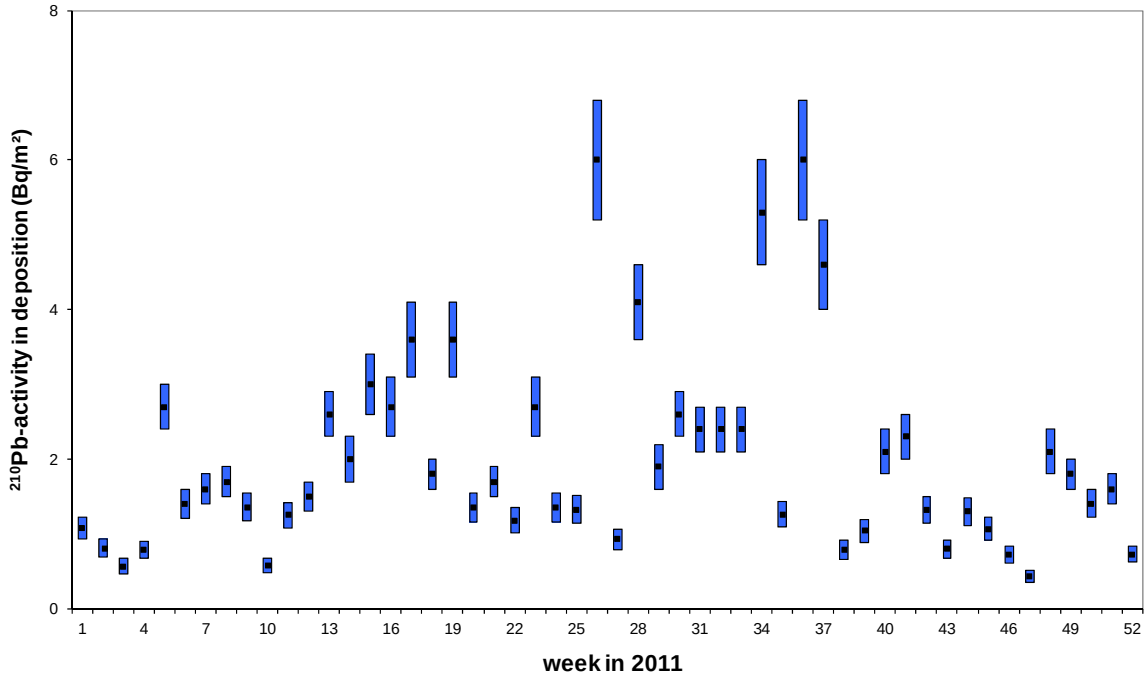


Figure 3.12: Weekly deposited ^{210}Pb activity at RIVM
Weekly averages (black dots) are shown with a 68% confidence range (coloured bars).

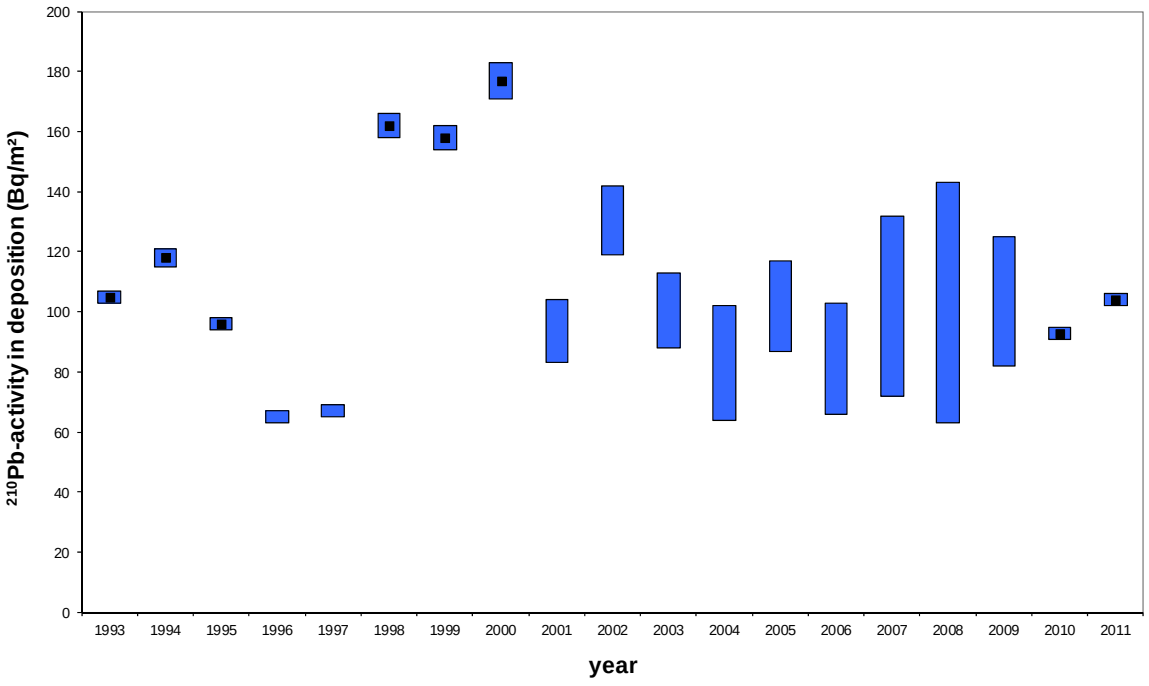


Figure 3.13: Yearly ^{210}Pb activity deposited at RIVM from 1993 to 2011
Yearly averages (black dots) are shown with a 68% confidence range (coloured bars). Only the 68% confidence range is shown if the yearly result is made up of at least one detection limit.

3.3 Additional results following the incident at Fukushima (Japan)

In the weeks following the incident at the nuclear site at Fukushima (Japan), a few changes were made to the regular monitoring program.

During weeks 12 to 15 a sub-sample was taken out of the original sample and measured in a 250 ml container on a coaxial detector (70,000–86,400 seconds counting time) to determine volatile γ-emitters. After this measurement the sub-sample was added to the original sample and the standard procedure, as described at the beginning of this chapter, was followed.

In addition, sampling was carried out with a different frequency (3 and 4 days instead of 1 week) in week 13. The relevant results are presented in Table 3.2.

Table 3.2: Deposited ^{131}I activity [(1)] at RIVM in the period following the Fukushima incident

Week number	Period	^{131}I $Bq \cdot m^{-2}$
12	18/03–25/03	< 12
13A	25/03–28/03	< 2
13B	28/03–01/04	3.4 ± 1.3
14	01/04–08/04	1.4 ± 0.3
15	08/04–15/04	< 9

[(1)] Uncertainties are given as 1σ.

4 National Radioactivity Monitoring Network

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

The NMR consists of 167 sites at which the ambient dose equivalent rate is determined. At 14 measuring sites gross α and artificial β activity concentrations are determined as well as the ambient dose equivalent rate (at a height of 3.5 m above ground level) [41]. At another 153 measuring sites only the ambient dose equivalent rate is determined (at 1 m above ground level).

Since the dose equivalent rate monitors are placed differently at the 14 sites than at the 153 sites with regard to height and surface covering, results can differ between the two types of measuring site [42]. Hence, the 14 dose equivalent rate monitors are not taken into account when calculating the yearly averaged ambient dose equivalent. The reported artificial β activity concentrations are calculated from the difference between the measured gross β activity concentration and the natural gross β activity derived from the measured gross α activity concentration.

During the second half of 2002, the 14 aerosol FAG FHT59S monitors were gradually replaced by 14 new Berthold BAI 9128 monitors. Due to differences in detection method, filter transport, calibration nuclides and algorithms the results for the activity concentrations are not exactly the same. By running both monitors simultaneously at the same location, the measured gross α activity concentration was compared. On average, the Berthold monitor systematically reported about 20% higher values than the FAG monitor [43]. The estimated random uncertainty for both types of monitor is about 20%. No correction was applied for the difference in the gross α activity concentration between the Berthold and FAG monitor.

The data presented in this chapter are based on 10-minute measurements. Averages over the year are calculated per location using daily averages from the 10-minute measurements (Tables A13 and A14). The data on external radiation, expressed in ambient dose equivalent, contain a systematic uncertainty because of an overestimation of the cosmogenic dose rate. However, NMR data are not corrected for these response uncertainties.

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

Figure 4.2 presents the yearly averages of gross α activity concentration from 1990 to 2011, while Figure 4.4 presents the yearly averages of ambient dose equivalent rate from 1996 to 2011.

In 2011 the yearly averaged gross α activity concentration in air dust was 4.1 $Bq \cdot m^{-3}$ (based on the yearly averages of the 14 measurement locations). To compare this value (yearly average of 4.1 $Bq \cdot m^{-3}$) with data collected before 2002, it should be noted that the Berthold measurements are 20% higher than the FAG measurements and the value can be corrected to 3.4 $Bq \cdot m^{-3}$. The yearly average of the artificial β activity concentration does not deviate significantly from zero.

Between 1996 and 2003 the analysis of the ambient dose equivalent rate was based on a set of 163 stations. Since 2004, the analysis of the ambient dose equivalent rate has been based on a set of 153 stations (10 stations have been dismantled). The yearly averaged ambient dose equivalent rate in 2011 was calculated using 151 stations (2 stations were not operational).

In 2011, the yearly averaged measured value for the ambient dose equivalent rate was 73.1 $nSv\ h^{-1}$. Figure 4.5 shows the influence of the 11-year solar cycle on the cosmogenic contribution to the effective dose rate, which is related to the ambient dose equivalent rate. The decrease in the ambient dose equivalent rate (as given by the NMR) from 1996 to 2003 (Figure 4.4) might be related to the decrease in the cosmogenic contribution. However, the correlation between the increase in the cosmogenic contribution since 2004 and the measured ambient dose equivalent rate is less evident (Figure 4.4).

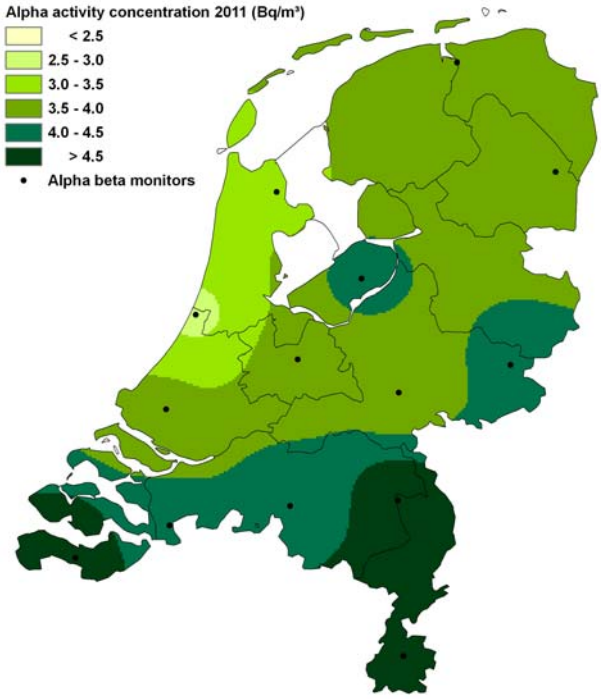


Figure 4.1: Spatial variation in the average gross α activity concentration of (mainly) short-lived nuclides in air dust
The dots represent the locations of the aerosol monitors.

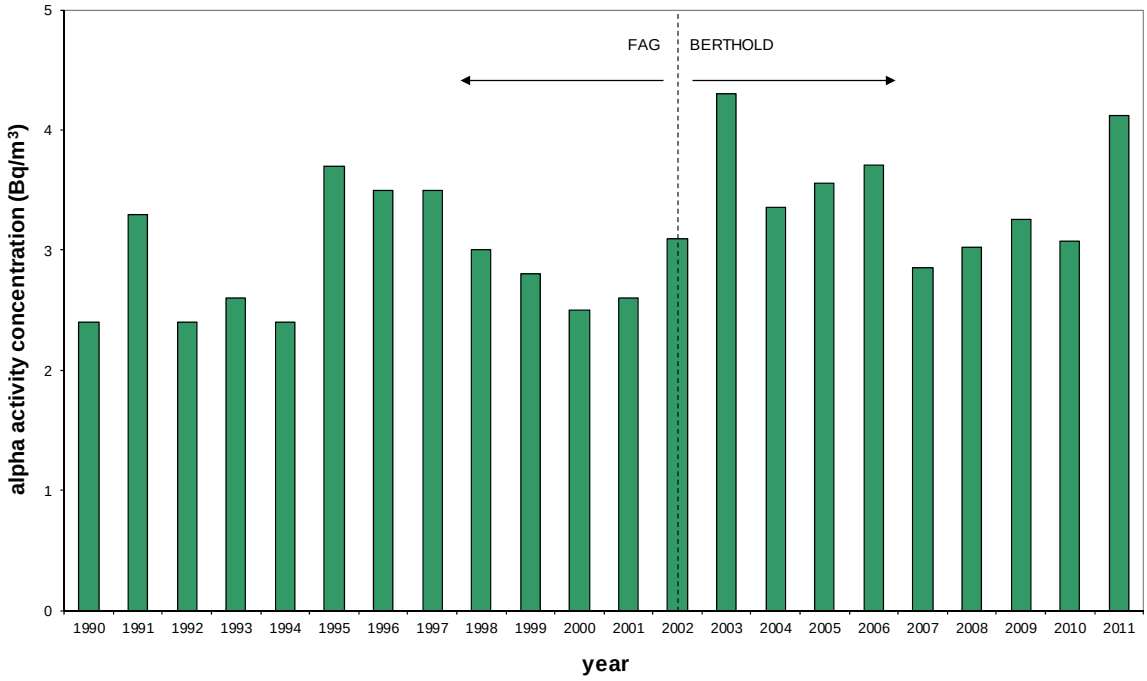


Figure 4.2: Yearly averaged gross α activity concentration of (mainly) short-lived nuclides in air dust
During the second half of 2002 the FAG monitors were replaced by Berthold monitors.

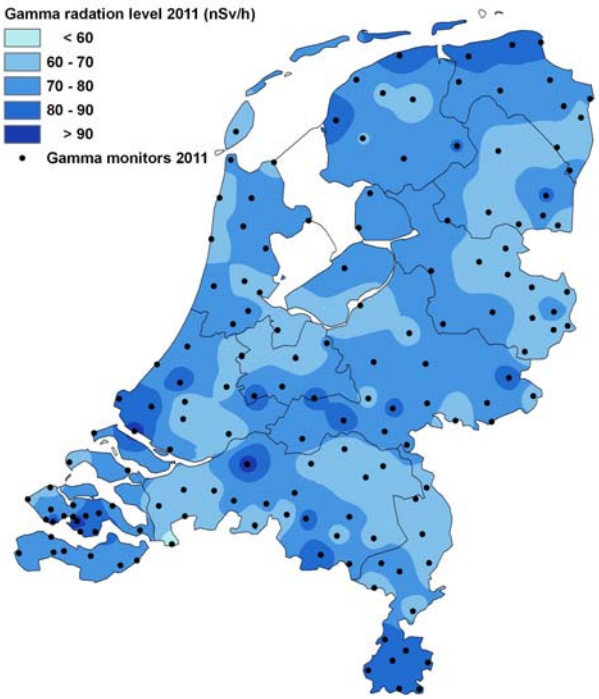


Figure 4.3: Spatial variation in the average ambient dose equivalent rate
The dots represent the locations of the dose equivalent rate monitors.

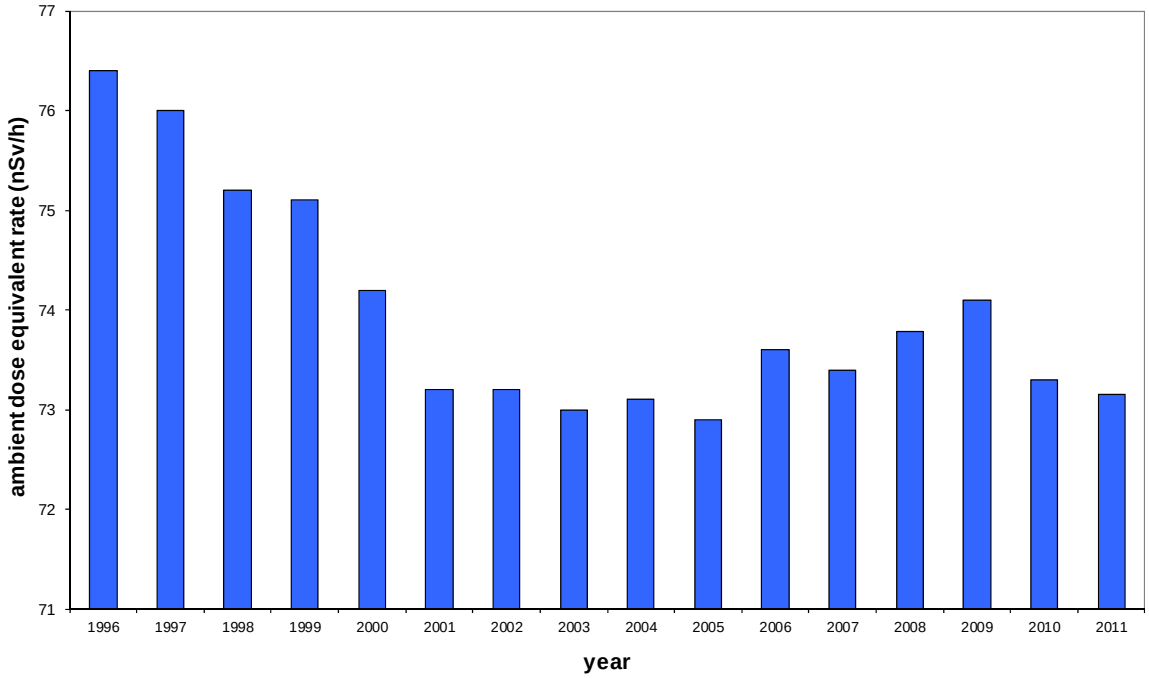


Figure 4.4: The yearly averaged ambient dose equivalent rate

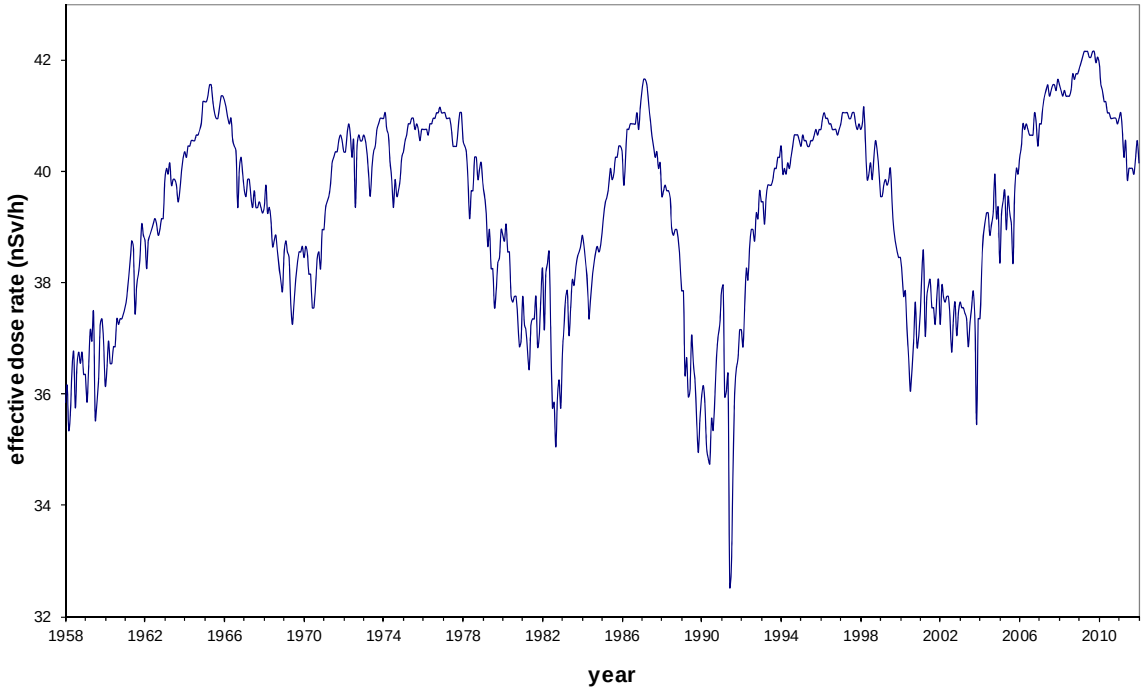


Figure 4.5: Cosmogenic contribution to the effective dose rate (at sea level), influenced by the solar cycle: location 51° 26' north and 3° 43' east (in the south-west of the Netherlands), air pressure 1019 hPa
Figure derived from data supplied by the Federal Aviation Administration [44]

5 Surface water and seawater

5.1 Introduction

Rijkswaterstaat (RWS) regularly monitors the concentration of a number of radioactive nuclides in surface water and seawater. The monitoring program presented here forms only part of its entire monitoring program. A more detailed description of the monitoring program, underlying strategy and results of radioactivity measurements in Dutch waters are reported elsewhere [45, 46, 47, 48].

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

Since 2010, measurements in sediment have been added to the entire monitoring program, but the results are not presented in this report. These results are presented elsewhere [48].

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

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

Continued on the next page

Table 5.1: Continued

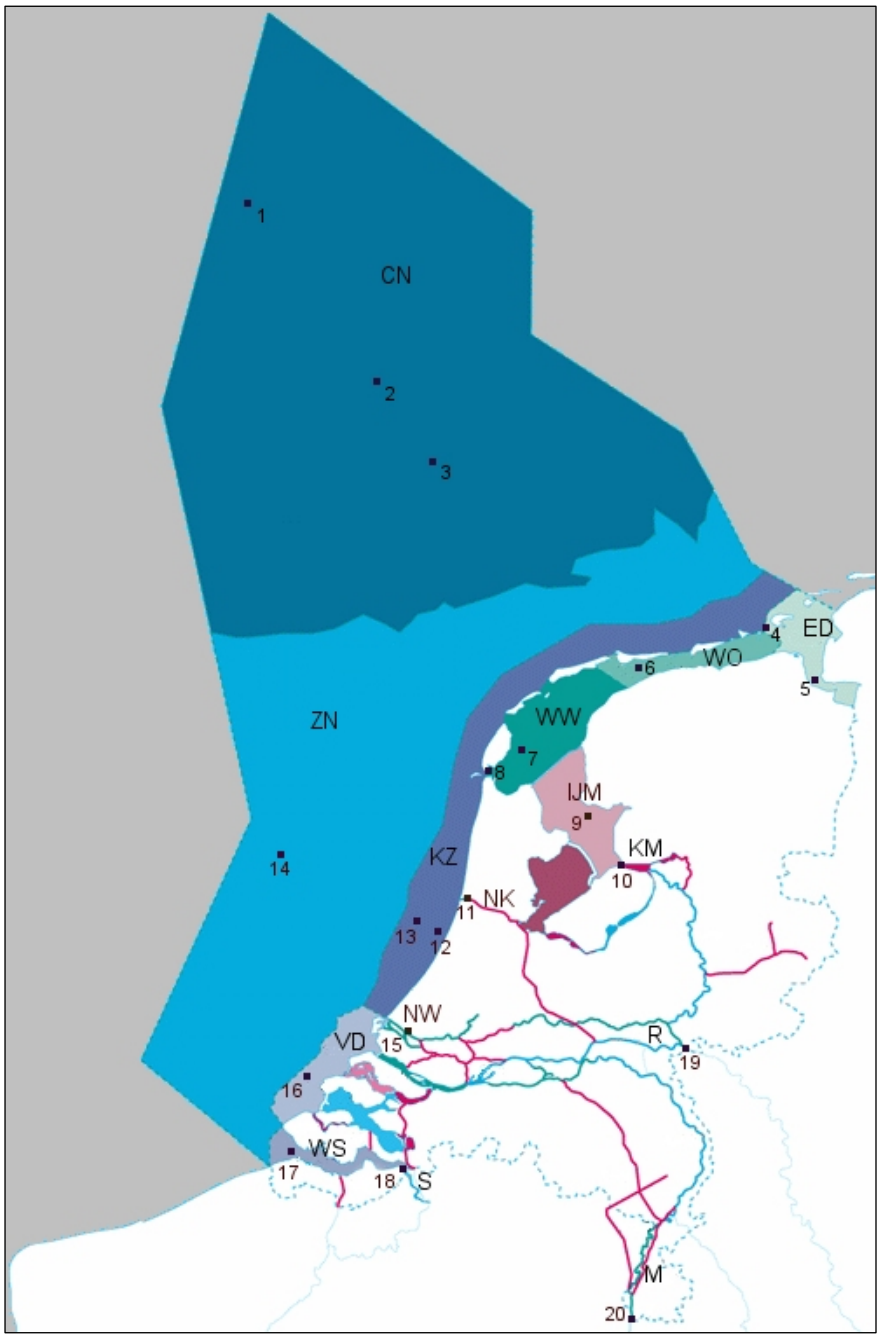
Location	Parameter	Matrix	Monitoring frequency (per year)
Rhine	Gross α	Water	13
(Lobith)	Residual β	Water	13
	^{3}H	Water	13
	^{90}Sr	Water	6
	^{226}Ra	Water	6
	^{60}Co	Suspended solids	17
	^{131}I	Suspended solids	17
	^{137}Cs	Suspended solids	17
	^{210}Pb	Suspended solids	6
Scheldt	Gross α	Water	13
(Schaar van Ouden Doel)	Residual β	Water	13
	^{3}H	Water	7
	^{226}Ra	Water	7
	^{60}Co	Suspended solids	13
	^{131}I	Suspended solids	13
	^{137}Cs	Suspended solids	13
	^{210}Pb	Suspended solids	7
Meuse	Gross α	Water	13
(Eijsden)	Residual β	Water	13
	^{3}H	Water	13
	^{90}Sr	Water	6
	^{226}Ra	Water	6
	^{60}Co	Suspended solids	52
	^{131}I	Suspended solids	52
	^{137}Cs	Suspended solids	52
	^{210}Pb	Suspended solids	6

The radioactive nuclides were measured according to standard procedures [49, 50]. In the Netherlands, target values are used for radioactive materials in surface water, which are given in the Fourth Memorandum on Water Management (Vierde Nota waterhuishouding) [51]. The yearly averages are compared with those target values.

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

Area	Location	Parameter	Matrix	Monitoring frequency (per year)
Coastal area (KZ)	Noordwijk 2 [(1)]	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
		^{137}Cs	Suspended solids	4
		^{210}Pb	Suspended solids	4
Southern North Sea (ZN)	Noordwijk 70 [(1)]	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
		^{90}Sr	Water	4
Central North Sea (CN)	Terschelling 235 [(1)]	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
		^{90}Sr	Water	4
Delta Coastal Waters (VD)	Schouwen 10 [(1)]	Gross α	Water	11
		Residual β	Water	11
		^{3}H	Water	11
		^{90}Sr	Water	4
Westerscheldt (WS)	Vlissingen Boei	Gross α	Water	13
		Residual β	Water	13
		^{3}H	Water	13
		^{90}Sr	Water	13
		^{137}Cs	Suspended solids	4
		^{210}Pb	Suspended solids	4
Eems-Dollard (ED)	Huibergat Oost	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
	Bocht van Watum	^{137}Cs	Suspended solids	3
		^{210}Pb	Suspended solids	3
Wadden Sea West (WW)	Marsdiep Noord	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4
	Doove Balg West	^{137}Cs	Suspended solids	3
		^{210}Pb	Suspended solids	3
Wadden Sea East (WO)	Dantziggat	Gross α	Water	4
		Residual β	Water	4
		^{3}H	Water	4

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



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

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

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

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

Terschelling 135 km offshore and Terschelling 100 km offshore were the old monitoring locations for the Central North Sea during 1989 (135 km offshore) and 1988–1994 (100 km offshore). Terschelling 235 km offshore has been the monitoring location for the Central North Sea from 1995 and onwards. Noordwijk 10 km offshore was the old monitoring location for the Coastal Area during 1988–1998. Noordwijk 2 km offshore has been the monitoring location for the Coastal Area since 1999 [45]. Ketelmeer West has not been a monitoring location since 2009.

5.2 The results for surface water

The general monitoring strategy for surface water is to monitor the inland and border crossing waters of the Netherlands. Therefore, the locations mentioned in Table 5.1 are used for monitoring as they represent the major inland, incoming and outgoing waters of the Netherlands. The results for surface water are presented in Tables A15 and A16 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 2011 were within the range of those in previous years. The gross α activity concentration in the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse exceeded the target value (100 $mBq \cdot L^{-1}$) in 1 out of the 12, 9 out of the 12, 10 out of the 13, 1 out of the 13, 13 out of the 13 and 1 out of the 13 samples taken, respectively. In 2011, the yearly averaged gross α activity concentrations in the Noordzeekanaal, Nieuwe Waterweg and Scheldt (165, 180 and 290 $mBq \cdot L^{-1}$, respectively) were above the target value of 100 $mBq \cdot L^{-1}$.

The yearly averaged residual β activity concentrations were below the target value of 200 $mBq \cdot L^{-1}$. Residual β in the Noordzeekanaal, Nieuwe Waterweg and Scheldt has shown a change in trend since 1994, which was caused by a change in measuring technique that only applies to salt and brackish water [45]. Therefore, this change in trend was not seen for residual β in the IJsselmeer, Rhine or Meuse.

The ^{3}H activity concentration in the Rhine, Scheldt and Meuse exceeded the target value (10 $Bq \cdot L^{-1}$) in 2 out of the 13, 5 out of the 7 and 10 out of the 13 samples taken, respectively. The elevated level of ^{3}H in the Rhine could have originated from several nuclear power plants or research reactors in Germany, France or Switzerland. The elevated levels of ^{3}H in the Meuse could have originated from the nuclear power plants at Tihange (Belgium) or Chooz (France). The elevated levels of ^{3}H in the Scheldt could have originated from the nuclear power plant at Doel (Belgium). The yearly averaged ^{3}H activity concentrations in 2011 were within the range of those in previous years. In 2011, the yearly averaged ^{3}H activity concentration in the Scheldt and Meuse (14.0 and 28.0 $Bq \cdot L^{-1}$, respectively) were above the target value of 10 $Bq \cdot L^{-1}$.

The nuclide ^{90}Sr is released into the environment by nuclear power plants and nuclear reprocessing plants. The yearly averaged ^{90}Sr activity concentrations in 2011 were within the range of those in previous years. The yearly averaged ^{90}Sr activity concentrations were below the target value of 10 $mBq \cdot L^{-1}$.

The nuclide ^{226}Ra is released into the environment by the ore processing industry. The ^{226}Ra activity concentration in the Nieuwe Waterweg and Scheldt exceeded the target value (5 $mBq \cdot L^{-1}$) in 1 out of the 7 and 5 out of the 7 samples taken, respectively. The yearly averaged ^{226}Ra activity concentrations in 2011 were within the range of those in previous years. In 2011 the yearly averaged ^{226}Ra activity concentration in the Scheldt (7.3 $mBq \cdot L^{-1}$) was above the target value of 5 $mBq \cdot L^{-1}$.

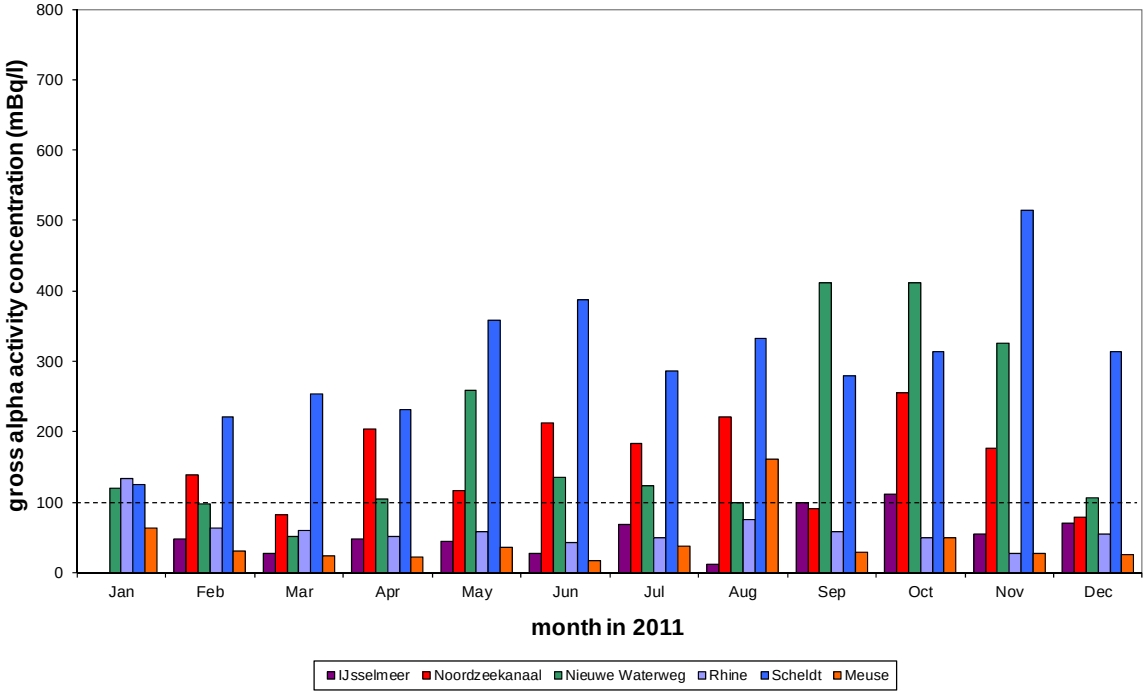


Figure 5.2: Gross α activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 53, 165, 180, 60, 290 and 43 mBq·L^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 100 mBq·L^{-1} [51].

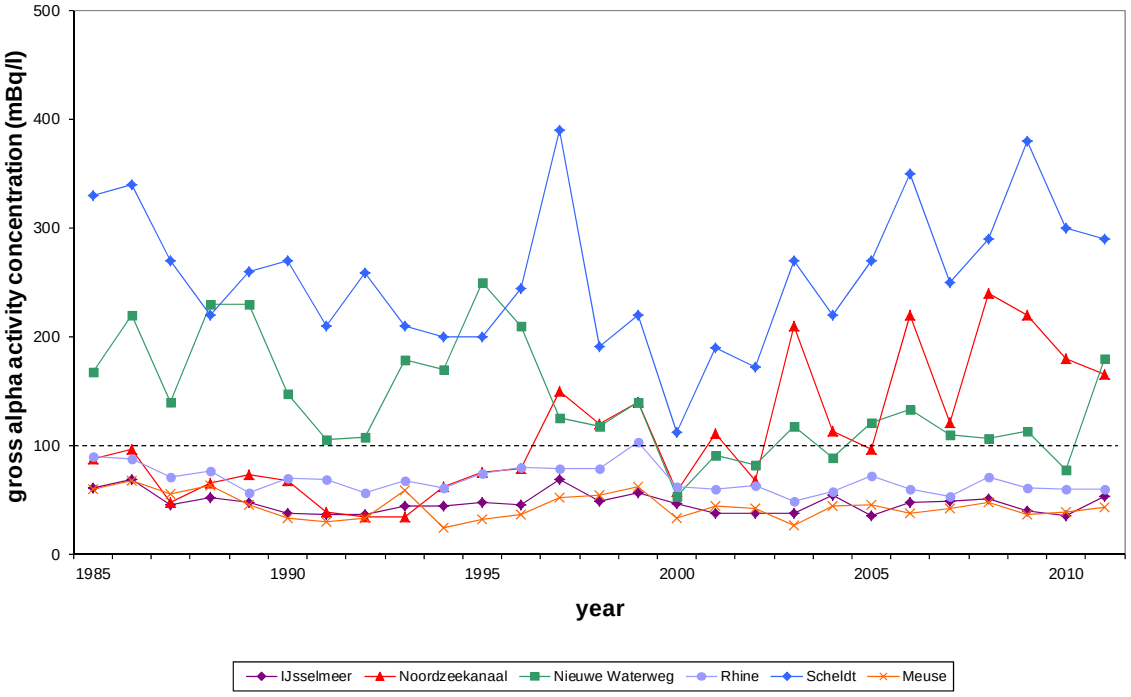


Figure 5.3: Yearly averaged gross α activity concentrations

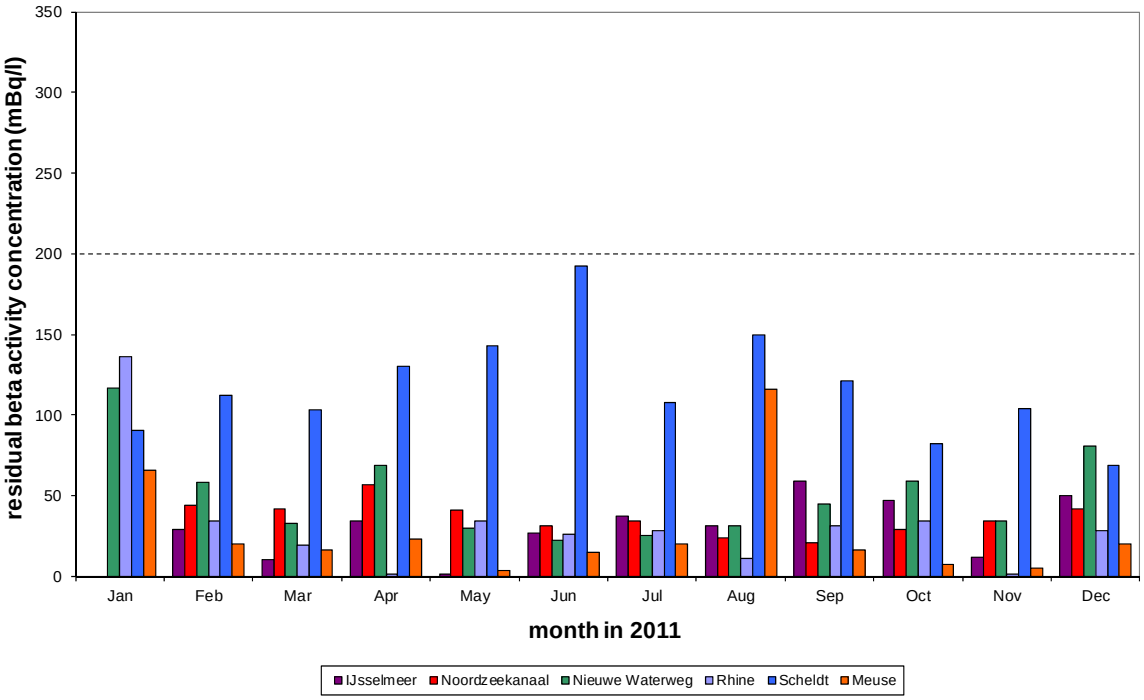


Figure 5.4: Residual β activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 29, 35, 49, 32, 115 and 25 mBq·L^{-1}, respectively
Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 200 mBq·L^{-1} [51].

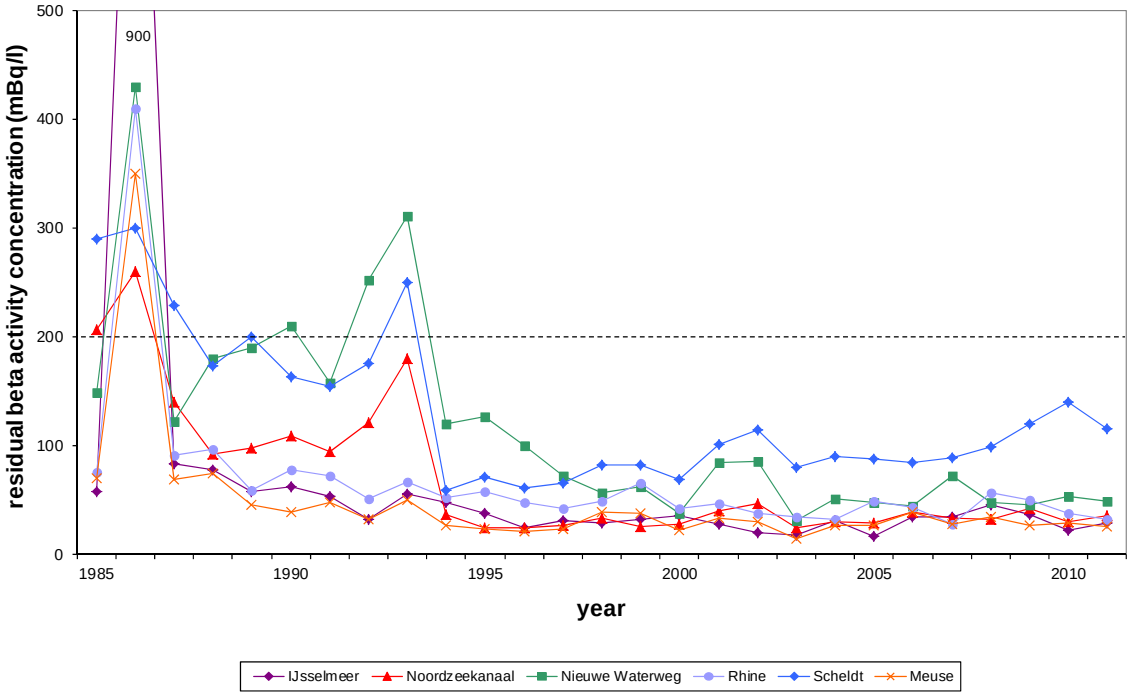


Figure 5.5: Yearly averaged residual β activity concentrations

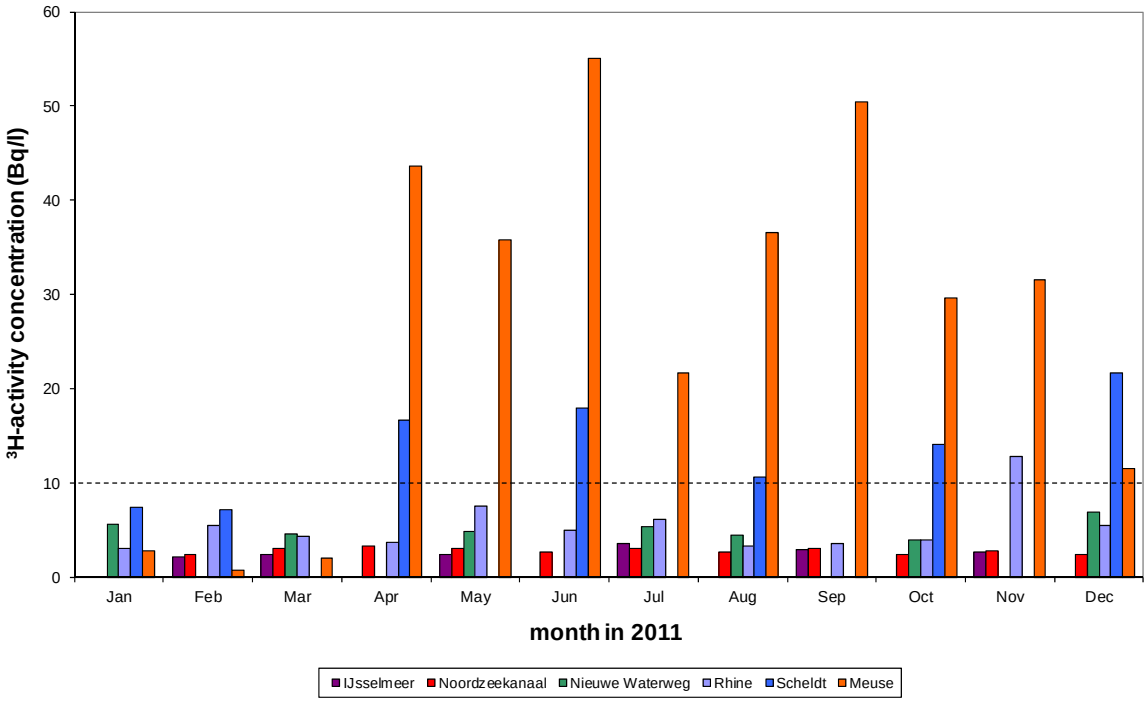


Figure 5.6: ^{3}H activity concentrations for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 2.7, 2.8, 5.1, 5.5, 14.0 and 28.0 Bq·L^{-1}, respectively
Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 10 Bq·L^{-1} [51].

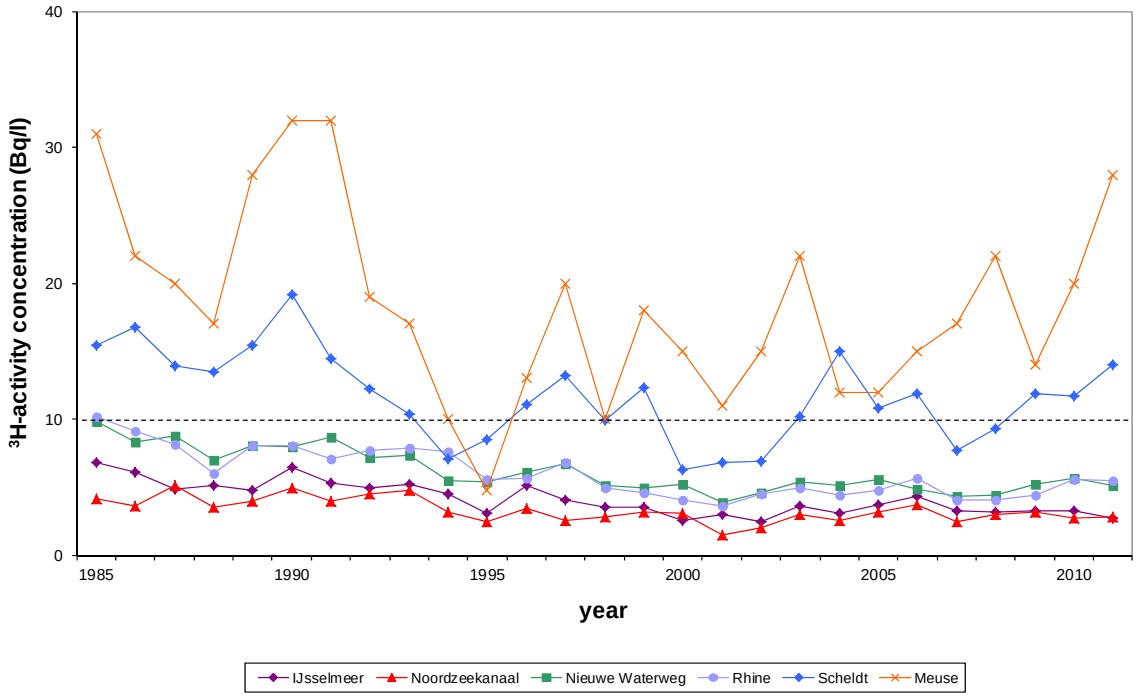


Figure 5.7: Yearly averaged ^{3}H activity concentrations

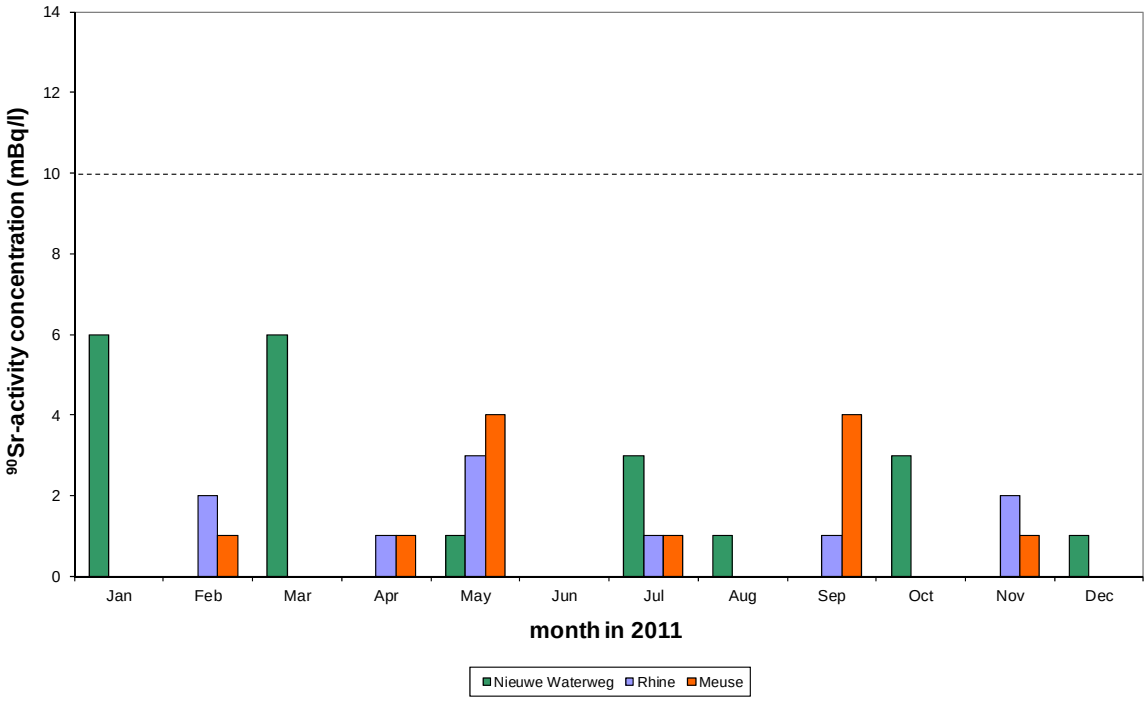


Figure 5.8: ^{90}Sr activity concentrations for the Nieuwe Waterweg, Rhine and Meuse, with yearly averages of 2.9, 1.5 and 1.8 mBq·L^{-1}, respectively
Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 10 mBq·L^{-1} [51].

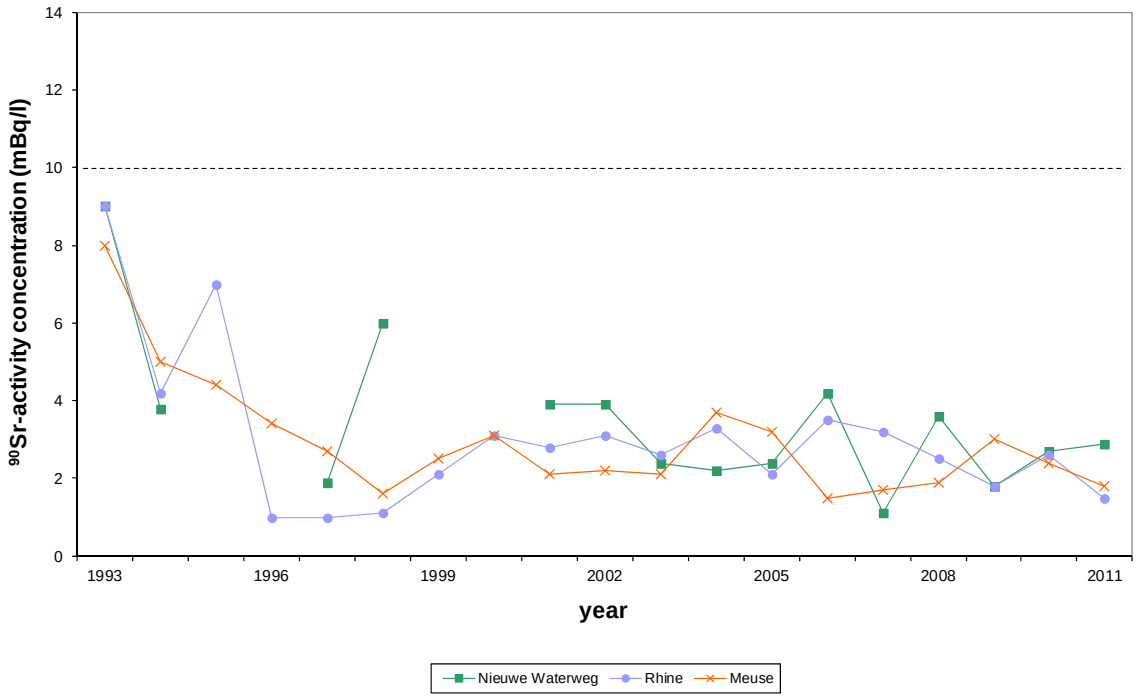


Figure 5.9: Yearly averaged ^{90}Sr activity concentrations
Data are not available for the Nieuwe Waterweg in 1995, 1996, 1999 and 2000.

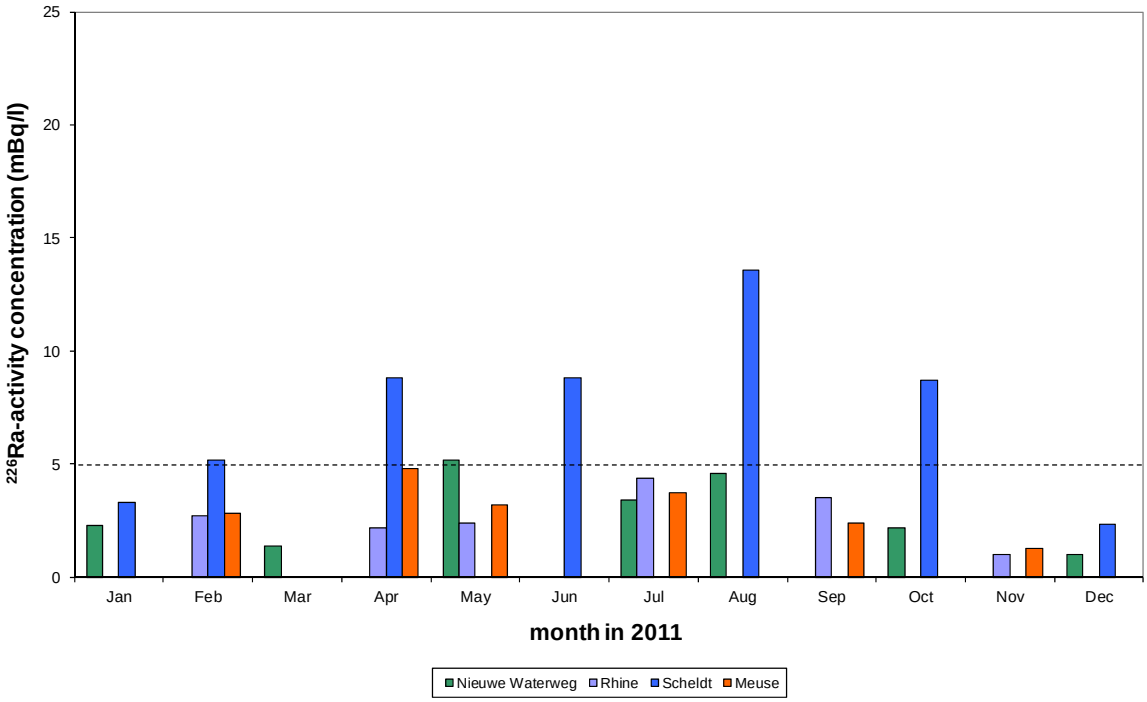


Figure 5.10: ^{226}Ra activity concentrations for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 2.9, 2.7, 7.3 and 3.0 mBq·L^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 5 mBq·L^{-1} [51].

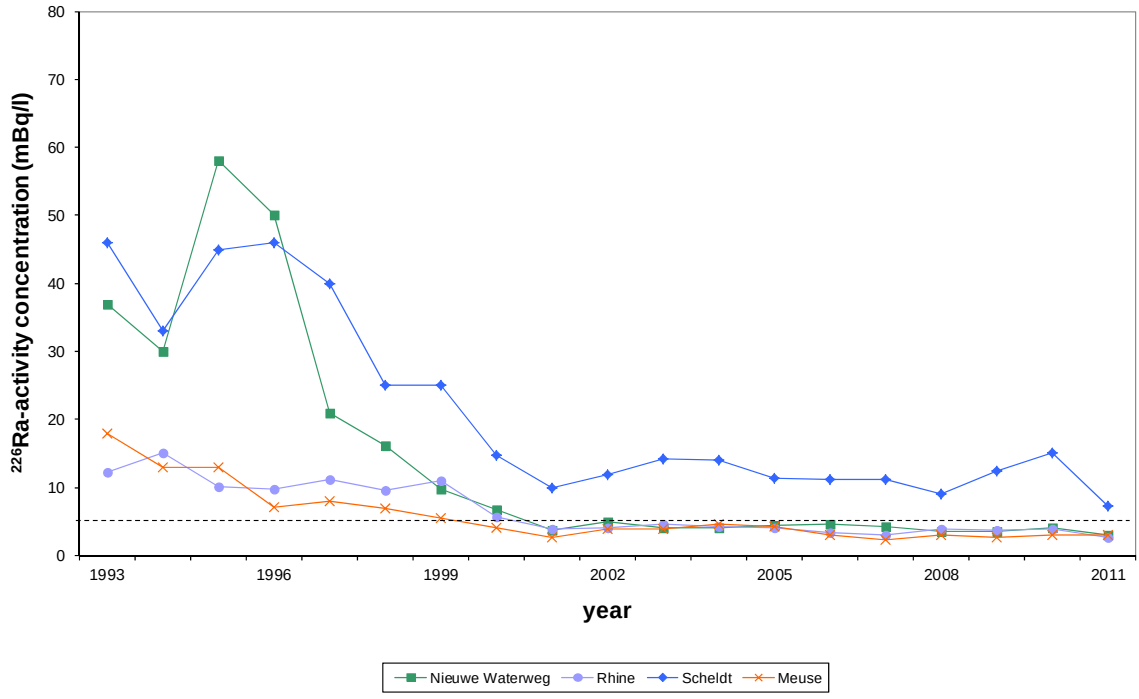


Figure 5.11: Yearly averaged ^{226}Ra activity concentrations

The nuclide ^{60}Co is a known corrosion product of nuclear power plants. The ^{60}Co activity concentration in suspended solids in the Meuse exceeded the target value (10 Bq·kg^{-1}) in 3 out of the 52 samples taken. In 2011, the yearly averaged ^{60}Co activity concentrations were 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 exceeded the target value (20 Bq·kg^{-1}) in 6 out of the 6 and 16 out of the 52 samples taken, respectively. In 2011, the yearly averaged ^{131}I activity concentration in the Noordzeekanaal (54 Bq·kg^{-1}) was higher than those in previous years, and exceeded the target value of 20 Bq·kg^{-1}. The contribution of the Fukushima incident to the ^{131}I activity concentration in suspended solids is insignificant.

The yearly averaged concentrations of ^{137}Cs in suspended solids in 2011 were within the range of those in previous years. The yearly averaged ^{137}Cs concentrations were below the target value of 40 Bq·kg^{-1}.

Since ^{210}Po is regularly in equilibrium with ^{210}Pb in suspended solids, RWS reports only ^{210}Pb. The nuclides ^{210}Po and ^{210}Pb originate from the uranium decay chain and are released by the phosphate processing industry [45]. The ^{210}Pb activity concentration in the Nieuwe Waterweg, Rhine, Scheldt and Meuse exceeded the target value (100 Bq·kg^{-1}) in 3 out of the 7, 4 out of the 6, 2 out of the 7 and 6 out of the 6 samples taken, respectively. In 2011 the yearly averaged ^{210}Pb activity concentrations in the Rhine and Meuse (104 and 165 Bq·kg^{-1}, respectively) were above the target value of 100 Bq·kg^{-1}, but within the range of those in previous years.

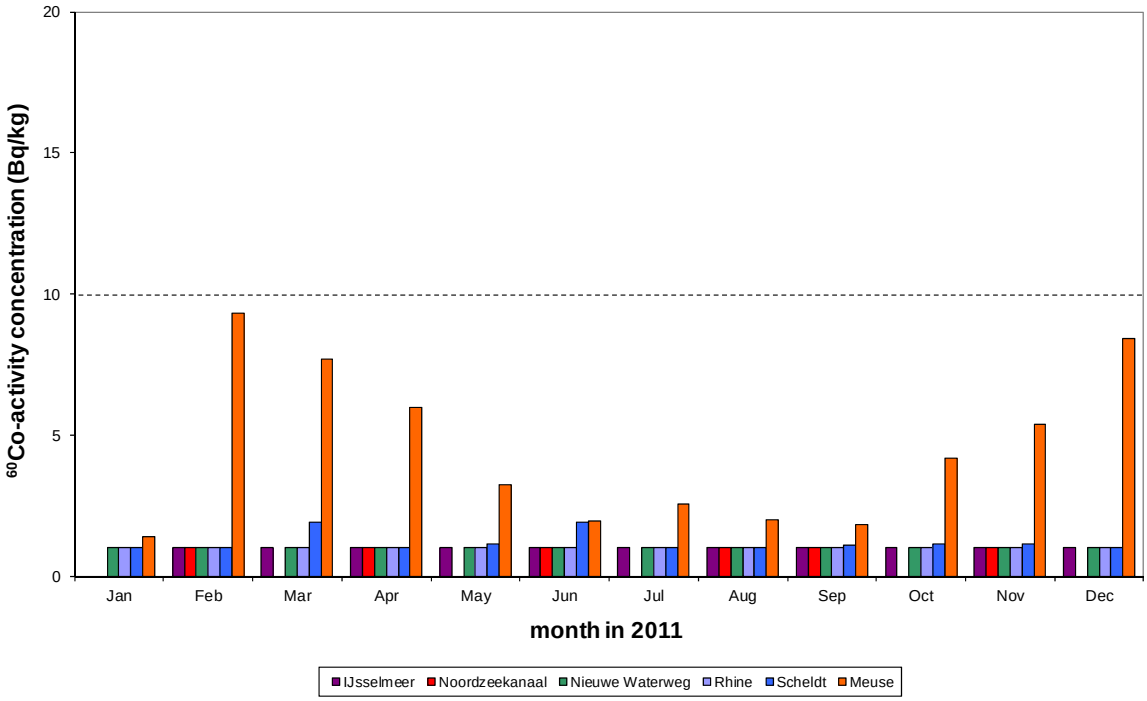


Figure 5.12: ^{60}Co activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, the yearly averages of all except for the Meuse (4.4 Bq·kg^{-1}) being < 1 Bq·kg^{-1}
Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 10 Bq·kg^{-1} [51].

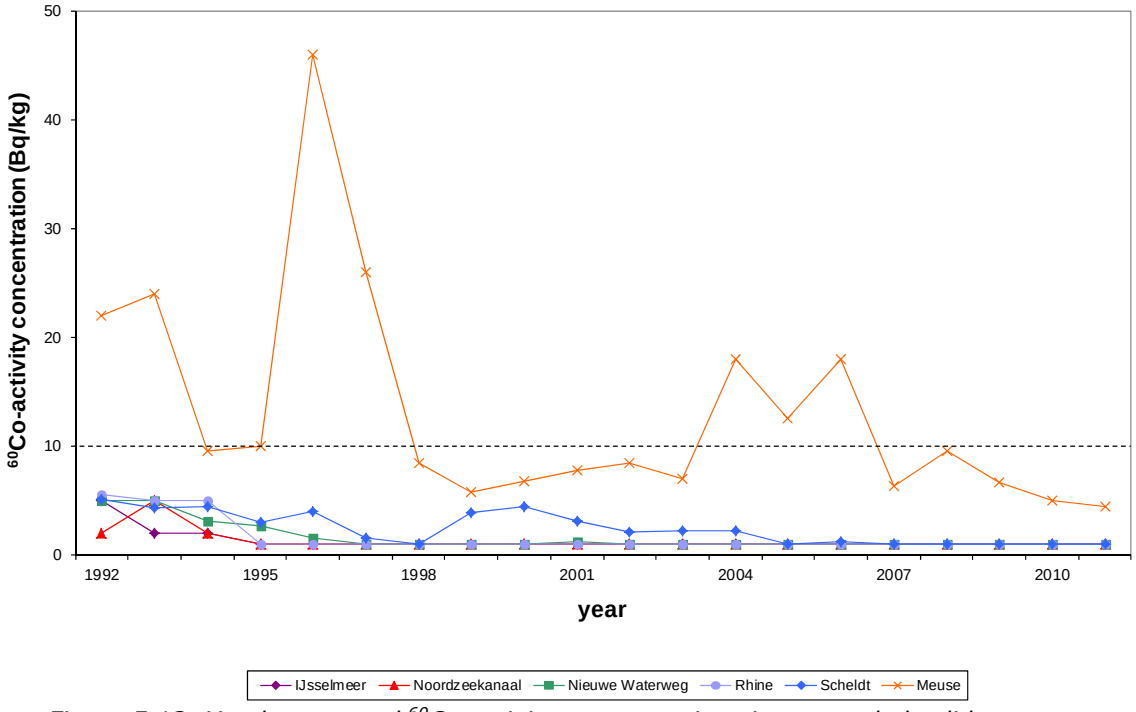


Figure 5.13: Yearly averaged ^{60}Co activity concentrations in suspended solids

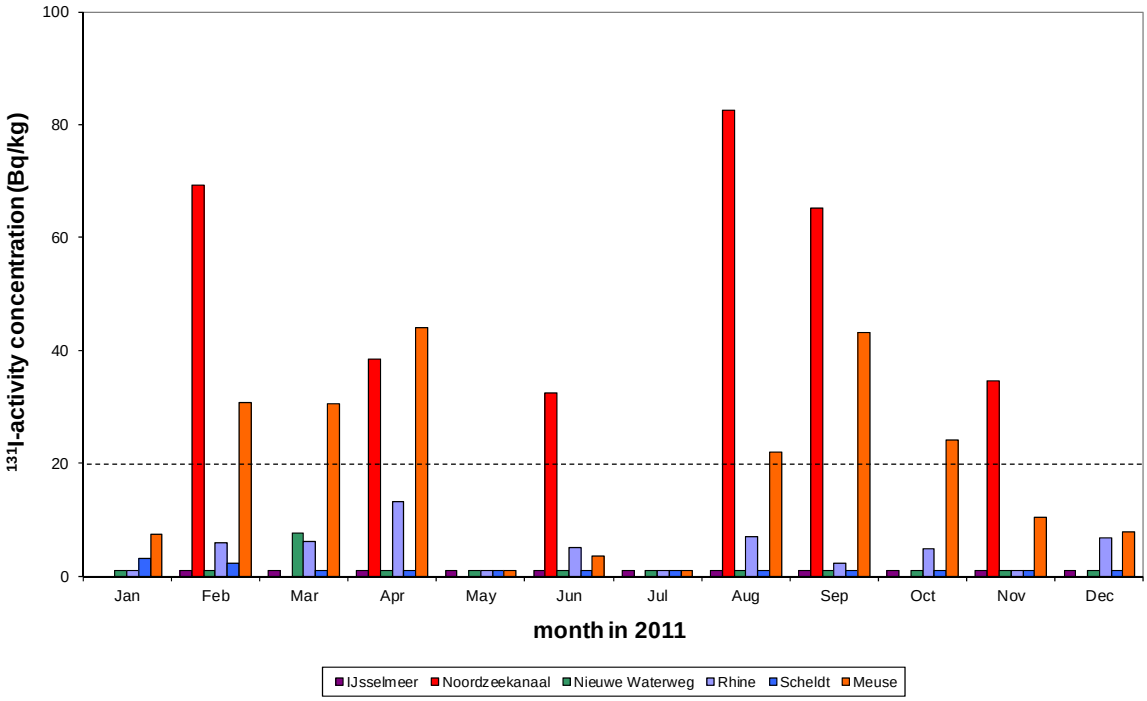


Figure 5.14: ^{131}I activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of < 1, 54, < 1.1, 4.6, < 1, and 18 Bq·kg^{-1}, respectively
Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 20 Bq·kg^{-1} [51].

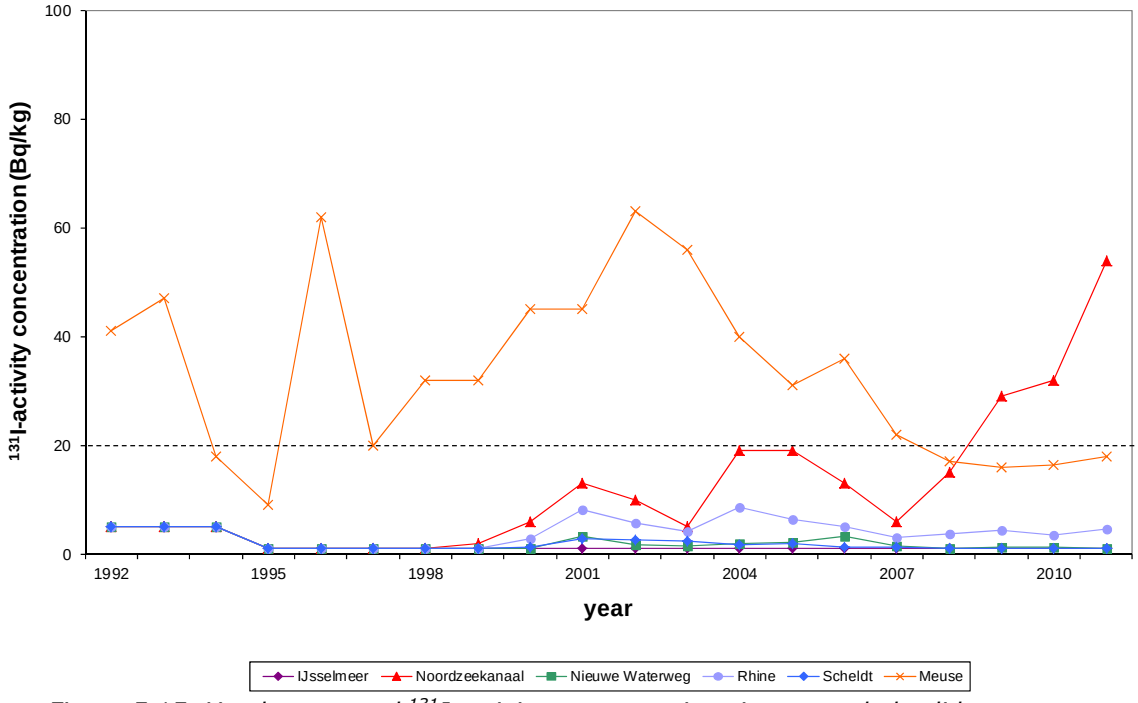


Figure 5.15: Yearly averaged ^{131}I activity concentrations in suspended solids

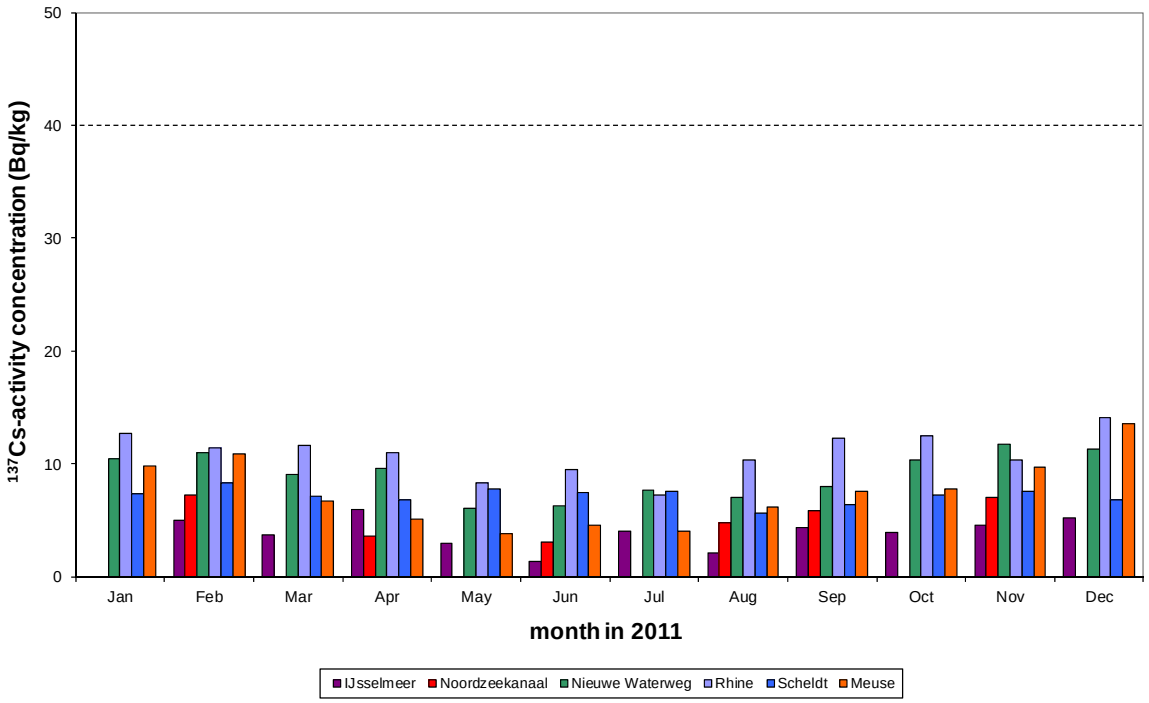


Figure 5.16: ^{137}Cs activity concentrations in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 3.9, 5.3, 8.9, 10.6, 7.2, and 7.4 Bq·kg^{-1}, respectively
Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 40 Bq·kg^{-1} [51].

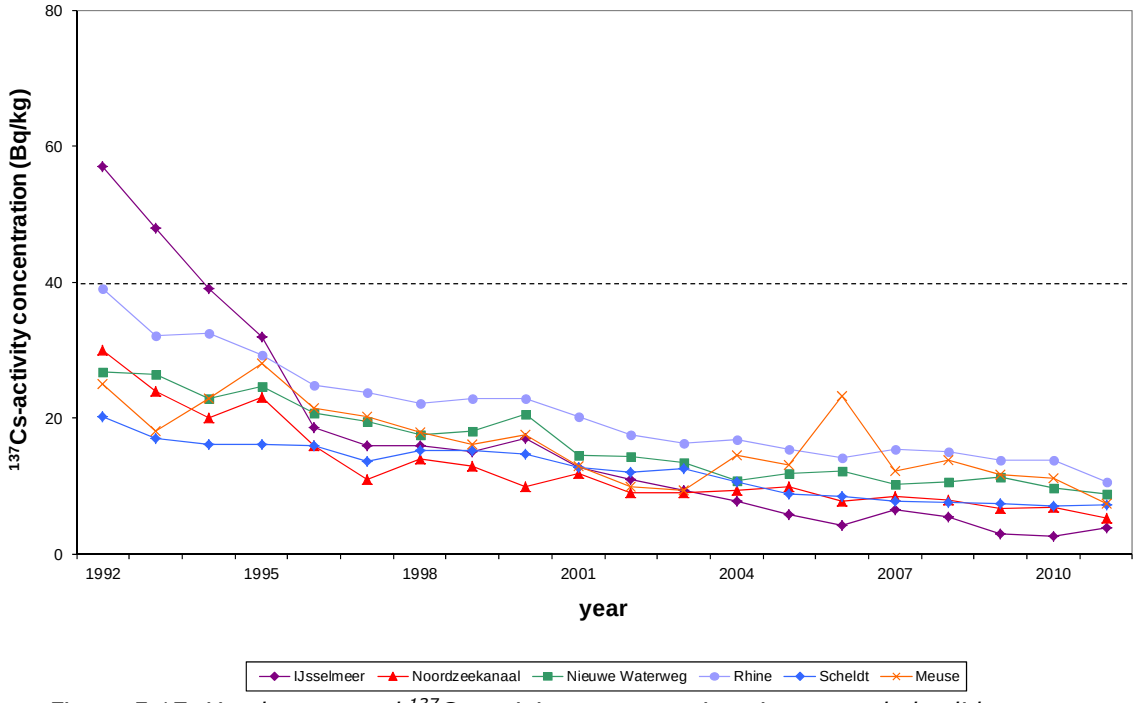


Figure 5.17: Yearly averaged ^{137}Cs activity concentrations in suspended solids

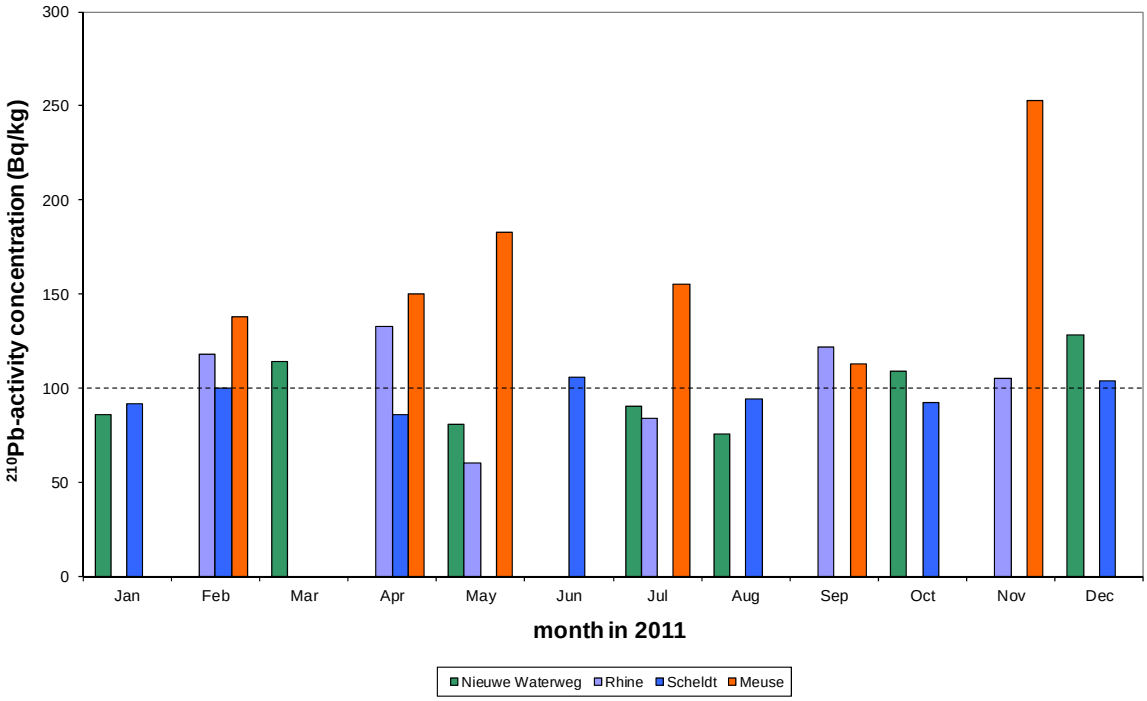


Figure 5.18: ^{210}Pb activity concentrations in suspended solids for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 98, 104, 96, and 165 Bq·kg^{-1}, respectively

Averaged values are shown in the case of multiple measurements per month. The dotted line represents the target value of 100 Bq·kg^{-1} [51].

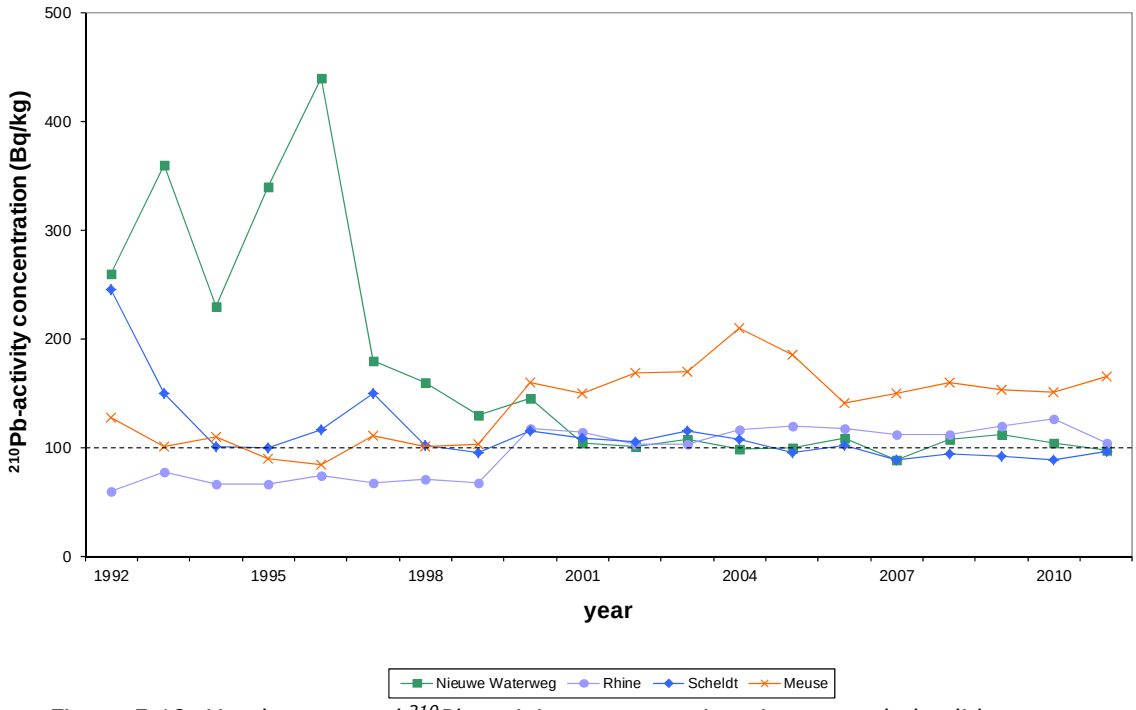


Figure 5.19: Yearly averaged ^{210}Pb activity concentrations in suspended solids

5.3 The results for seawater

The results for seawater are presented in Tables A17 and A18 and in Figures 5.20 to 5.31.

Gross α and residual β are indicative parameters [45]. In the first half of 2000 the background of the measuring equipment was unstable and higher than usual, which resulted in lower results. Therefore, yearly averaged concentrations of gross α in 2000 were based on data starting from the end of July 2000. Changes in the trend of gross α in the period from 1985 to 1997 are explained elsewhere [45]. The yearly averaged gross α activity concentrations in 2011 were within the range of those in previous years (Figure 5.21).

Residual β shows an apparent change in trend since 1994 (Figure 5.23). This was caused by a change in measuring technique, which only applies to salt and brackish water [45]. The yearly averaged residual β activity concentrations in 2011 were within the range of those in previous years (Figure 5.23).

Nuclear power plants discharge the nuclides ^{3}H and ^{137}Cs. Nuclear fuel reprocessing plants discharge the nuclides ^{3}H and ^{90}Sr. Discharges from the nuclear power plants at Doel (Belgium) and Borssele (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 [45]. 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 2011 were within the range of those in previous years (Figure 5.25). The yearly averaged ^{90}Sr concentrations in 2011 were within the range of those in previous years (Figure 5.27).

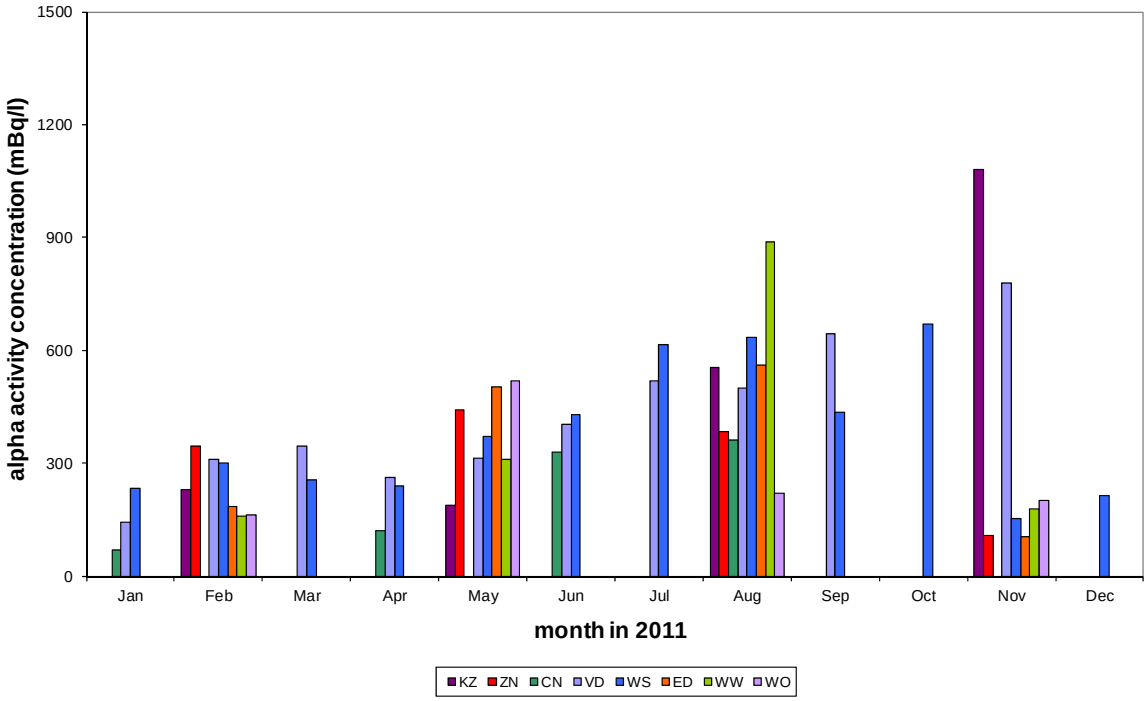


Figure 5.20: Gross α activity concentrations in seawater for the Coastal Area (KZ), Southern North Sea (ZN), Central North Sea (CN), Delta Coastal Waters (VD), Westerscheldt (WS), Eems-Dollard (ED), Wadden Sea West (WW) and Wadden Sea East (WO), with yearly averages of 500, 320, 220, 450, 370, 340, 380 and 280 mBq·L^{-1}, respectively

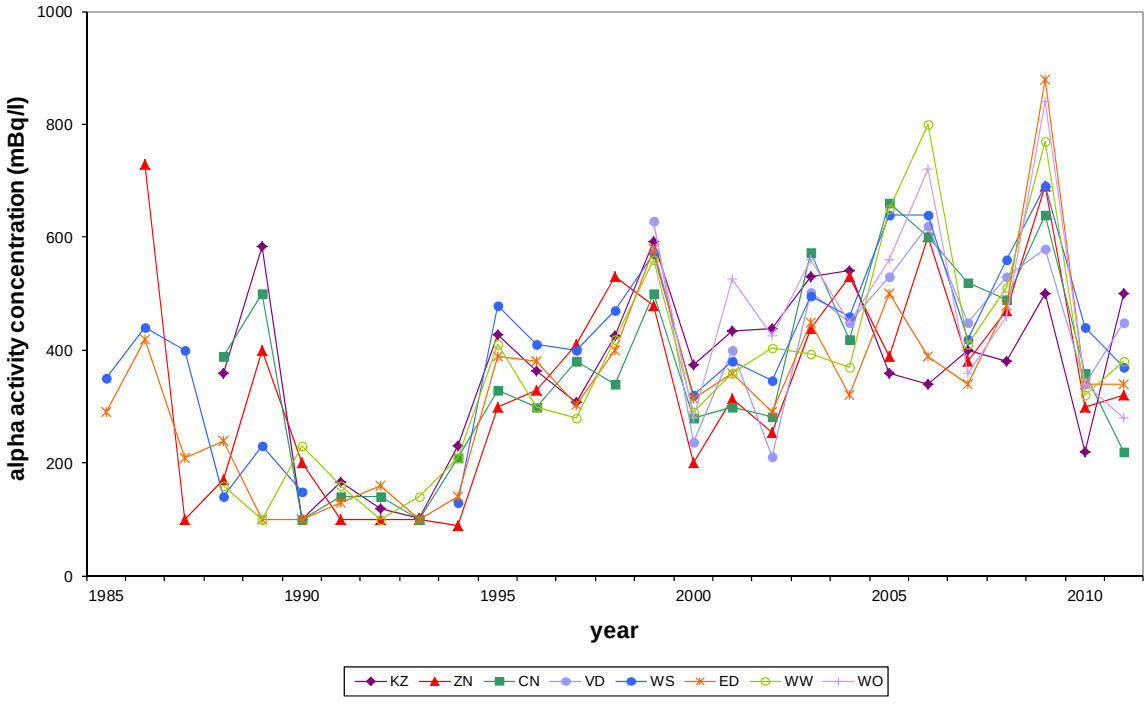


Figure 5.21: Yearly averaged gross α activity concentrations

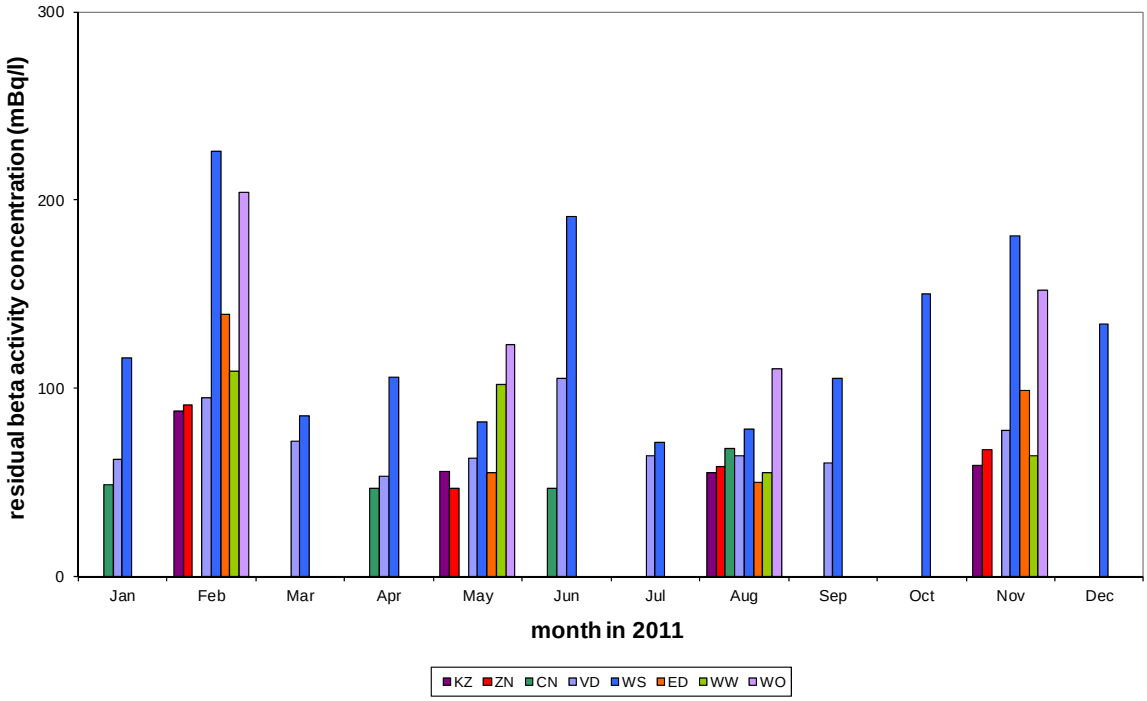


Figure 5.22: Residual β activity concentrations in seawater for the Coastal Area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East, with yearly averages of 64, 66, 53, 72, 124, 90, 82, and 150 mBq·L^{-1}, respectively

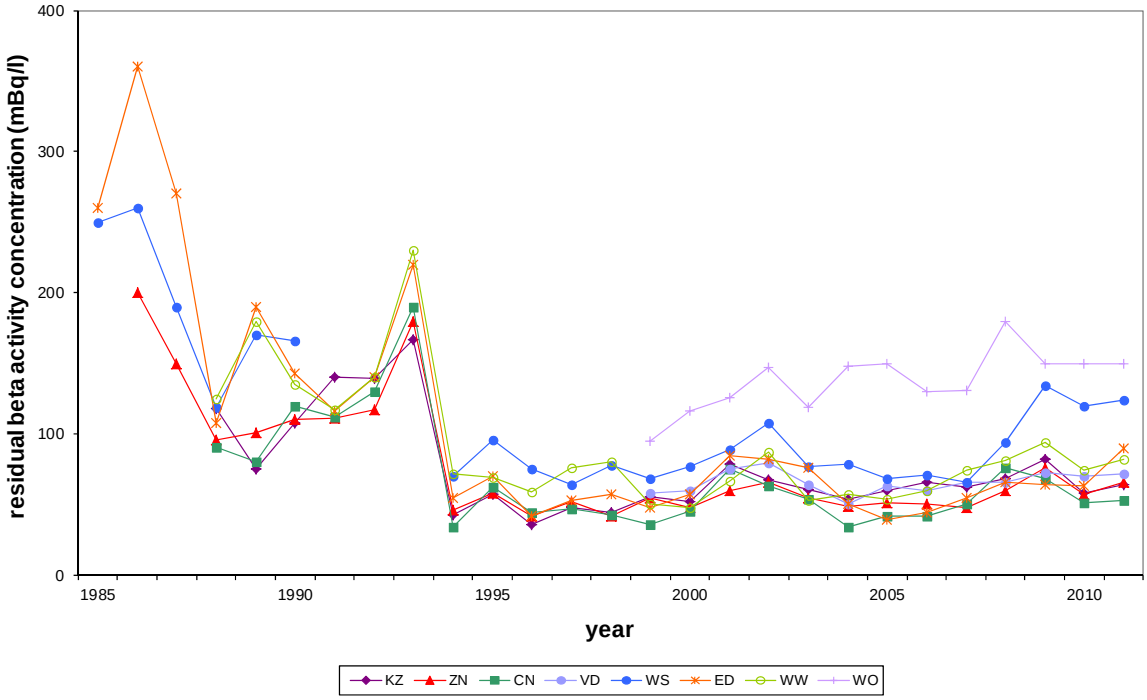


Figure 5.23: Yearly averaged residual β activity concentrations

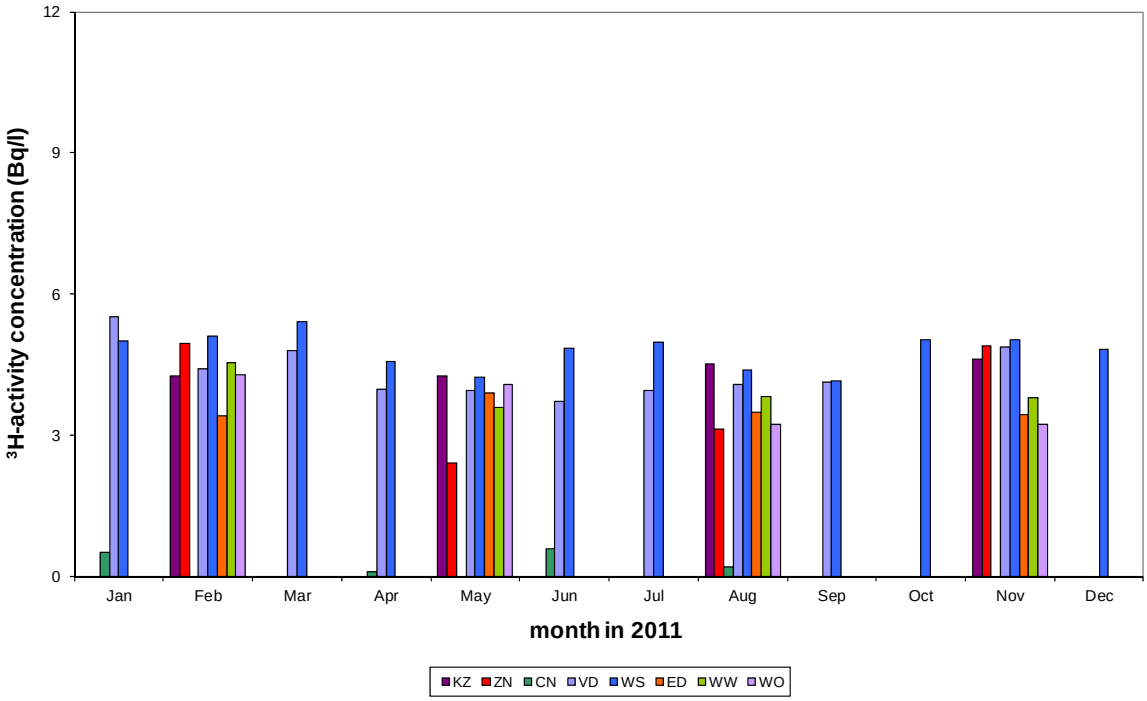


Figure 5.24: ^{3}H activity concentrations in seawater for the Coastal Area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East, with yearly averages of 4.4, 3.8, 0.36, 4.4, 4.8, 3.6, 3.9, and 3.7 $Bq \cdot L^{-1}$, respectively

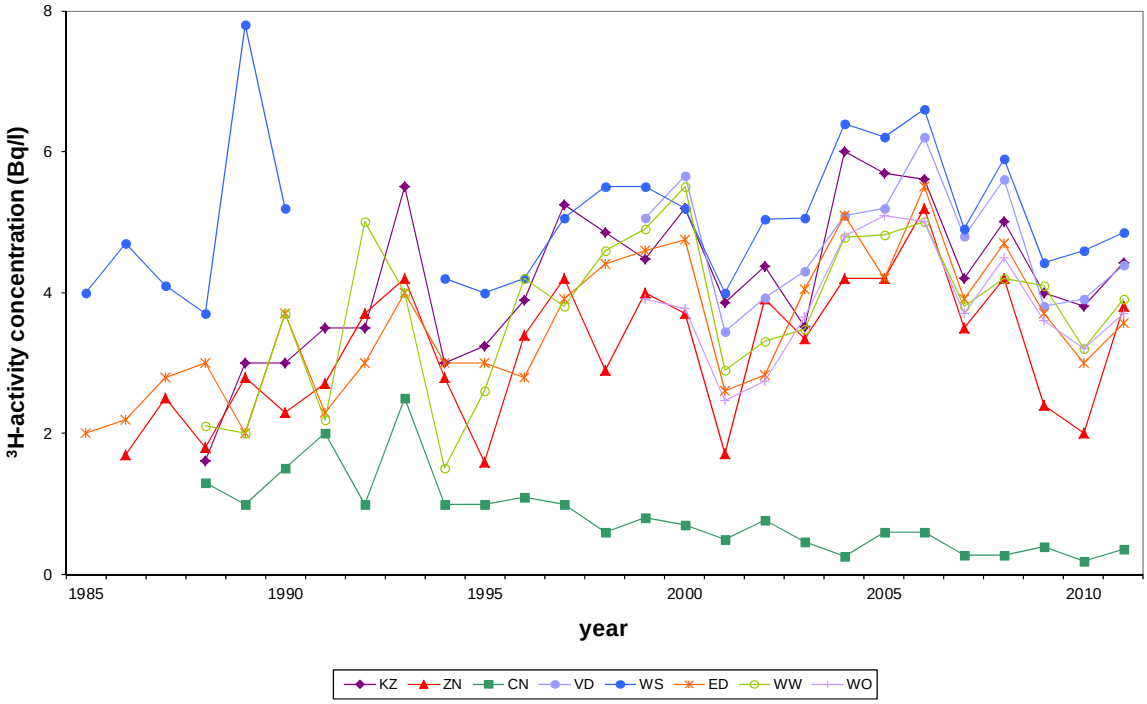


Figure 5.25: Yearly averaged ^{3}H activity concentrations

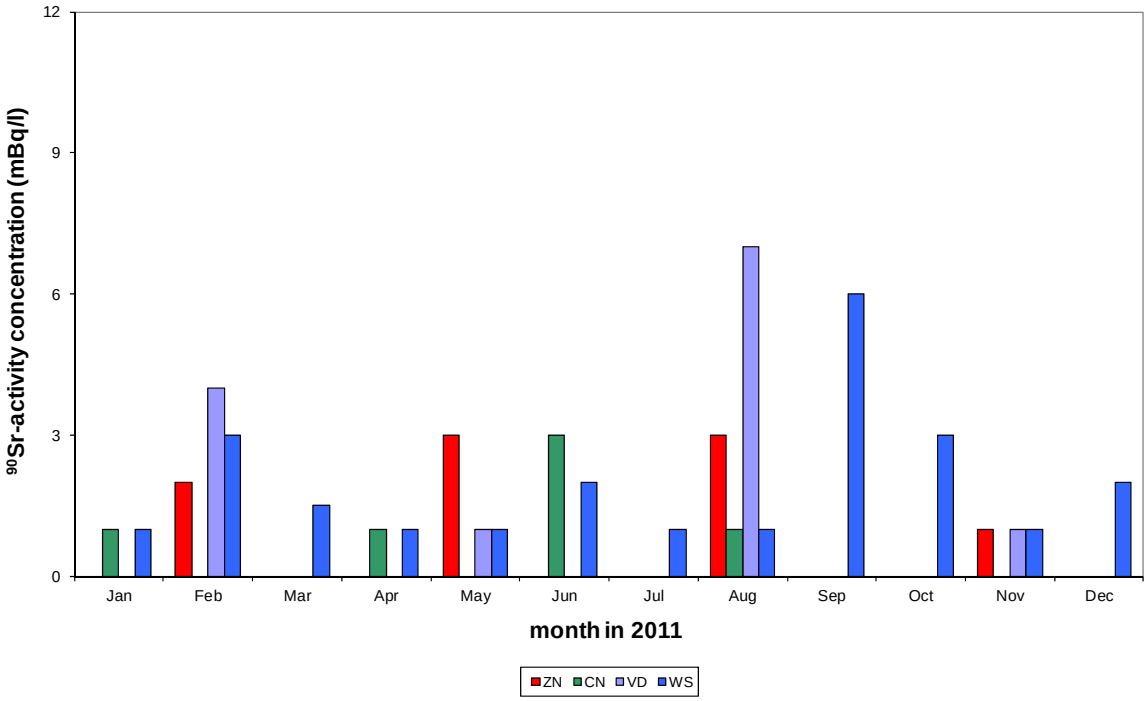


Figure 5.26: ^{90}Sr activity concentrations in seawater for Southern North Sea, Central North Sea, Delta Coastal Waters and Westerscheldt, with yearly averages of 2.1, 1.4, 3, and 1.7 mBq·L^{-1}, respectively

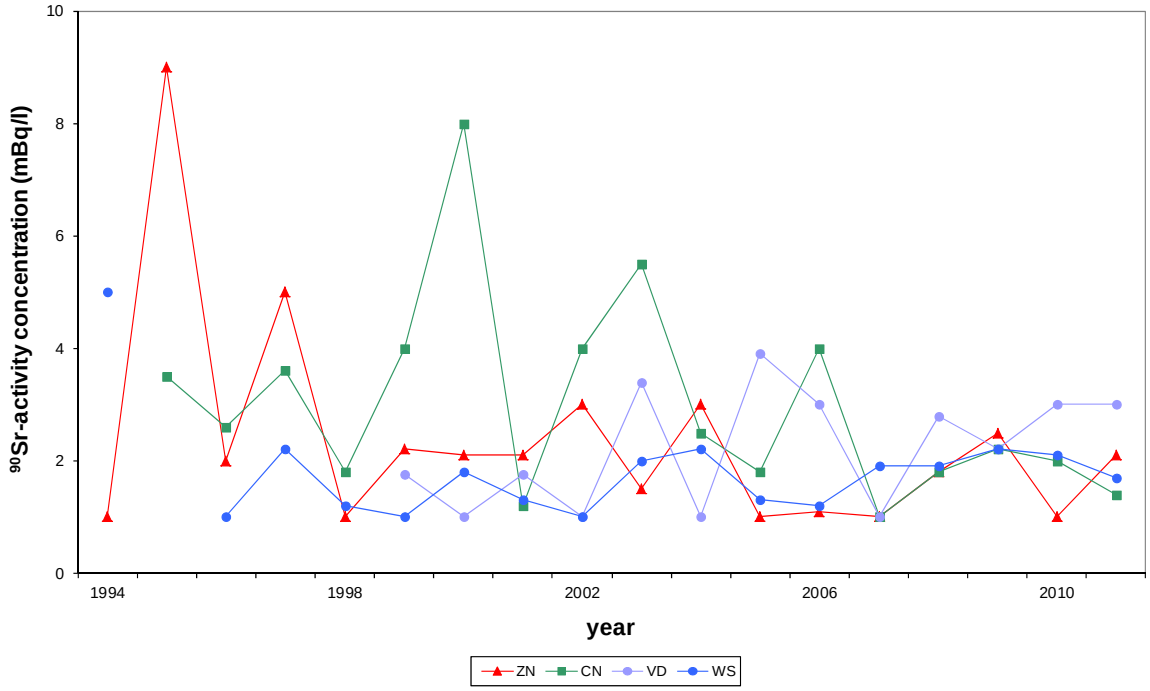


Figure 5.27: Yearly averaged ^{90}Sr activity concentrations

Since ^{210}Po is regularly in equilibrium with ^{210}Pb in suspended solids, RWS reports only ^{210}Pb (analogous to surface water). In cases where the gross α value is increased, ^{210}Po is determined as well. The nuclides ^{210}Pb and ^{210}Po originate from the uranium decay chain and are released, for example, by the phosphate processing industry and production platforms for oil and gas [45]. Discharges via the main rivers are monitored in the Coastal Area (KZ). Discharges by the ore and phosphate processing industries in Belgium and the Netherlands are monitored in the Westerscheldt (WS). Discharges by Germany, Delfzijl and Eemshaven are monitored in the Eems-Dollard (ED). The impact of these discharges is monitored indirectly in the Wadden Sea (WW and WO) together with activity originating from the North Sea.

Since 2009, ^{137}Cs and ^{210}Pb have been determined at Wadden Sea West instead of Wadden Sea East. The yearly averaged concentrations of ^{137}Cs in 2011 were within the range of those in previous years (Figure 5.29). The yearly averaged concentrations of ^{210}Pb in 2011 were within the range of those in previous years (Figure 5.31).

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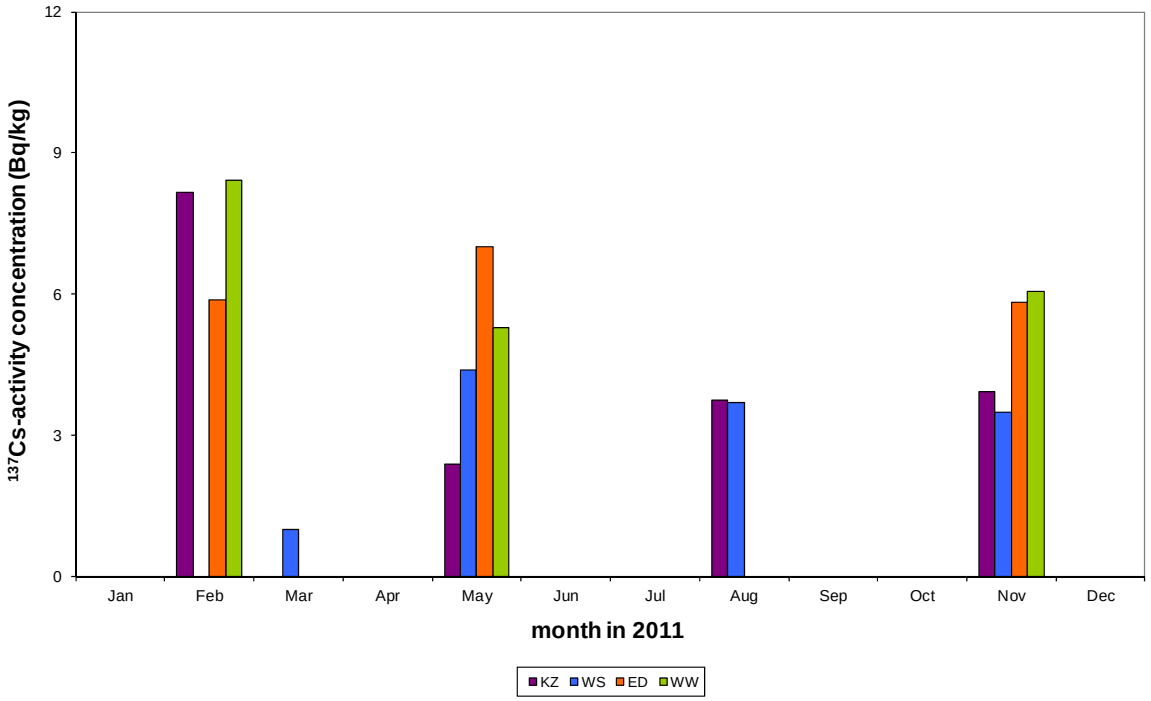

Figure 5.28: ^{137}Cs activity concentrations in suspended solids in seawater for the Coastal Area, Westerscheldt, Eems-Dollard and Wadden Sea West, with yearly averages of 4.6, 3.0, 6.2 and 6.6 Bq·kg^{-1}, respectively

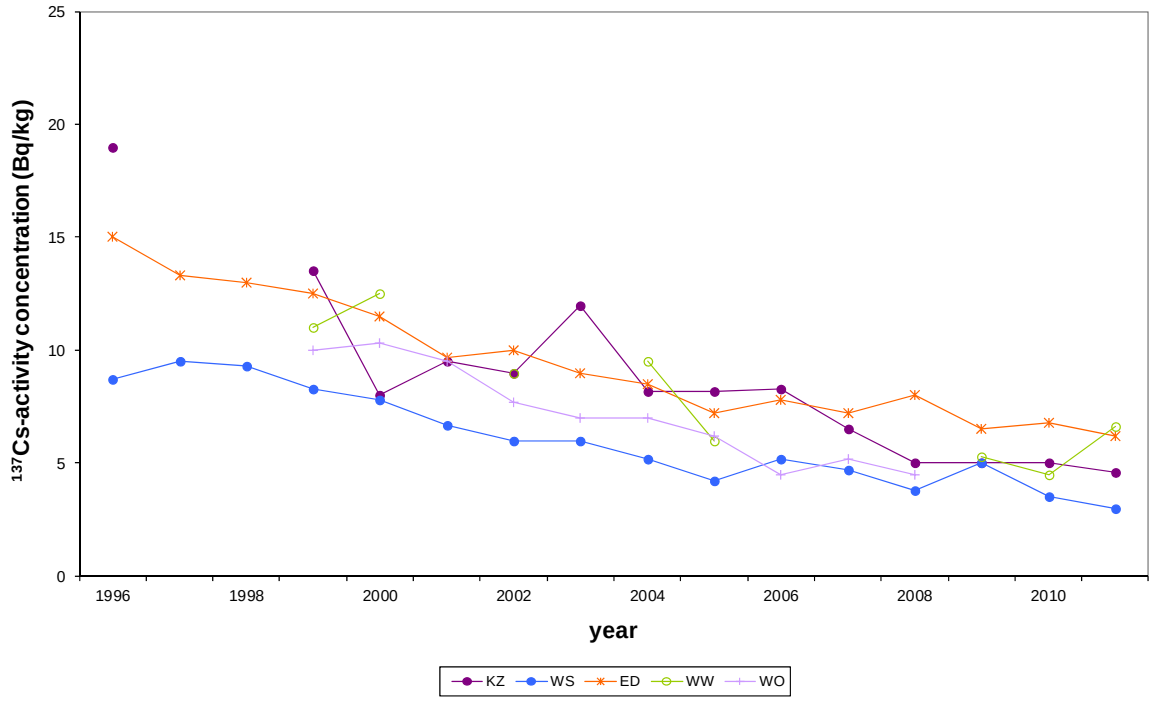

Figure 5.29: Yearly averaged ^{137}Cs activity concentrations in suspended solids
Since 2009, ^{137}Cs has been determined at Wadden Sea West instead of Wadden Sea East.

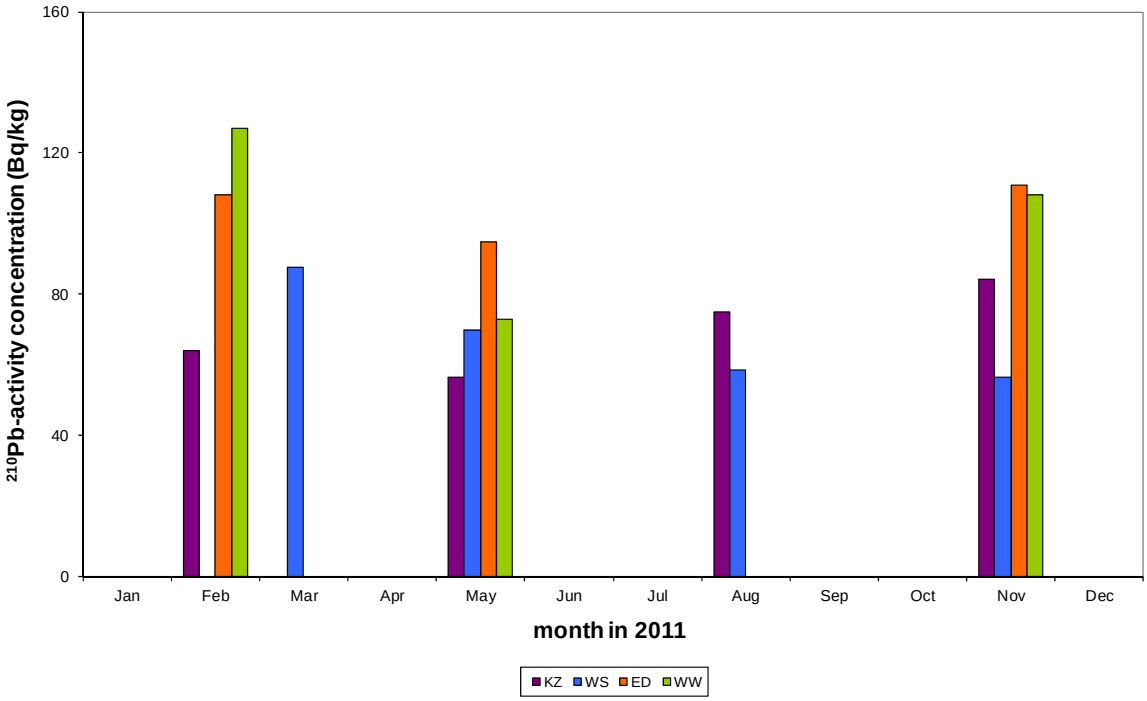

Figure 5.30: ^{210}Pb activity concentrations in suspended solids in seawater for the Coastal Area, Westerscheldt, Eems-Dollard and Wadden Sea West, with yearly averages of 70, 68, 105 and 103 Bq·kg^{-1}, respectively

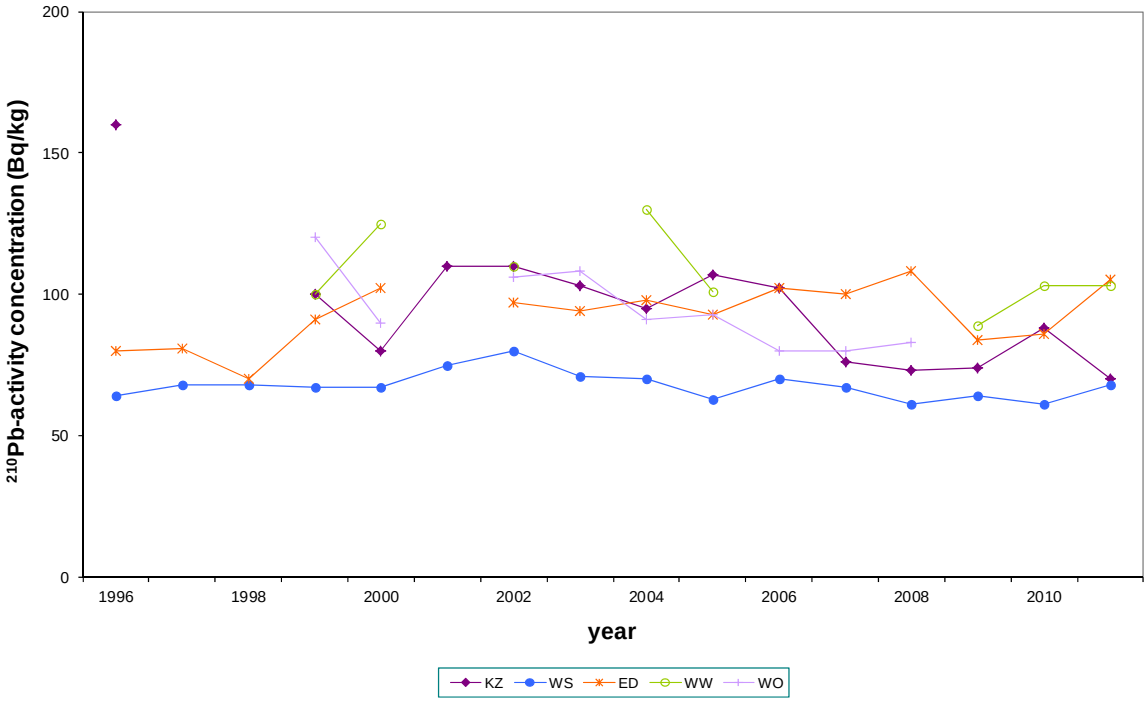

Figure 5.31: Yearly averaged ^{210}Pb activity concentrations in suspended solids
Since 2009, ^{210}Pb has been determined at Wadden Sea West instead of Wadden Sea East.

6 Water for human consumption

In addition to the Recommendation on the Application of Article 36 of the Euratom Treaty [1], regulations for the monitoring of drinking water are given in Council Directive 98/83/EC [52]. According to this directive, the parameters ^{3}H and the total indicative dose should be monitored. Screening methods for gross α and gross β activity concentrations may be used to monitor the total indicative dose. If the gross α and gross β activity concentrations are less than 0.1 and 1.0 $Bq \cdot L^{-1}$, respectively, it can be assumed that the total indicative dose is less than the parametric value of 0.1 $mSv \cdot year^{-1}$ [53, 54, 55].

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

The results for 2011 are presented in Table 6.1. For gross α, ^{3}H, gross β and residual β, several hundred analyses were performed at 174 to 191 production stations.

Table 6.1: Drinking water analyses in 2011

Parameter	Gross α	^{3}H	Residual β	Gross β
Average value [(1)]	< 0.1 $Bq \cdot L^{-1}$	< 4.2 $Bq \cdot L^{-1}$	< 0.2 $Bq \cdot L^{-1}$	< 0.1 $Bq \cdot L^{-1}$
No. of all production stations	185	188	174	191
No. of all analyses	355	400	377	414
Maximum value [(2)]	0.1 $Bq \cdot L^{-1}$	19 $Bq \cdot L^{-1}$	< 0.5 $Bq \cdot L^{-1}$	0.5 $Bq \cdot L^{-1}$
No. of production stations [(3)]	1	1	11	11
No. of analyses [(4)]	1	4	111	111

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

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

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

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

For gross α, ^{3}H, gross β and residual β, the results were within the range of those in previous years [7, 56, 57, 58, 59, 60, 61, 62, 63]. Since there was almost no ^{40}K present, there was no difference between average gross β and residual β activity concentrations. The gross α activity concentrations were equal to or below 0.1 $Bq \cdot L^{-1}$. The gross β activity concentrations were below 1.0 $Bq \cdot L^{-1}$ and the ^{3}H activity concentrations were below the parametric value of 100 $Bq \cdot L^{-1}$ [52, 54, 55].

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 [64]. The average concentration found was 2.2 $Bq \cdot L^{-1}$ for drinking water produced from groundwater. The difference between this value and those mentioned in Table 6.1 is due to the contribution of short-lived and volatile natural radionuclides (radon daughters), which are not included in the gross α, gross β and residual β activity concentrations.

7 Milk

RIKILT Wageningen UR monitors radioactivity in milk on a weekly basis, mainly via the National Monitoring Network Radioactivity in Food (Landelijk Meetnet Radioactiviteit in Voedsel, LMRV). The LMRV is a monitoring network that has been set up as an emergency network for monitoring relatively high contamination levels. The LMRV consists of 70 NaI monitors, of which 24 are stationed at dairy factories. The results of the weekly samples from all locations are combined into a monthly average for the whole country. The monthly averages for 2011 are presented in Table 7.1. None of the samples exceeded the limit of 370 Bq·kg^{-1} for radiocesium activity (sum of ^{134}Cs and ^{137}Cs) set by the European Union [65].

Table 7.1: Monthly averaged activity concentrations in milk in 2011 (1)

Month	Number of samples	^{40}K Bq·L^{-1}	^{60}Co Bq·L^{-1}	^{131}I Bq·L^{-1}	^{134}Cs Bq·L^{-1}	^{137}Cs Bq·L^{-1}
January	59	58.3 ± 11.9	< 1.4	< 0.6	< 0.6	< 0.5
February	56	57.7 ± 11.5	< 1.4	< 0.6	< 0.6	< 0.5
March	99	53.8 ± 11.5	< 1.4	< 0.6	< 0.6	< 0.5
April	102	56.3 ± 10.6	< 1.4	< 0.6	< 0.6	< 0.5
May	81	58.5 ± 13.3	< 1.4	< 0.6	< 0.6	< 0.5
June	64	57.9 ± 10.5	< 1.4	< 0.6	< 0.6	< 0.5
July	86	63.1 ± 14.6	< 1.4	< 0.6	< 0.6	< 0.5
August	67	59.2 ± 13.3	< 1.4	< 0.6	< 0.6	< 0.5
September	63	60.8 ± 14.4	< 1.4	< 0.6	< 0.6	< 0.5
October	84	57.9 ± 13.9	< 1.4	< 0.6	< 0.6	< 0.5
November	67	57.4 ± 15.2	< 1.4	< 0.6	< 0.6	< 0.5
December	63	54.8 ± 13.2	< 1.4	< 0.6	< 0.6	< 0.5
Average	891 (2)	59.3 ± 12.8	< 1.4	< 0.6	< 0.6	< 0.5

(1) Uncertainty is given as 1σ.

(2) Yearly total.

RIKILT Wageningen UR analysed 50 milk samples for ^{90}Sr in 2011. The samples were collected across the Netherlands. The ^{90}Sr activity concentration was below the detection limit (0.6 Bq·L^{-1}) in all samples taken, so none of the samples exceeded the set limit of 125 Bq·kg^{-1} [66]. The detection limit was lower than in previous years, due to a significant improvement of the precipitation procedure.

8 Food

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

The measurements on food performed by the Netherlands Food and Consumer Product Safety Authority were carried out according to standard procedures [67, 68]. Since 2005, the Netherlands Food and Consumer Product Safety Authority has monitored activity concentrations in a mixed diet every year. Over a period of four weeks in 2011, 544 samples were taken from retail shops, wholesale produce auctions and distribution centres, including 91 samples of honey [69]. Though honey is not considered to be part of the mixed diet, samples are taken each year because it is a product that is known sometimes to contain higher levels of radioactivity.

The separate ingredients were divided into the following product groups: grain and grain products, vegetables, fruit and fruit products, milk and dairy products, meat and meat products, game and poultry, salads, oil and butter, and honey. The 2011 results are presented in Table 8.1. None of the samples exceeded the set limit of 600 $Bq \cdot kg^{-1}$ (or 370 $Bq \cdot kg^{-1}$ for milk and dairy products) [65].

In 2011, RIKILT Wageningen UR also measured radioactivity in food products – especially meat, eggs and fish – as part of a monitoring programme for export certification. Samples were taken every two weeks and measurements were carried out according to standard procedures. The 2011 results are presented in Table 8.2. A total of 993 samples were analysed and one sample exceeded the set limit of 600 $Bq \cdot kg^{-1}$ (or 370 $Bq \cdot kg^{-1}$ for milk and dairy products).

In addition, radioactivity was measured in 727 food products for individual screening purposes via the National Monitoring Network Radioactivity in Food, especially fruit, fruit products and vegetables (data not shown).

In 2011, RIKILT Wageningen UR analysed 41 mixed diets for ^{90}Sr content. In all analysed meals, ^{90}Sr concentration was below the detection limit of 5 $Bq \cdot kg^{-1}$, which is well below the set limit of 750 $Bq \cdot kg^{-1}$ [66].

8.1 Honey

In total, 91 samples of honey were analysed by the Netherlands Food and Consumer Product Safety Authority [69]. The activity (sum of ^{134}Cs and ^{137}Cs) was found to be below the set limit of 600 $Bq \cdot kg^{-1}$ [65]. Only eight samples of honey contained ^{137}Cs and the activity varied from 15 up to 209 $Bq \cdot kg^{-1}$.

8.2 Game and poultry

In the product group 'Game and poultry', which was analysed by RIKILT Wageningen UR, all 18 samples that contained ^{137}Cs were game. The activity varied from 3.3 up to 830 $Bq \cdot kg^{-1}$. In 17 out of the 18 samples the radiocesium activity (sum of ^{134}Cs and ^{137}Cs) was below the set limit of 600 $Bq \cdot kg^{-1}$ [65].

One sample of boar (originating from the Netherlands in January 2011) was above the set limit of 600 Bq·kg^{-1} and contained 830 ± 26 Bq·kg^{-1} ^{137}Cs. This result was reported to the Netherlands Food and Consumer Product Safety Authority that performed a follow up by taking several actions. A risk assessment has been made for the consumption of boar. The consumption of a regular portion (a few ounces) does not pose a threat to public health. Additional samples were taken from another boar from the same supplier, the activity (sum of ^{134}Cs and ^{137}Cs) was found to be below the set limit of 600 Bq·kg^{-1}.

Table 8.1: Results of 2011 analysis of food for ^{134}Cs and ^{137}Cs as measured by the Netherlands Food and Consumer Product Safety Authority

Product	**Number of samples**	**^{134}Cs (1) Bq·kg^{-1}**	**^{137}Cs (1) Bq·kg^{-1}**
Grain and grain products	70	< 10 (0)	< 10 (0)
Vegetables	130	< 10 (0)	< 10 (0)
Fruit and fruit products	57	< 10 (0)	< 10 (0)
Milk and dairy products	44	< 10 (0)	< 10 (0)
Meat and meat products	61	< 10 (0)	< 10 (0)
Game and poultry	35	< 10 (0)	< 10 (0)
Salads	30	< 10 (0)	< 10 (0)
Oil and butter	36	< 10 (0)	< 10 (0)
Honey	91	< 10 (0)	15–209 (8)

(1) Number of samples above the reporting limit of 10 Bq·kg^{-1} in brackets.

Table 8.2: Results of 2011 analysis of food for ^{134}Cs and ^{137}Cs as measured by RIKILT Wageningen UR

Product	**Number of samples**	**^{134}Cs (1) Bq·kg^{-1}**	**^{137}Cs (2) Bq·kg^{-1}**
Vegetables	50	< 0.6 (0)	< 0.5 (0)
Meat and meat products	471	< 0.6 (0)	< 0.5 (0)
Game and poultry	196	< 0.6 (0)	3.3–830 (18)
Eggs	125	< 0.6 (0)	< 0.5 (0)
Fish and seafood products	151	< 0.6 (0)	< 0.5 (0)

(1) Number of samples above the detection limit of 0.6 Bq·kg^{-1} in brackets.

(2) Number of samples above the detection limit of 0.5 Bq·kg^{-1} in brackets.

9 Grass

The National Monitoring Network Radioactivity in Food (Landelijk Meetnet Radioactiviteit in Voedsel, LMRV), referred to in Chapter 7, is part of the National Plan for Nuclear Emergency Management and Response (Nationaal Plan Kernongevallenbestrijding, NPK). In addition to measurements on milk and food, RIKILT Wageningen UR performed measurements on grass samples in 2011 [70].

Grass is an important matrix, which is investigated for possible radioactive contamination by deposition shortly after a nuclear or radiological incident. For this purpose a selection of reference pastures and fields have been designated across the Netherlands in proximity to the companies and organisations which participate in the LMRV. In this way the extent of radioactive deposition can be surveyed rapidly by the LMRV in the event of a nuclear or radiological incident.

In 2011 RIKILT Wageningen UR performed measurements on grass samples taken on two separate occasions. The sampling and measuring procedures are described elsewhere [70].

Grass samples were taken and measured on 28 March and 18 April 2011 on account of the nuclear incident at Fukushima. The main aim of this sampling campaign was to provide information for the food producing industry and the Dutch population concerning possible deposition of artificial radioactivity in the Netherlands. In total, 76 grass samples were analysed during this campaign.

On 12 and 13 October 2011 a national nuclear emergency response exercise (Nationale Stafoefening nucleair, NSO-n) was held. Within the framework of this exercise grass samples were taken at the LMRV locations. The main aim of this sampling campaign was to practise sampling of and perform measurements on grass and to practise rapid communication with the parties involved. In total, 54 grass samples were analysed during this campaign.

In addition to achieving these main aims, both sampling campaigns provided information on the natural background levels of radioactivity in grass. During the Fukushima campaign, the grass samples were analysed on natural radionuclides such as ^{7}Be and ^{40}K and the artificial radionuclides ^{60}Co, ^{131}I, ^{132}Te, ^{134}Cs and ^{137}Cs. Detection limits were approximately 5 Bq·m^{-2} for the artificial radionuclides ^{60}Co, ^{131}I, ^{132}Te, ^{134}Cs and ^{137}Cs.

None of the grass samples taken during either campaign contained artificial radionuclides above the detection limits. Natural ^{40}K was detected in 111 out of the 130 samples taken. The activity of ^{40}K in the samples taken varied from 5 to 300 Bq·m^{-2}. This variation can be attributed to factors such as fertilisation, grass species, length of stalk and soil type. An impression of the spatial variation of the ^{40}K activity in grass is given in Figure 9.1.

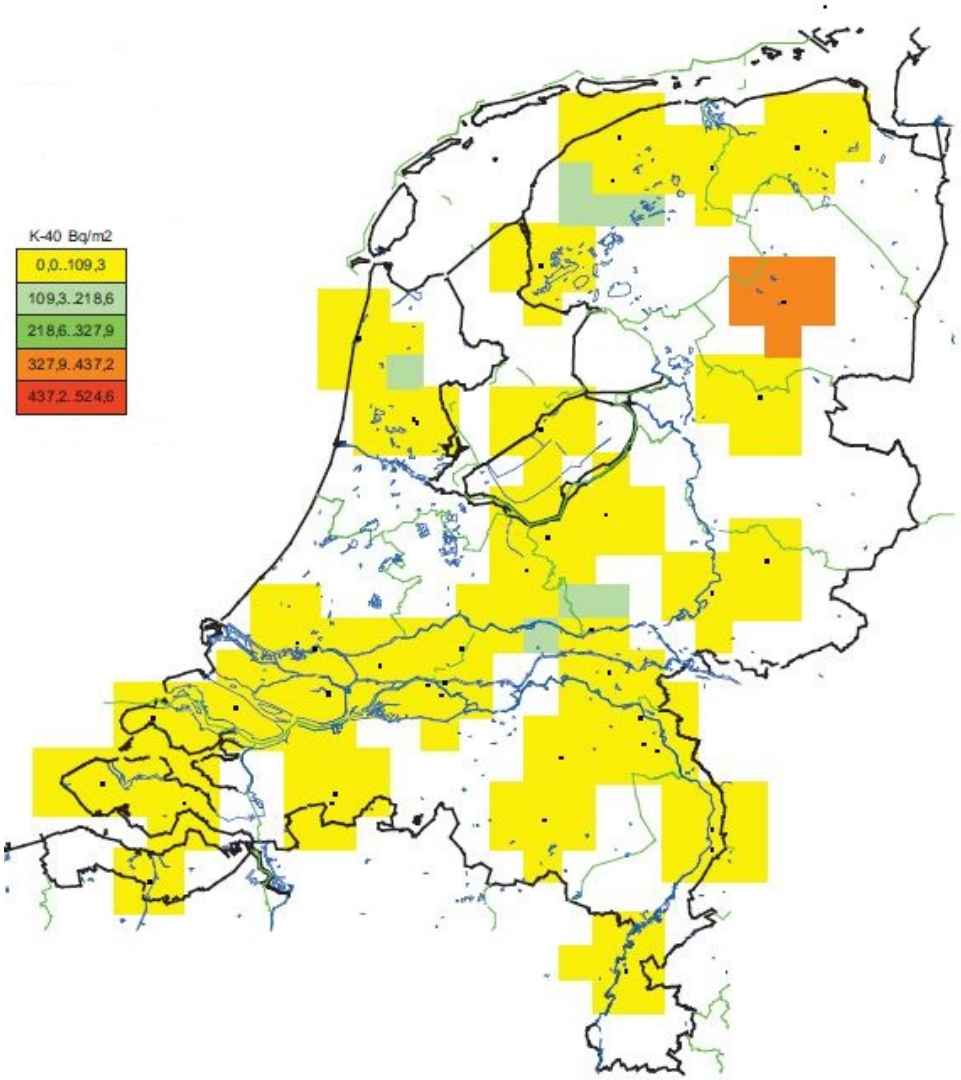

Figure 9.1: Spatial variation of ^{40}K activity in grass in 2011 as measured by RIKILT Wageningen UR [70]

10 Nuclear power plant at Borssele

The Nuclear Research & Consultancy Group (NRG) is commissioned by Elektriciteits-Productiemaatschappij Zuid-Nederland (N.V. EPZ) to perform monthly measurements on environmental samples taken in the vicinity of the nuclear power plant at Borssele (owned by N.V. EPZ). Samples are taken to monitor the compartments air, water and soil. The monitoring program [71] presented here forms only part of the total monitoring program performed near the nuclear power plant. A more detailed description of the monitoring program and underlying strategy can be found elsewhere [72]. The 2011 monitoring program is outlined in Table 9.1 and Figure 9.1. Radioactive nuclides were determined in air dust, grass, soil, water, suspended solids, seaweed and sediment.

Table 9.1: Monitoring program for environmental samples near the nuclear power plant at Borssele in 2011

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

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

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

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

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

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

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

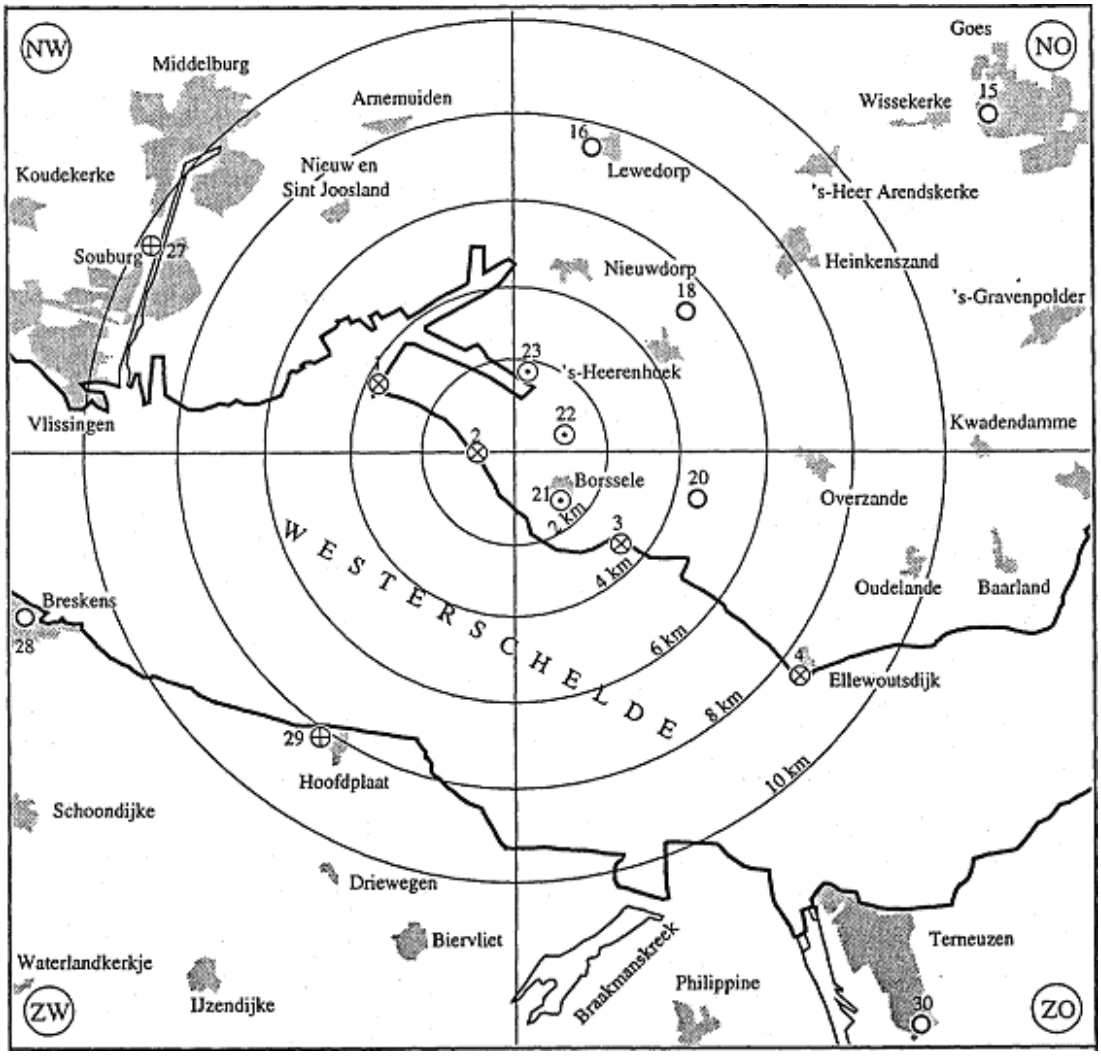

Figure 9.1: Overview of monitoring locations for the monitoring program conducted by NRG near the nuclear power plant at Borssele
The numbers given in Table 9.1 correspond with the locations on the map.

10.1 Air

The results of gross α and β activity concentrations in air dust are presented in Tables A19 and A20. 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 [5]. The period between sampling and analysis was at least five days, which is long compared with the decay time of the short-lived decay products of ^{222}Rn and ^{220}Rn. This is to ensure that these naturally occurring decay products do not contribute to the measured α and β activity concentrations.

The 2011 yearly averages of the gross α and β activity concentrations of long-lived nuclides were within the range of the results from previous years, as illustrated in Figures 9.2 and 9.3.

The results for the nuclides considered in the gammaspectroscopic analysis are given in Table A21. The levels of ^{131}I detected in air on 6 April are within the range of levels found by the RIVM in the weeks following the Fukushima incident.

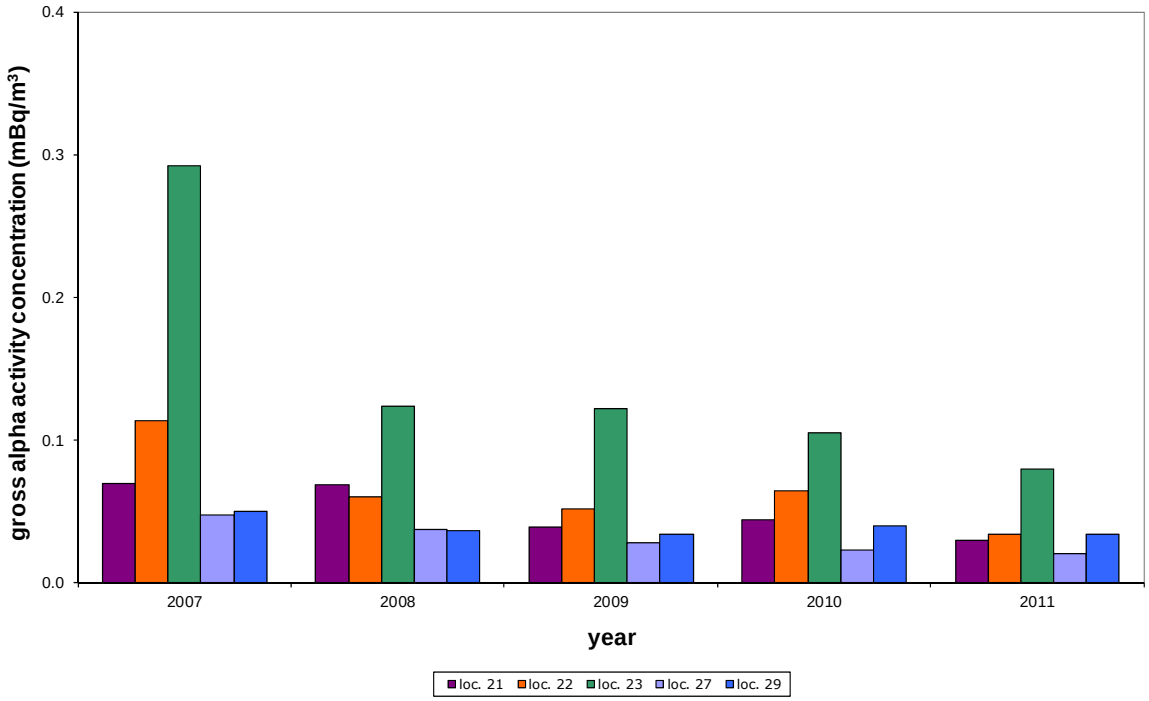

Figure 9.2: Yearly averaged gross α activity concentrations in air dust at five locations near Borssele (see Figure 9.1)

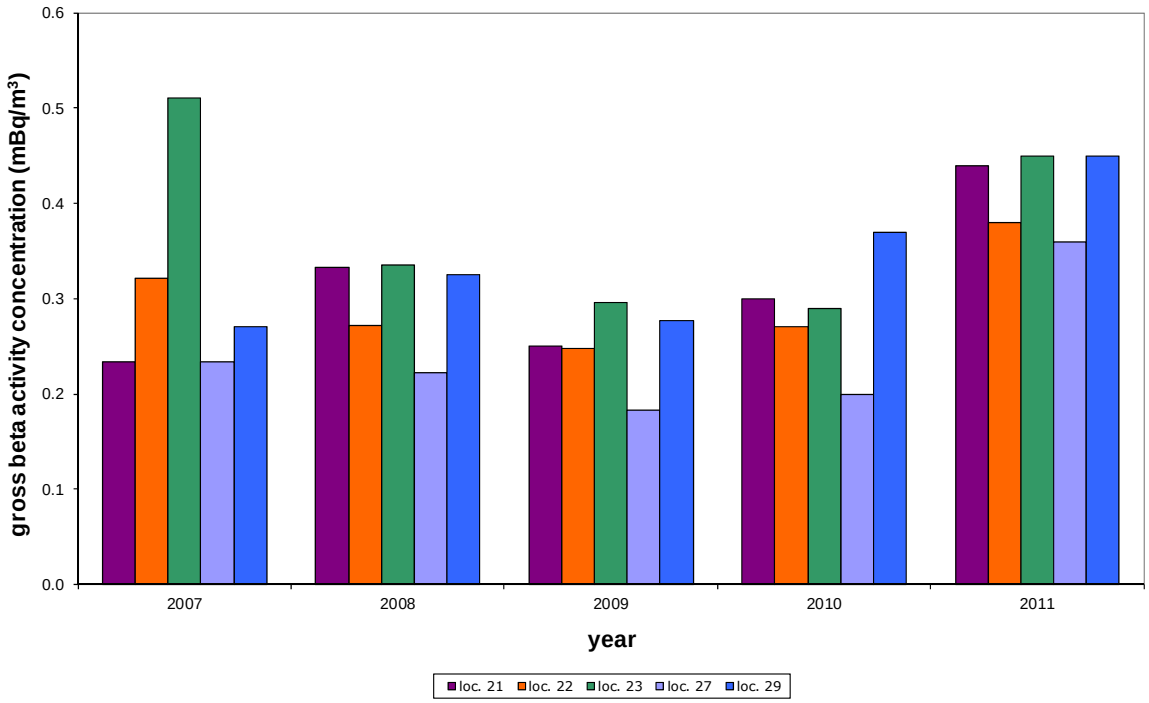

Figure 9.3: Yearly averaged gross β activity concentrations in air dust at five locations near Borssele (see Figure 9.1)

10.2 Soil and grass

The results for the nuclides considered in the gammaspectroscopic analysis of grass and soil are given in Tables A22 and A23. The four soil samples were taken near the outlet of the nuclear power plant. In 2011, the yearly averaged concentrations of ^{54}Mn, ^{60}Co, ^{134}Cs and ^{137}Cs in soil were within the range of those in previous years [60, 61, 62, 63].

In the grass sample taken on 6 April 2011, ^{131}I was detected (10.5 ± 0.7 Bq·kg^{-1} dry weight corresponding to a deposition of 3.2 Bq·m^{-2}). The NRG result of 3.2 Bq·m^{-2} is within the range of the deposition results measured by the RIVM following the incident at Fukushima (see Table 3.2). Furthermore, the NRG result is consistent with the results reported in Chapter 9. The detection limit for the measurements performed by NRG (0.4 to 0.7 Bq·m^{-2}) is much lower than that of the measurements performed by the LMRV (approximately 5 Bq·m^{-2}) due to different measuring procedures and equipment.

10.3 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 A24, A25 and A26.

In 2011, the yearly averages of the residual β and ^{3}H activity concentrations in water and gross β activity concentrations in suspended solids were within the range of the results from previous years, as illustrated in Figures 9.4, 9.5 and 9.6.

The results for the nuclides considered in the gammaspectroscopic analysis of seaweed and sediment are given in Tables A27 and A28.

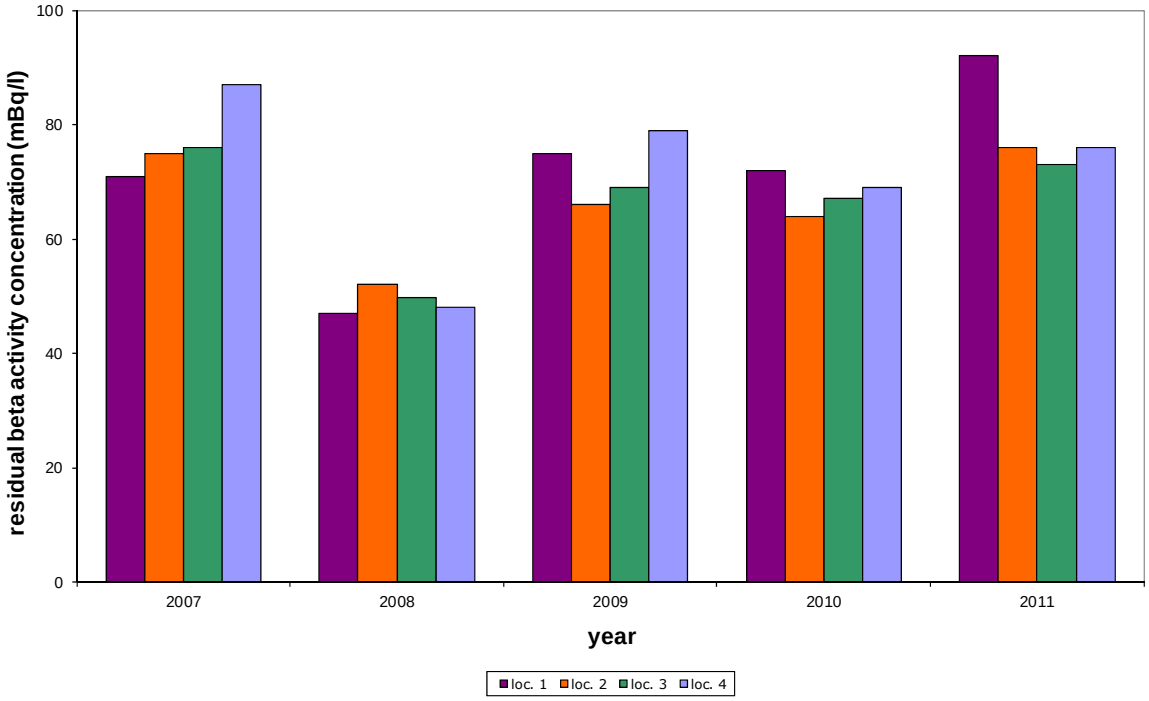

Figure 9.4: Yearly averaged residual β activity concentrations in water from the Westerscheldt at four locations near Borssele (see Figure 9.1)

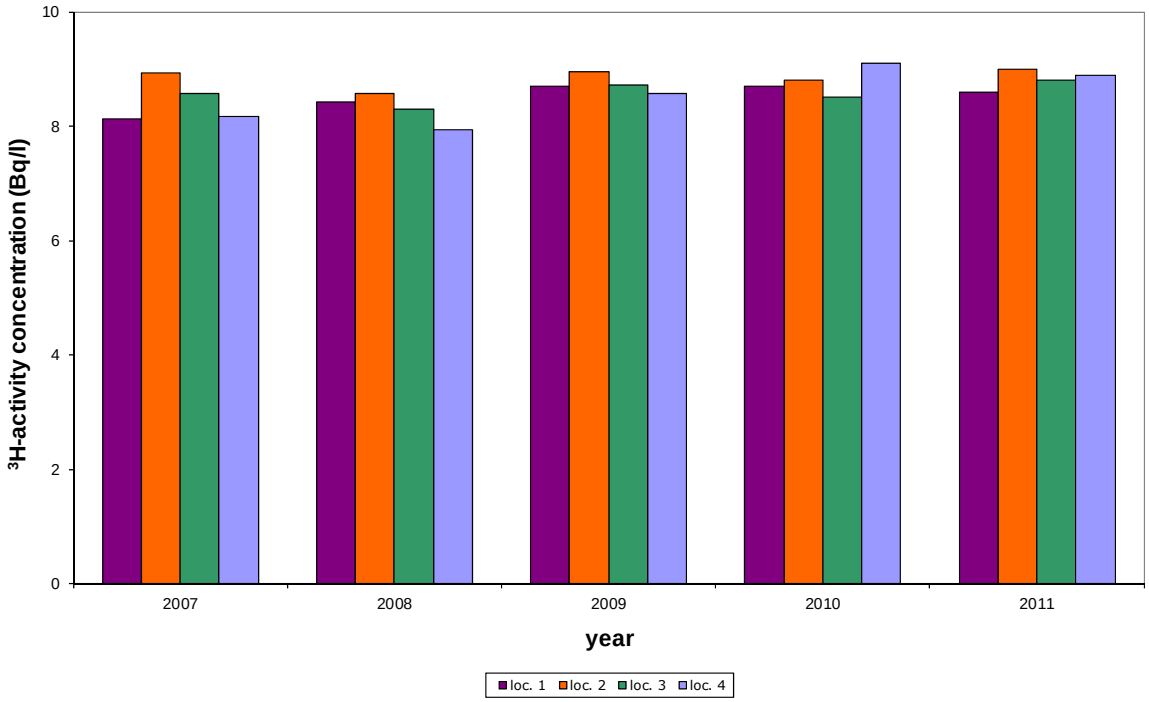

Figure 9.5: Yearly averaged ^{3}H activity concentrations in water from the Westerscheldt at four locations near Borssele (see Figure 9.1)

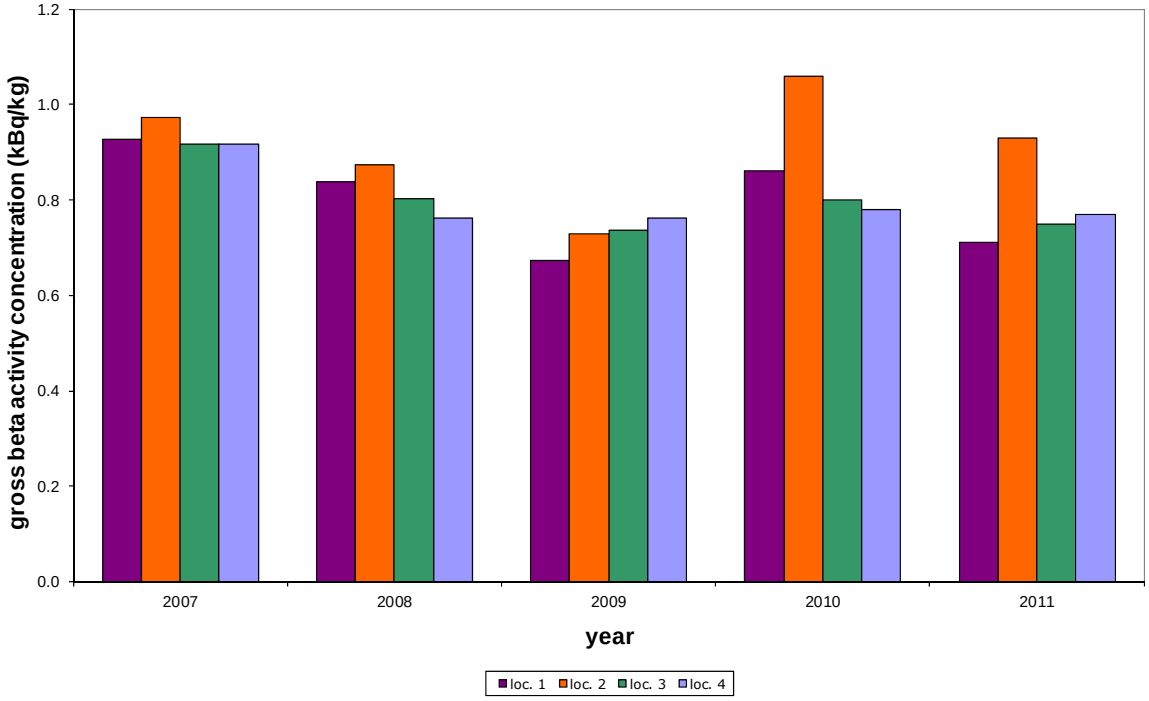

Figure 9.6: Yearly averaged gross β activity concentrations in suspended solids from the Westerscheldt at four locations near Borssele (see Figure 9.1)

11 Conclusions

In 2011 two radiological incidents occurred which could be detected in the Netherlands. In the weeks (from 18 March until 10 June) following the incident at the nuclear site at Fukushima (Japan) radionuclides originating from the incident (^{129}Te, ^{129m}Te, ^{132}Te, ^{131}I, ^{132}I, ^{134}Cs, ^{136}Cs and ^{137}Cs) were measured in air dust and deposition. During week 45 (from 3 until 11 November) ^{131}I was measured in air dust, probably as a result of an incident at the Institute of Isotopes, Budapest.

The levels of radionuclides measured following the Fukushima and Budapest incidents do not pose a threat to public health. The absorbed dose as a result of inhalation of ^{131}I following the Fukushima incident is less than 0.00001 mSv. To put this into perspective, the dose that a resident of the Netherlands receives annually is 2.4 mSv on average. The dose from other paths of exposure and from the other radionuclides measured following the Fukushima incident are much lower than the dose as a result of inhalation of ^{131}I, and is therefore insignificant, as is the dose as a result of ^{131}I following the Budapest incident.

The yearly total activity in deposition from ^{210}Po (61.4 Bq·m^{-2}) was the highest since 1993. However, this level does not pose a threat to public health.

In surface waters, yearly averaged gross α activity concentrations exceeded the target value of 100 mBq·L^{-1} in the Noordzeekanaal (165 mBq·L^{-1}), Nieuwe Waterweg (180 mBq·L^{-1}) and Scheldt (290 mBq·L^{-1}). The concentrations were within the range of those in previous years.

Yearly averaged ^{3}H activity concentrations exceeded the target value of 10 Bq·L^{-1} in the Scheldt (14.0 Bq·L^{-1}) and the Meuse (28.0 Bq·L^{-1}). The concentrations were within the range of those in previous years.

The yearly averaged ^{226}Ra activity concentration exceeded the target value of 5 mBq·L^{-1} in the Scheldt (7.3 mBq·L^{-1}). The concentration was within the range of those in previous years.

The yearly averaged ^{131}I activity concentration in the Noordzeekanaal (54 Bq·kg^{-1}) exceeded the target value (20 Bq·kg^{-1}) and was the highest since 1992. The contribution of the Fukushima incident to the ^{131}I activity concentration in suspended solids is insignificant.

Yearly averaged ^{210}Pb activity concentrations in suspended solids exceeded the target value of 100 Bq·kg^{-1} in the Rhine (104 Bq·kg^{-1}) and the Meuse (165 Bq·kg^{-1}). The concentrations were within the range of those in previous years.

Radioactivity was measured in well over 1,500 food products, of which 26 samples contained ^{137}Cs. Eight samples of honey contained ^{137}Cs and the activity varied from 15 up to 209 Bq·kg^{-1}. Eighteen samples of game contained ^{137}Cs and the activity varied from 3.3 up to 830 Bq·kg^{-1}. Only one sample was above the set limit of 600 Bq·kg^{-1}. A sample of boar (originating from the Netherlands in January 2011) contained 830 ± 26 Bq·kg^{-1} ^{137}Cs.

In addition to measurements on milk and food, RIKILT Wageningen UR performed measurements on grass samples on two separate occasions in 2011. None of the grass samples taken during either campaign contained artificial radionuclides above the detection limits (approximately 5 $Bq \cdot m^{-2}$). Natural occurring ^{40}K was detected in 111 out of the 130 samples taken, and the activity varied from 5 to 300 $Bq \cdot m^{-2}$.

The results of all other radioactivity measurements were within the range of those in previous years. In 2011, the Netherlands complied with the Euratom recommendations on annually measuring radioactivity in the environment and in food.

Appendix A – Tables of results

Table A1: Weekly averaged gross α and gross β activity concentrations in air dust sampled with the Snow White high volume sampler at RIVM in 2011

Week [1] number	Gross α [2] mBq.m^{-3}	Gross β mBq.m^{-3}	Week [1] number	Gross α [2] mBq.m^{-3}	Gross β mBq.m^{-3}
1	0.015	0.39 ± 0.04	27	0.014	0.22 ± 0.02
2	0.018	0.173 ± 0.018	28	0.013	0.19 ± 0.02
3	0.011	0.23 ± 0.02	29	0.009	0.184 ± 0.019
4	0.007	0.20 ± 0.02	30	0.013	0.25 ± 0.03
5	0.021	0.31 ± 0.03	31	0.024	0.39 ± 0.04
6	0.023	0.37 ± 0.04	32	0.020	0.20 ± 0.02
7	0.023	0.37 ± 0.04	33	0.016	0.24 ± 0.03
8	0.066	1.05 ± 0.11	34	0.047	0.51 ± 0.05
9	0.057	1.11 ± 0.08	35	0.016	0.22 ± 0.02
10	0.036	0.45 ± 0.05	36	0.032	0.58 ± 0.06
11	0.036	0.57 ± 0.06	37	0.017	0.20 ± 0.02
12	0.020	0.24 ± 0.02	38	0.037	0.41 ± 0.04
13	0.025	0.60 ± 0.05	39	0.061	1.07 ± 0.11
14	0.033	0.65 ± 0.07	40	0.071	1.23 ± 0.13
15	0.020	0.47 ± 0.05	41	0.023	0.32 ± 0.03
16	0.036	0.80 ± 0.08	42	0.028	0.41 ± 0.04
17	0.033	0.90 ± 0.09	43	0.036	0.69 ± 0.07
18	0.030	0.54 ± 0.06	44	0.049	1.00 ± 0.10
19	0.040	0.73 ± 0.08	45	0.075	1.70 ± 0.15
20	0.033	0.34 ± 0.04	46	0.054	1.15 ± 0.12
21	0.026	0.32 ± 0.03	47	0.065	1.18 ± 0.10
22	0.043	0.33 ± 0.04	48	0.020	0.36 ± 0.04
23	0.022	0.31 ± 0.03	49	0.010	0.181 ± 0.019
24	0.019	0.26 ± 0.03	50	0.008	0.139 ± 0.015
25	0.014	0.182 ± 0.019	51	0.015	0.158 ± 0.017
26	0.021	0.38 ± 0.04	52	0.021	0.22 ± 0.02
Average				0.029	0.494 ± 0.008 [3]
SD [4]				0.017	0.4

[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 [5].

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

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

Table A2: Detection limits (µBq/m^3) in the residue measurement of air dust sampled during a seven-day sampling period with the Snow White high volume sampler at RIVM in 2011

Measurements were carried out on the ash residue of the filter on a well-type detector with a 10-day delay between sampling and the start of measurement and a sample volume of about 125,000 m^3. Between 2000 and July 2009, the detection limits were higher than before 2000 [73] due to a different detector set-up. The detector set-up changed again in the second half of 2009, including a change in counting time from 100,000 seconds to 178,200 seconds. Therefore, detection limits were lower since July 2009. A change in high volume sampler (and consequently the sample volume) in 2011 resulted in a further reduction of the detection limits.

Nuclide	Detection limit µBq·m^{-3}
^{7}Be	2.0
^{22}Na	0.2
^{60}Co	0.1
^{131}I	2.3 (1)
^{137}Cs	0.1
^{210}Pb	3.2

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

Table A3: Weekly averaged ^{7}Be, ^{137}Cs and ^{210}Pb activity concentrations in air dust sampled with the Snow White high volume sampler at RIVM in 2011

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
1	31/12–07/01	2,900 ± 300	0.22 ± 0.04	250 ± 20
2	07/01–14/01	2,400 ± 200	0.08 ± 0.03	150 ± 15
3	14/01–21/01	3,000 ± 300	< 0.11	200 ± 20
4	21/01–28/01	2,500 ± 300	0.16 ± 0.03	162 ± 16
5	28/01–04/02	3,400 ± 300	0.17 ± 0.03	310 ± 30
6	04/02–11/02	3,700 ± 400	0.11 ± 0.03	390 ± 40
7	11/02–18/02	3,300 ± 300	0.27 ± 0.04	420 ± 40
8	18/02–25/02	4,700 ± 500	1.74 ± 0.17	1,390 ± 140
9	25/02–04/03	3,600 ± 300	1.27 ± 0.10	1,360 ± 100
10	04/03–11/03	5,000 ± 500	0.37 ± 0.05	420 ± 40
11	11/03–18/03	3,500 ± 300	0.44 ± 0.05	680 ± 70
12 (1)	18/03–25/03	2,800 ± 300	1.14 ± 0.11	200 ± 20
13 (1)	25/03–01/04	3,900 ± 300	40 ± 3	259 ± 18
14 (1)	01/04–08/04	4,400 ± 400	54 ± 5	320 ± 30
15 (1)	08/04–15/04	3,500 ± 300	48 ± 4	250 ± 20
16 (1)	15/04–22/04	7,200 ± 700	17.6 ± 1.7	760 ± 70
17 (1)	22/04–29/04	8,000 ± 800	12.4 ± 1.2	780 ± 80
18 (1)	29/04–06/05	5,500 ± 500	12.0 ± 1.1	440 ± 40
19 (1)	06/05–13/05	6,800 ± 700	2.1 ± 0.2	680 ± 70
20 (1)	13/05–20/05	4,300 ± 400	1.14 ± 0.11	240 ± 20
21 (1)	20/05–27/05	4,200 ± 400	1.76 ± 0.17	240 ± 20
22 (1)	27/05–01/06	4,000 ± 400	0.57 ± 0.07	250 ± 20
23 (1)	01/06–10/06	4,200 ± 400	0.59 ± 0.06	230 ± 20
24	10/06–17/06	4,500 ± 400	0.20 ± 0.03	210 ± 20
25	17/06–24/06	2,900 ± 300	0.08 ± 0.03	140 ± 14
26	24/06–01/07	4,300 ± 400	0.17 ± 0.04	370 ± 40

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Table A3: Continued

Week number	Period	^{7}Be µBq·m^{-3}	^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}
27	01/07–08/07	3,800 ± 400	0.12 ± 0.03	154 ± 15
28	08/07–15/07	2,900 ± 300	0.17 ± 0.03	161 ± 16
29	15/07–22/07	2,400 ± 200	< 0.10	169 ± 17
30	22/07–29/07	3,400 ± 300	0.14 ± 0.03	220 ± 20
31	29/07–05/08	3,700 ± 400	0.22 ± 0.04	420 ± 40
32	05/08–12/08	2,800 ± 300	0.10 ± 0.03	166 ± 16
33	12/08–19/08	3,300 ± 300	< 0.10	190 ± 19
34	19/08–26/08	4,600 ± 500	0.31 ± 0.05	530 ± 50
35	26/08–02/09	3,200 ± 300	0.038 ± 0.011	176 ± 17
36	02/09–09/09	4,300 ± 400	0.14 ± 0.03	570 ± 60
37	09/09–16/09	2,400 ± 200	< 0.10	160 ± 16
38	16/09–23/09	3,800 ± 400	< 0.15	390 ± 40
39	23/09–30/09	5,100 ± 500	0.23 ± 0.04	1,220 ± 120
40	30/09–07/10	5,200 ± 500	0.29 ± 0.04	1,470 ± 140
41	07/10–14/10	2,800 ± 300	0.13 ± 0.03	240 ± 20
42	14/10–21/10	3,400 ± 300	0.29 ± 0.04	380 ± 40
43	21/10–28/10	4,100 ± 400	0.46 ± 0.06	740 ± 70
44	28/10–03/11	4,000 ± 400	0.32 ± 0.05	1,140 ± 110
45	03/11–11/11	4,100 ± 400	0.80 ± 0.07	2,260 ± 180
46	11/11–17/11	2,800 ± 300	0.93 ± 0.10	1,500 ± 150
47	17/11–25/11	2,020 ± 150	0.76 ± 0.07	1,600 ± 130
48	25/11–02/12	3,400 ± 300	< 0.18	340 ± 30
49	02/12–09/12	3,200 ± 300	< 0.12	124 ± 12
50	09/12–16/12	2,900 ± 300	< 0.18	97 ± 10
51	16/12–23/12	3,200 ± 300	< 0.2	121 ± 12
52	23/12–30/12	2,900 ± 300	0.106 ± 0.018	173 ± 17
Average		3,820 ± 50 [2]	4.72 ± 0.18 [2, 3, 4]	496 ± 9 [2]
SD [5]		1,200	12	500

[1] During this week additional radionuclides originating from the incident at Fukushima Japan could be measured, as presented in Table A4.

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

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

[4] If the results from the Fukushima period (weeks 12–23) are excluded, the yearly average is 0.445 ± 0.011 (SD=0.5) µBq·m^{-3}.

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

Table A4: Activity concentrations [1, 2] of γ-emitters in air dust following the incidents at Fukushima (weeks 12–23) and Budapest (week 45)

The samples were sampled with the Snow White high volume sampler and measured directly as a folded filter on a coaxial Ge detector.

Week number	Period	^{129}Te µBq·m^{-3}	^{129m}Te µBq·m^{-3}	^{132}Te µBq·m^{-3}	^{131}I µBq·m^{-3}
12 [3]	18/03–25/03	< 16	< 40	0.9 ± 0.7	30 ± 3
13A	25/03–28/03	17 ± 4	20 ± 10	15 ± 2	440 ± 40
13B	28/03–01/04	27 ± 5	56 ± 11	13 ± 2	690 ± 60
14	01/04–08/04	17 ± 5	27 ± 9	3.0 ± 1.2	520 ± 40
15	08/04–15/04	11 ± 2	27 ± 6	< 5	141 ± 12
16	15/04–22/04	< 20	< 40	< 9	50 ± 5
17	22/04–29/04	< 19	< 40	< 6	19.0 ± 1.9
18	29/04–06/05	< 17	< 40	< 5	7.5 ± 0.9
19	06/05–13/05	< 18	< 40	< 6	1.6 ± 0.5
20	13/05–20/05	< 15	< 40	< 7	< 3
21	20/05–27/05	< 15	< 40	< 5	< 2
22	27/05–01/06	< 20	< 50	< 8	< 3
23	01/06–10/06	< 12	< 30	< 6	< 2
45A	03/11–09/11	-	-	-	12.5 ± 1.4
45B	09/11–11/11	-	-	-	< 4
		^{132}I µBq·m^{-3}	^{134}Cs µBq·m^{-3}	^{136}Cs µBq·m^{-3}	^{137}Cs µBq·m^{-3}
12 [3]	18/03–25/03	< 4	< 1.3	< 1.6	0.84 ± 0.17
13A	25/03–28/03	15.0 ± 1.7	22 ± 3	2.7 ± 0.7	23 ± 2
13B	28/03–01/04	16.1 ± 1.7	56 ± 9	4.6 ± 1.0	58 ± 5
14	01/04–08/04	2.5 ± 0.5	56 ± 9	3.8 ± 0.7	57 ± 5
15	08/04–15/04	< 6	55 ± 8	2.3 ± 0.5	56 ± 5
16	15/04–22/04	< 9	18 ± 3	< 1.8	19.5 ± 1.8
17	22/04–29/04	< 5	12.2 ± 1.9	< 1.5	14.2 ± 1.3
18	29/04–06/05	< 5	12.0 ± 1.8	< 1.5	14.0 ± 1.3
19	06/05–13/05	< 5	1.6 ± 0.3	< 1.5	2.0 ± 0.3
20	13/05–20/05	< 6	1.3 ± 0.2	< 1.6	1.3 ± 0.2
21	20/05–27/05	< 5	< 1.1	< 1.5	2.1 ± 0.3
22	27/05–01/06	< 7	< 1.5	< 2	< 1.5
23	01/06–10/06	< 5	0.34 ± 0.09	< 1.2	0.57 ± 0.14
45A	03/11–09/11	-	-	-	-
45B	09/11–11/11	-	-	-	-

[1] The activity concentrations are averaged over the sampling period.

[2] Uncertainties are given as 1σ.

[3] Based on the results of the daily samples taken with the former high volume sampler (presented in Table A7), the activity in week 12 can be contributed to the last 3 days. In that case, the activity concentrations of ^{132}Te, ^{131}I and ^{137}Cs are 2.0 ± 1.7, 70 ± 7 and 2.0 ± 0.4 µBq·m^{-3}, respectively.

Table A5: Activity concentrations [1, 2] of γ-emitters in air dust following the incident at Fukushima

The samples were sampled with the Snow White high volume sampler and measured after several days as ash residue on a well-type Ge detector.

Week number	Period	^{129}Te µBq·m^{-3}	^{129m}Te µBq·m^{-3}	^{134}Cs µBq·m^{-3}	^{136}Cs µBq·m^{-3}	^{137}Cs µBq·m^{-3}
12 [3]	18/03–25/03	< 3	< 5	0.9 ± 0.6	< 1.0	1.14 ± 0.11
13A	25/03–28/03	14 ± 3	19 ± 4	25 ± 17	< 4	22 ± 2
13B	28/03–01/04	24 ± 3	34 ± 5	60 ± 40	6 ± 5	54 ± 5
14	01/04–08/04	16 ± 2	26 ± 4	50 ± 30	4 ± 3	54 ± 5
15	08/04–15/04	15 ± 2	26 ± 4	50 ± 40	3 ± 2	48 ± 4
16	15/04–22/04	2.4 ± 0.8	2.7 ± 0.9	17 ± 12	< 1.6	17.6 ± 1.7
17	22/04–29/04	< 5	< 7	12 ± 8	< 1.3	12.4 ± 1.2
18	29/04–06/05	< 5	< 8	12 ± 8	< 1.1	12.0 ± 1.1
19	06/05–13/05	< 4	< 5	2.1 ± 1.5	< 0.8	2.1 ± 0.2
20	13/05–20/05	< 4	< 6	1.5 ± 1.1	< 1.1	1.14 ± 0.11
21	20/05–27/05	< 4	< 6	0.6 ± 0.4	< 1.3	1.76 ± 0.17
22	27/05–01/06	< 5	< 7	< 0.4	< 1.4	0.57 ± 0.07
23	01/06–10/06	< 3	< 4	0.6 ± 0.4	< 0.6	0.59 ± 0.06

[1] The activity concentrations are averaged over the sampling period.

[2] Uncertainties are given as 1σ.

[3] Based on the results of the daily samples taken with the former high volume sampler (presented in Table A7), the activity in week 12 can be contributed to the last 3 days. In that case, the activity concentrations of ^{134}Cs and ^{137}Cs are 2.1 ± 1.4 and 2.7 ± 0.3 µBq·m^{-3}, respectively.

Table A6: ^{131}I activity concentrations [1, 2, 3, 4, 5] in air sampled with the three-stage sampler and measured on a coaxial Ge detector

^{131}I is either aerosol bound, elementary I_2 or organically bound.

Week number	Period	Aerosol µBq·m^{-3}	Elementary µBq·m^{-3}	Organic µBq·m^{-3}
13A	25/03–28/03	410 ± 50 (41%)	190 ± 30 (19%)	410 ± 50 (41%)
13B	28/03–29/03	560 ± 80 (34%)	160 ± 40 (10%)	940 ± 150 (57%)
13C	29/03–01/04	550 ± 70 (30%)	320 ± 40 (17%)	960 ± 100 (52%)
14A	01/04–04/04	230 ± 30 (24%)	290 ± 40 (31%)	430 ± 60 (45%)
14B	05/04–08/04	300 ± 40 (25%)	350 ± 50 (29%)	550 ± 70 (46%)
15A	08/04–11/04	300 ± 40 (23%)	290 ± 50 (22%)	730 ± 80 (55%)
15B	11/04–14/04	140 ± 30 (26%)	90 ± 20 (17%)	310 ± 50 (57%)
Average		330 ± 50 (29%)	250 ± 40 (21%)	580 ± 90 (50%)

[1] The activity concentrations are averaged over the sampling period.

[2] Uncertainties are given as 1σ.

[3] The average is calculated by weighing the periodical values by means of the number of sampling days in the respective period with respect to the total number of sampling days (from 25 March to 14 April).

[4] The total uncertainty in the average is generically set at 15% to account for the uncertainty in the calculation of the average activity concentration. In each period the activity concentration is presumed homogeneous, which is an approximation.

[5] Fraction of total activity of ^{131}I is given in brackets.

Table A7: Activity concentrations [1, 2, 3, 4] of γ-emitters in air dust following the incident at Fukushima

The samples were sampled with the former high volume sampler and measured directly as a folded filter on a coaxial Ge detector.

Week number	Period	^{129}Te µBq·m^{-3}	^{132}Te µBq·m^{-3}	^{131}I µBq·m^{-3}	^{132}I µBq·m^{-3}
12A	18/03–23/03	-	< 8	< 6	-
12B	23/03–24/03	-	5 ± 3	149 ± 16	-
12C	24/03–25/03	-	< 17	29 ± 4	-
13A	25/03–26/03	-	< 20	8 ± 3	-
13B	26/03–27/03	-	11 ± 5	430 ± 40	< 30
13C	27/03–28/03	-	34 ± 8	1,100 ± 100	28 ± 4
13D	28/03–29/03	-	18 ± 4	800 ± 80	22 ± 4
13E	29/03–30/03	-	14 ± 7	560 ± 60	10 ± 4
13F	30/03–31/03	-	25 ± 6	1,320 ± 120	25 ± 5
13G	31/03–01/04	-	6.6 ± 1.4	450 ± 40	9.1 ± 1.6
14A	01/04–02/04	-	13.7 ± 1.7	430 ± 40	16 ± 2
14B	02/04–03/04	-	4 ± 3	560 ± 50	7.6 ± 1.8
14C	03/04–04/04	-	4.5 ± 1.5	390 ± 40	10 ± 2
14D	04/04–05/04	-	8 ± 2	1,220 ± 110	10 ± 2
14E	05/04–06/04	-	9 ± 2	1,230 ± 120	8.0 ± 1.8
14F	06/04–07/04	-	16 ± 3	510 ± 50	8 ± 2
14G	07/04–08/04	-	< 19	250 ± 30	-
15A	08/04–09/04	140 ± 30	5.4 ± 1.7	760 ± 70	-
15B	09/04–10/04	-	< 20	410 ± 40	-
15C	10/04–11/04	-	< 30	230 ± 30	-
15D	11/04–12/04	-	< 15	153 ± 16	-
15E	12/04–13/04	-	< 17	130 ± 15	-
15F	13/04–14/04	-	< 20	144 ± 16	-
15G	14/04–15/04	-	< 20	166 ± 17	-
16A	15/04–18/04	-	< 12	79 ± 8	-
16B	18/04–19/04	-	< 20	75 ± 10	-
16C	19/04–20/04	-	< 30	60 ± 11	-
16D	20/04–22/04	-	< 15	35 ± 4	-
17A	22/04–26/04	-	< 8	22 ± 2	-
17B	26/04–29/04	-	< 9	14 ± 3	-
18A	29/04–04/05	-	< 10	9.3 ± 1.5	-
18B-19A	04/05–09/05	-	< 7	2.0 ± 0.8	-
19B	09/05–13/05	-	< 7	1.4 ± 0.8	-
Average			12.4 ± 1.9	240 ± 40	14 ± 2

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Table A7: Continued

Week number	Period	^{134}Cs µBq·m^{-3}	^{136}Cs µBq·m^{-3}	^{137}Cs µBq·m^{-3}
12A	18/03–23/03	< 3	< 4	< 4
12B	23/03–24/03	14 ± 2	< 13	18 ± 3
12C	24/03–25/03	< 12	< 13	< 13
13A	25/03–26/03	< 9	< 11	< 9
13B	26/03–27/03	15 ± 3	< 13	22 ± 3
13C	27/03–28/03	48 ± 8	< 13	49 ± 5
13D	28/03–29/03	44 ± 7	< 15	48 ± 5
13E	29/03–30/03	31 ± 5	< 16	36 ± 4
13F	30/03–31/03	42 ± 8	< 40	43 ± 7
13G	31/03–01/04	48 ± 8	< 14	44 ± 5
14A	01/04–02/04	17 ± 3	< 19	27 ± 3
14B	02/04–03/04	65 ± 10	< 17	51 ± 5
14C	03/04–04/04	36 ± 6	< 20	31 ± 4
14D	04/04–05/04	98 ± 15	< 16	99 ± 9
14E	05/04–06/04	69 ± 11	< 19	60 ± 6
14F	06/04–07/04	49 ± 8	< 20	42 ± 5
14G	07/04–08/04	20 ± 4	< 19	20 ± 3
15A	08/04–09/04	160 ± 20	9 ± 3	158 ± 15
15B	09/04–10/04	37 ± 6	< 20	35 ± 4
15C	10/04–11/04	24 ± 5	< 30	37 ± 5
15D	11/04–12/04	17 ± 3	< 15	17 ± 2
15E	12/04–13/04	38 ± 7	< 17	34 ± 4
15F	13/04–14/04	22 ± 4	< 20	29 ± 4
15G	14/04–15/04	26 ± 4	< 20	28 ± 4
16A	15/04–18/04	18 ± 3	< 9	22 ± 2
16B	18/04–19/04	16 ± 3	< 20	19 ± 3
16C	19/04–20/04	23 ± 4	< 20	25 ± 4
16D	20/04–22/04	15 ± 2	< 6	17 ± 2
17A	22/04–26/04	8.4 ± 1.3	< 4	11.4 ± 1.2
17B	26/04–29/04	10.2 ± 1.7	< 7	11.7 ± 1.4
18A	29/04–04/05	11.9 ± 1.9	< 3	14.4 ± 1.4
18B-19A	04/05–09/05	3.5 ± 0.6	< 3	4.3 ± 0.6
19B	09/05–13/05	1.0 ± 0.2	< 3	1.4 ± 0.3
Average		24 ± 4	9 ± 3	26 ± 4

(1) The activity concentrations are averaged over the sampling period.

(2) Uncertainties are given as 1σ.

(3) The average is calculated by weighing the periodical values by means of the number of sampling days in the respective period with respect to the total number of sampling days (from 23 March to 13 May).

(4) The total uncertainty in the average is generically set at 15% to account for the uncertainty in the calculation of the average activity concentration. In each period the activity concentration is presumed homogeneous, which is an approximation.

Table A8: Precipitation per month and monthly deposited ^{3}H, long-lived gross α and gross β activity sampled at RIVM in 2011

Month	Precipitation mm	^{3}H (1) Bq·m^{-2}	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}
January	95.3	< 160	2.0 ± 0.2	3.6 ± 0.3
February	62.5	< 100	3.8 ± 0.4	12.1 ± 0.9
March	22.8	< 40	3.5 ± 0.4	7.6 ± 0.6
April	8.9	17 ± 4	9.5 ± 0.9	20.2 ± 1.6
May	27.1	44 ± 13	3.5 ± 0.4	5.7 ± 0.5
June	105.8	190 ± 50	5.1 ± 0.5	13.4 ± 1.0
July	178.0	< 300	3.6 ± 0.4	9.4 ± 0.7
August	91.7	160 ± 50	2.3 ± 0.3	13.0 ± 1.0
September	85.6	< 140	4.2 ± 0.5	13.5 ± 1.1
October	71.1	< 110	3.9 ± 0.4	11.0 ± 0.9
November	36.2	< 60	2.3 ± 0.3	7.7 ± 0.6
December	110.3	< 170	1.4 ± 0.2	5.4 ± 0.4
Total	895.0	-	45.0 ± 1.5 (2)	123 ± 3 (2)
Lower limit (3)	-	332		
Upper limit (3)	-	1,540		

(1) The detection limit (Bq·m^{-2}) is mainly dependent on the amount of precipitation as the detection limit of the counting sample itself is more or less constant (1.4-1.6 Bq·L^{-1}).

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

(3) The lower and upper limits are defined in Appendix B.

Table A9: Yearly totals for long-lived gross α, gross β and ^{3}H activity in deposition since 1993

Either the yearly total with uncertainty (1) or the lower and upper limits (2) of the 68% confidence range are given.

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

(1) Uncertainties are given as 1σ.

(2) Lower and upper limits are given as defined in Appendix B.

Table A10: Monthly deposited ^{210}Po activity [(1)] sampled at RIVM in 2011

Month	**^{210}Po**
	Bq·m^{-2}
January	5.5 ± 0.4
February	10.3 ± 0.5
March	6.5 ± 0.3
April	9.9 ± 0.5
May	6.9 ± 0.4
June	4.6 ± 0.2
July	2.48 ± 0.16
August	3.8 ± 0.2
September	3.5 ± 0.2
October	3.69 ± 0.19
November	2.60 ± 0.12
December	1.62 ± 0.10
Total	61.4 ± 1.0 [(2)]
Lower limit [(3)]	-
Upper limit [(3)]	-

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

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

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

Table A11: Yearly totals for ^{7}Be, ^{137}Cs, ^{210}Pb and ^{210}Po activity in deposition since 1993

Either the yearly total with uncertainty [1] or the lower and upper limits [2] of the 68% confidence range are given.

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

[1] Uncertainties are given as 1σ.

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

[3] Data from γ-spectroscopy.

[4] Data from α-spectroscopy.

[5] Not available. Result rejected [74].

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

[7] Results revised in RIVM Report 610791003.

Table A12: Weekly deposited ^{7}Be, ^{137}Cs and ^{210}Pb activity (1) sampled at RIVM in 2011

Week number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{137}Cs Bq·m^{-2}	^{210}Pb Bq·m^{-2}
1	31/12–07/01	18.8	8.5 ± 1.1	< 0.02	1.08 ± 0.15
2	07/01–14/01	35.3	21 ± 3	< 0.02	0.81 ± 0.12
3	14/01–21/01	28.0	20 ± 3	< 0.02	0.57 ± 0.10
4	21/01–28/01	8.4	16 ± 2	< 0.02	0.79 ± 0.12
5	28/01–03/02	4.9	8.0 ± 1.0	< 0.02	2.7 ± 0.3
6	03/02–11/02	10.2	11.6 ± 1.5	< 0.02	1.40 ± 0.19
7	11/02–18/02	17.4	18 ± 2	< 0.02	1.6 ± 0.2
8	18/02–25/02	7.0	10.5 ± 1.3	< 0.02	1.7 ± 0.2
9	25/02–04/03	28.0	24 ± 3	< 0.02	1.36 ± 0.19
10	04/03–11/03	1.1	4.9 ± 0.6	< 0.02	0.58 ± 0.10
11	11/03–18/03	3.5	5.3 ± 0.7	< 0.02	1.25 ± 0.17
12	18/03–25/03	10.8	9.2 ± 1.2	< 0.02	1.5 ± 0.2
13 (2)	25/03–01/04	7.4	10.4 ± 1.0	0.21 ± 0.03	2.6 ± 0.3
14	01/04–08/04	1.4	9.1 ± 1.2	0.081 ± 0.012	2.0 ± 0.3
15	08/04–15/04	6.2	13.8 ± 1.8	0.085 ± 0.013	3.0 ± 0.4
16	15/04–22/04	0.0	3.6 ± 0.5	0.04 ± 0.007	2.7 ± 0.4
17	22/04–29/04	1.3	12.4 ± 1.6	0.047 ± 0.007	3.6 ± 0.5
18	29/04–06/05	0.0	4.4 ± 0.6	0.03 ± 0.005	1.8 ± 0.2
19	06/05–13/05	4.5	25 ± 3	0.018 ± 0.006	3.6 ± 0.5
20	13/05–20/05	7.9	13.7 ± 1.8	< 0.02	1.35 ± 0.19
21	20/05–27/05	10.9	16 ± 2	0.023 ± 0.007	1.7 ± 0.2
22	27/05–01/06	3.9	15.0 ± 1.9	< 0.02	1.18 ± 0.17
23	01/06–10/06	14.8	45 ± 6	< 0.02	2.7 ± 0.4
24	10/06–17/06	28.5	39 ± 5	< 0.02	1.35 ± 0.19
25	17/06–24/06	30.0	50 ± 6	< 0.02	1.33 ± 0.19
26	24/06–01/07	32.5	83 ± 11	< 0.02	6.0 ± 0.8

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Table A12: Continued

Week number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{137}Cs Bq·m^{-2}	^{210}Pb Bq·m^{-2}
27	01/07–08/07	2.3	6.7 ± 0.9	< 0.02	0.93 ± 0.14
28	08/07–15/07	111.3	95 ± 12	< 0.02	4.1 ± 0.5
29	15/07–22/07	24.5	25 ± 3	< 0.03	1.9 ± 0.3
30	22/07–29/07	40.0	58 ± 7	< 0.016	2.6 ± 0.3
31	29/07–05/08	3.5	13.1 ± 1.7	< 0.02	2.4 ± 0.3
32	05/08–12/08	21.1	40 ± 5	< 0.02	2.4 ± 0.3
33	12/08–19/08	29.3	52 ± 7	< 0.02	2.4 ± 0.3
34	19/08–26/08	14.2	54 ± 7	< 0.02	5.3 ± 0.7
35	26/08–02/09	23.8	34 ± 4	< 0.02	1.26 ± 0.17
36	02/09–09/09	62.0	101 ± 13	< 0.02	6.0 ± 0.8
37	09/09–16/09	19.0	48 ± 6	< 0.03	4.6 ± 0.6
38	16/09–23/09	2.4	9.6 ± 1.2	< 0.03	0.79 ± 0.13
39	23/09–30/09	2.3	8.0 ± 1.0	< 0.02	1.04 ± 0.15
40	30/09–07/10	9.6	16 ± 2	< 0.02	2.1 ± 0.3
41	07/10–14/10	36.0	51 ± 7	< 0.02	2.3 ± 0.3
42	14/10–21/10	15.3	26 ± 3	< 0.02	1.32 ± 0.18
43	21/10–28/10	3.6	4.0 ± 0.5	< 0.02	0.80 ± 0.12
44	28/10–03/11	6.6	11.9 ± 1.5	< 0.02	1.30 ± 0.18
45	03/11–11/11	0.0	3.8 ± 0.5	< 0.02	1.07 ± 0.15
46	11/11–18/11	0.2	2.3 ± 0.3	< 0.02	0.72 ± 0.11
47	18/11–25/11	0.5	1.6 ± 0.2	< 0.02	0.43 ± 0.08
48	25/11–02/12	35.5	19 ± 2	< 0.02	2.1 ± 0.3
49	02/12–09/12	32.5	42 ± 5	< 0.02	1.8 ± 0.2
50	09/12–16/12	39.0	38 ± 5	< 0.02	1.41 ± 0.19
51	16/12–23/12	25.5	39 ± 5	< 0.02	1.6 ± 0.2
52	23/12–30/12	13.3	26 ± 3	< 0.02	0.73 ± 0.11
Total [3]		895.0	1,320 ± 30	-	104 ± 2
Lower limit [4]		-	-	0.5	-
Upper limit [4]		-	-	1.5	-

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

[2] Week 13 was split into samplingperiods of 3 and 4 days. The deposited ^{137}Cs activity during the first 3 days was <0.02 Bq·m^{-2} and during the last 4 days 0.21 ± 0.03 Bq·m^{-2}.

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

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

Table A13: Yearly averaged α activity concentration in air and ambient dose equivalent rate in 2011 as measured by the NMR stations equipped with aerosol monitors

Station	No.	α activity concentration $Bq.m^{-3}$	Ambient dose equivalent rate [1] $nSv.h^{-1}$
Arnhem [2]	970	3.8	67
Kollumerwaard	972	3.6	71
Valthermond [3]	974	3.9	59
Vlaardingen	976	3.5	70
Braakman	978	4.8	66
Huijbergen	980	4.1	57
Houtakker	982	4.2	68
Wijnandsrade	984	7.1	72
Eibergen	986	4.0	61
De Zilk	988	3.0	65
Wieringerwerf	990	3.4	69
Vredepeel	992	4.7	67
Biddinghuizen	994	4.1	74
Bilthoven	998	3.6	61

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

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

[3] This station was formerly known as Witteveen.

Table A14: Yearly averaged ambient dose equivalent rate for the NMR stations in 2011

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Den Burg	1001	67	Lelystad	1103	77
Den Helder [1]	1002	71	Urk	1105	74
Den Oever	1003	69	Eemshaven	1106	83
Petten	1006	61	Uithuizen	1107	82
Kolhorn	1007	77	Wagenborgen	1109	75
Egmond aan Zee	1009	66	Winschoten	1110	74
Heerhugowaard	1011	73	Ter Apel	1111	72
Haarlem-Noord	1014	73	Stadskanaal	1112	62
Nederhorst Den Berg	1015	60	Nieuweschans	1113	71
Enkhuizen	1018	79	Bellingwolde	1114	60
Oosthuizen	1019	78	Groningen	1116	75
Zaandam	1021	68	Leens	1117	88
Gouda	1024	69	Grijpskerk	1118	73
Dordrecht	1027	63	Meppel	1125	77
Zuid Beijerland	1028	72	Hoogeveen	1126	61
Rotterdam-Schiebroek[2]	1031	65	Steenwijksmoer	1129	65
Pijnacker	1032	86	Nieuw Amsterdam	1130	79
Maasvlakte	1035	84	Nw. Schoonebeek/	1131	61
Rotterdam-Waalhaven	1036	65	Weiteveen		
Maassluis	1037	82	Emmen	1132	81
Hellevoetsluis	1038	92	Hengelo (Ov)	1135	69
Ouddorp	1039	73	Hengelo (Gld) [5]	1136	-
Wekerom	1041	74	Enschede	1139	64
Wageningen	1043	68	Losser	1140	62
Amersfoort	1046	70	Oldenzaal	1141	77
Harderwijk	1050	65	Westerhaar	1142	63
Wijk bij Duurstede	1056	81	Rijssen	1143	74
Nieuwegein	1062	78	's Heerenberg	1144	61
Zegveld [3]	1063	64	Dinxperlo	1145	78
Lopik (Cabauw) [4]	1064	83	Varsseveld	1146	70
Apeldoorn	1066	69	Groenlo	1147	84
Heerenveen	1071	70	Deventer	1148	77
Oosterwolde	1072	80	Etten-Leur	1154	69
Bergum	1074	67	Den Bosch	1157	69
Witmarsum	1076	87	Raamsdonkveer	1159	91
Sneek	1077	70	Ulvenhout	1160	72
St Jacobiparochie	1081	77	Baarle Nassau	1161	62
Holwerd	1082	88	Uden	1163	64
Leeuwarden	1085	69	Mill	1164	62
Zwolle-Zuid	1087	73	Oss	1167	64
Ommen	1093	64	Nuenen	1172	71
Hardenberg	1095	65	Bergeijk	1174	87
Assen	1097	65	Waalre	1175	68
Rutten	1099	75	Someren (Dorp)	1176	69

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Table A14: Continued

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Oisterwijk	1178	71	Hoensbroek	1225	84
Riel	1179	71	Gennep [5]	1228	-
Oostelbeers	1180	83	Elst (Gld)	1229	82
Hilvarenbeek	1181	65	Zevenaar	1230	72
Venray	1183	62	Nijmegen	1231	74
Nieuw-Bergen	1184	62	Amstelveen	1233	73
Sevenum	1185	69	Amsterdam Oost	1234	67
Reuver	1188	67	Aalsmeer	1236	71
Nederweert	1189	71	Nispen	1237	61
Heythuysen	1190	73	Groesbeek	1240	78
Mariahoop	1191	69	Tubbergen	1243	68
Stramproy	1192	64	Haaksbergen	1244	67
Eerbeek	1193	73	Scheveningen	1247	77
Leiden	1196	75	Zaltbommel	1251	71
Hulst	1197	75	IJzendijke	1252	77
Terneuzen	1199	71	Ritthem	1253	98
Sluis	1201	74	Vlissingen Haven	1254	72
Vlissingen	1202	77	Nieuwdorp	1255	75
Halsteren	1204	65	's Heerenhoek [6]	1256	116
Oud Gastel	1206	66	Driewegen	1257	82
Goes	1207	83	Arnemuiden	1258	72
Bruinisse	1209	74	Heinkenszand	1259	82
Burgh-Haamstede	1211	62	Baarland	1260	86
Vrouwenpolder	1212	63	Biervliet	1261	76
Wemeldinge	1214	76	Nummer Een	1262	76
Middelburg	1215	78	Rilland	1263	75
Westkapelle	1216	67	Putte	1264	56
Stein	1219	82	Nieuw Namen	1265	79
Maastricht	1220	90	Beneden Leeuwen	1272	85
Ravensbos (Arensgehout)	1221	84	Denekamp	1278	64
			Winterswijk (Kotten)	1279	68
Vaals	1222	82	Bilthoven	1280	61
Gulpen	1223	83	Gastel (Maarheze)	1281	75
Kerkrade	1224	87			

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

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

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

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

[5] Station was not operational in 2011.

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

Table A15: Gross α, residual β, ^{3}H, ^{90}Sr and ^{226}Ra activity concentrations ($mBq \cdot L^{-1}$) in surface water in 2011 as measured by RWS

Date	Gross α $mBq \cdot L^{-1}$	Residual β $mBq \cdot L^{-1}$	^{3}H $mBq \cdot L^{-1}$	^{90}Sr $mBq \cdot L^{-1}$	^{226}Ra $mBq \cdot L^{-1}$
Location	**IJsselmeer**				
01/02/11	47	29	2,170		
01/03/11	34	12			
29/03/11	22	8	2,370		
27/04/11	48	34			
25/05/11	45	< 1	2,360		
27/06/11	27	27			
19/07/11	68	37	3,590		
17/08/11	12	31			
13/09/11	99	59	2,940		
11/10/11	111	47			
08/11/11	54	12	2,720		
06/12/11	70	50			
Average	53	29	2,700		
Location	**Nieuwe Waterweg**				
19/01/11	120	117	5,580	6.0	2.3
16/02/11	98	58			
16/03/11	51	33	4,620	6.0	1.4
13/04/11	105	69			
11/05/11	259	30	4,840	< 1	5.2
08/06/11	136	22			
06/07/11	124	25	5,410	3.0	3.4
03/08/11	104	12			
31/08/11	94	51	4,510	1.0	4.6
28/09/11	412	45			
26/10/11	412	59	4,000	3.0	2.2
23/11/11	326	34			
21/12/11	106	81	6,910	< 1	1.0
Average	180	49	5,100	2.9	2.9
Location	**Noordzeekanaal**				
14/02/11	138	44	2,390		
14/03/11	82	42	3,090		
12/04/11	204	57	3,300		
09/05/11	117	41	3,020		
06/06/11	212	31	2,660		
04/07/11	184	34	3,040		
01/08/11	214	18	2,630		
29/08/11	227	30	2,780		
26/09/11	90	21	3,040		
24/10/11	256	29	2,450		
21/11/11	177	34	2,840		
19/12/11	78	42	2,440		
Average	165	35	2,810		

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Table A15: 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**				
12/01/11	133	136	3,120		
09/02/11	63	34	5,460	2.0	2.7
09/03/11	60	19	4,290		
06/04/11	51	< 1	3,720	< 1	2.2
03/05/11	54	43	3,310		
31/05/11	63	26	11,800	3.0	2.4
29/06/11	43	26	5,010		
27/07/11	50	28	6,190	< 1	4.4
24/08/11	75	11	3,380		
21/09/11	58	31	3,510	1.0	3.5
19/10/11	49	34	3,950		
16/11/11	28	< 1	12,800	2.0	1.0
14/12/11	54	28	5,510		
Average	60	32	5,500	1.5	2.7
Location	**Scheldt**				
05/01/11	128	103	7,400		3.3
31/01/11	121	78			
28/02/11	221	112	7,230		5.2
28/03/11	254	103			
26/04/11	232	130	16,700		8.8
23/05/11	358	143			
20/06/11	387	192	17,900		8.8
19/07/11	286	108			
17/08/11	332	150	10,600		13.6
14/09/11	280	121			
13/10/11	313	82	14,100		8.7
07/11/11	514	104			
05/12/11	314	69	21,700		2.4
Average	290	115	14,000		7.3
Location	**Meuse**				
11/01/11	64	66	2,860		
08/02/11	31	20	784	< 1	2.8
08/03/11	24	16	2,070		
05/04/11	22	23	43,600	< 1	4.8
03/05/11	50	1	24,900		
31/05/11	21	6	46,800	4.0	3.2
28/06/11	17	15	55,100		
26/07/11	38	20	21,700	1.0	3.8
23/08/11	161	116	36,600		
20/09/11	29	16	50,400	4.0	2.4
18/10/11	49	7	29,600		
15/11/11	27	5	31,600	< 1	1.3
13/12/11	25	20	11,500		
Average	43	25	28,000	1.8	3.0

Table A16: ^{60}Co, ^{131}I, ^{137}Cs and ^{210}Pb activity concentrations in suspended solids ($Bq \cdot kg^{-1}$) in surface water in 2011 as measured by RWS

Date	**^{60}Co $Bq \cdot kg^{-1}$**	**^{131}I $Bq \cdot kg^{-1}$**	**^{137}Cs $Bq \cdot kg^{-1}$**	**^{210}Pb $Bq \cdot kg^{-1}$**
Location	**IJsselmeer**			
01/02/11	< 1	< 1	5.0	
01/03/11	< 1	< 1	6.5	
29/03/11	< 1	< 1	< 1	
27/04/11	< 1	< 1	5.9	
25/05/11	< 1	< 1	3.0	
27/06/11	< 1	< 1	1.4	
19/07/11	< 1	< 1	4.1	
17/08/11	< 1	< 1	2.1	
13/09/11	< 1	< 1	4.3	
11/10/11	< 1	< 1	3.9	
08/11/11	< 1	< 1	4.6	
06/12/11	< 1	< 1	5.2	
Average	< 1	< 1	3.9	
Location	**Nieuwe Waterweg**			
19/01/11	< 1	< 1	10.5	86
16/02/11	< 1	< 1	11.0	
16/03/11	< 1	7.7	9.1	114
13/04/11	< 1	< 1	9.6	
11/05/11	< 1	< 1	6.0	81
08/06/11	< 1	< 1	6.3	
06/07/11	< 1	< 1	7.7	91
03/08/11	< 1	< 1	8.0	
31/08/11	< 1	< 1	6.2	76
28/09/11	< 1	< 1	8.0	
26/10/11	< 1	< 1	10.4	109
23/11/11	< 1	< 1	11.7	
21/12/11	< 1	< 1	11.3	128
Average	< 1	< 1.1	8.9	98
Location	**Noordzeekanaal**			
14/02/11	< 1	69.3	7.3	
12/04/11	< 1	38.5	3.6	
06/06/11	< 1	32.5	3.1	
01/08/11	< 1	82.6	4.8	
26/09/11	< 1	65.2	5.9	
21/11/11	< 1	34.6	7.1	
Average	< 1	54	5.3	

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Table A16: Continued

Date	^{60}Co Bq·kg^{-1}	^{131}I Bq·kg^{-1}	^{137}Cs Bq·kg^{-1}	^{210}Pb Bq·kg^{-1}
Location	**Rhine**			
12/01/11	< 1	< 1	12.7	
08/02/11	< 1	6.0	11.4	118
09/03/11	< 1	5.8	12.4	
23/03/11	< 1	6.4	10.9	
06/04/11	< 1	18.2	13.1	133
20/04/11	< 1	8.4	8.9	
03/05/11	< 1	< 1	10.4	
18/05/11	< 1	< 1	8.5	
31/05/11	< 1	< 1	6.2	60
15/06/11	< 1	3.7	9.4	
29/06/11	< 1	6.5	9.5	
13/07/11	< 1	< 1	7.3	84
24/08/11	< 1	7.0	10.4	
21/09/11	< 1	2.3	12.3	122
19/10/11	< 1	4.8	12.5	
16/11/11	< 1	< 1	10.4	105
13/12/11	< 1	6.9	14.1	
Average	< 1	4.6	10.6	104
Location	**Scheldt**			
05/01/11	< 1	4.1	7.0	92
31/01/11	< 1	2.4	7.8	
28/02/11	< 1	2.2	8.3	100
28/03/11	1.9	< 1	7.1	
26/04/11	< 1	< 1	6.8	86
23/05/11	1.1	< 1	7.8	
20/06/11	1.9	< 1	7.4	106
19/07/11	< 1	< 1	7.6	
17/08/11	< 1	< 1	5.7	94
14/09/11	1.1	< 1	6.4	
27/10/11	1.1	< 1	7.2	92
07/11/11	1.1	< 1	7.6	
05/12/11	< 1	< 1	6.9	104
Average	< 1	< 1	7.2	96
Location	**Meuse**			
04/01/11	2.3	4.9	10.8	
11/01/11	< 1	< 1	8.9	
18/01/11	1.0	9.1	9.4	
25/01/11	1.2	14.8	10.0	
01/02/11	23.7	10.5	11.0	
08/02/11	4.4	53.8	10.5	138
16/02/11	3.8	43.5	11.2	
22/02/11	5.4	15.6	10.8	

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Table A16: Continued

Date	^{60}Co Bq·kg^{-1}	^{131}I Bq·kg^{-1}	^{137}Cs Bq·kg^{-1}	^{210}Pb Bq·kg^{-1}
Location	**Meuse**			
01/03/11	3.4	82.5	10.1	
08/03/11	8.1	21.0	10.7	
15/03/11	5.6	19.1	4.6	
22/03/11	14.1	19.4	4.0	
29/03/11	7.4	11.0	4.0	
05/04/11	10.0	83.1	8.3	150
12/04/11	9.3	51.0	5.7	
19/04/11	3.6	18.0	3.8	
26/04/11	< 1	23.7	2.7	
03/05/11	2.8	< 1	3.5	
10/05/11	2.7	< 1	2.6	
17/05/11	< 1	< 1	4.3	
24/05/11	5.2	< 1	2.8	
30/05/11	4.5	< 1	6.3	183
07/06/11	< 1	< 1	6.8	
15/06/11	3.3	< 1	3.8	
22/06/11	2.6	5.4	4.3	
28/06/11	< 1	6.8	3.3	
05/07/11	2.2	< 1	2.7	
12/07/11	< 1	< 1	2.6	
19/07/11	3.7	< 1	5.5	
26/07/11	3.4	< 1	5.3	155
02/08/11	< 1	< 1	3.7	
09/08/11	3.5	28.5	4.9	
16/08/11	< 1	33.4	6.7	
23/08/11	< 1	23.5	5.5	
30/08/11	3.5	23.9	10.1	
06/09/11	2.7	13.3	7.7	
13/09/11	2.8	114.0	6.7	
20/09/11	< 1	28.0	6.3	113
27/09/11	< 1	17.4	9.5	
04/10/11	3.3	16.4	4.6	
11/10/11	< 1	27.5	8.0	
18/10/11	6.9	37.5	10.3	
25/10/11	5.6	15.6	8.3	
01/11/11	6.7	5.7	10.2	
08/11/11	2.8	13.4	2.9	
15/11/11	5.1	< 1	12.4	253
21/11/11	6.7	31.4	12.7	
29/11/11	5.6	< 1	10.2	
06/12/11	9.7	12.9	12.2	
13/12/11	15.3	10.4	16.1	
21/12/11	< 1	7.3	12.3	
27/12/11	7.6	< 1	13.6	
Average	4.4	18	7.4	165

Table A17: Gross α, residual β, ^{3}H and ^{90}Sr activity concentrations ($mBq \cdot L^{-1}$) in seawater in 2011 as measured by RWS

Date	Gross α $mBq \cdot L^{-1}$	Residual β $mBq \cdot L^{-1}$	^{3}H $mBq \cdot L^{-1}$	^{90}Sr $mBq \cdot L^{-1}$
Location	**Coastal Area**			
09/02/11	230	88	4,270	
12/05/11	189	56	4,260	
23/08/11	555	55	4,520	
21/11/11	1080	59	4,610	
Average	500	64	4,420	
Location	**Southern North Sea**			
09/02/11	346	91	4,940	2
12/05/11	443	47	2,410	3
23/08/11	386	58	3,130	3
21/11/11	109	67	4,890	< 1
Average	320	66	3,800	2.1
Location	**Central North Sea**			
18/01/11	70	49	513	1
12/04/11	120	47	108	< 1
08/06/11	330	47	596	3
17/08/11	363	68	209	1
Average	220	53	360	1.4
Location	**Delta Coastal Waters**			
11/01/11	145	62	5,520	
08/02/11	312	95	4,420	4
10/03/11	345	72	4,800	
14/04/11	264	53	3,980	
11/05/11	315	63	3,960	< 1
15/06/11	405	105	3,730	
04/07/11	518	64	3,950	
23/08/11	500	64	4,070	7
14/09/11	644	60	4,120	
15/11/11	601	77	4,730	< 1
28/11/11	955	78	5,000	
Average	450	72	4,390	3

Continued on the next page

Table A17: Continued

Date	Gross α $mBq \cdot L^{-1}$	Residual β $mBq \cdot L^{-1}$	^{3}H $mBq \cdot L^{-1}$	^{90}Sr $mBq \cdot L^{-1}$
Location	**Westerscheldt**			
03/01/11	234	116	5,010	< 1
02/02/11	300	226	5,110	3
01/03/11	260	80	5,870	2
30/03/11	253	91	4,970	< 1
27/04/11	240	106	4,570	< 1
25/05/11	373	82	4,220	< 1
22/06/11	429	191	4,850	2
18/07/11	615	71	4,970	1
16/08/11	635	78	4,380	< 1
13/09/11	435	105	4,160	6
10/10/11	670	150	5,040	3
09/11/11	154	181	5,030	< 1
06/12/11	216	134	4,830	2
Average	370	124	4,850	1.7
Location	**Eems-Dollard**			
14/02/11	186	139	3,420	
12/05/11	505	55	3,890	
08/08/11	562	50	3,480	
08/11/11	105	99	3,430	
Average	340	90	3,560	
Location	**Wadden Sea West**			
17/02/11	160	109	4,550	
17/05/11	312	102	3,600	
11/08/11	887	55	3,810	
14/11/11	178	64	3,790	
Average	380	82	3,900	
Location	**Wadden Sea East**			
15/02/11	163	204	4,280	
09/05/11	520	123	4,090	
10/08/11	221	110	3,240	
09/11/11	201	152	3,240	
Average	280	150	3,700	

Table A18: ^{137}Cs and ^{210}Pb activity concentrations in suspended solids ($Bq \cdot kg^{-1}$) in seawater in 2011 as measured by RWS

Date	**^{137}Cs $Bq \cdot kg^{-1}$**	**^{210}Pb (1) $Bq \cdot kg^{-1}$**
Location	**Coastal area**	
10/02/11	8.2	64
19/05/11	2.4	56
22/08/11	3.7	75
14/11/11	3.9	84
Average	4.6	70
Location	**Westerscheldt**	
02/03/11	< 1	88
24/05/11	4.4	70
18/08/11	3.7	58
08/11/11	3.5	57
Average	3.0	68
Location	**Eems-Dollard**	
11/02/11	5.9	108
11/05/11	7.0	95
17/11/11	5.8	111
Average	6.2	105
Location	**Wadden Sea West (2)**	
17/02/11	8.4	127
16/05/11	5.3	73
15/11/11	6.1	108
Average	6.6	103

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

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

Table A19: Monthly averaged gross α activity concentrations in air dust near the nuclear power plant at Borssele in 2011

Date (1)			**Gross α (2) $mBq \cdot m^{-3}$**		
Location	**21**	**22**	**23**	**27**	**29**
01/02/11	0.023	0.021	0.022	0.001	0.034
01/03/11	0.037	0.079	0.053	0.012	0.018
06/04/11	0.040	0.020	0.047	0.054	0.058
02/05/11	0.030	0.019	0.047	0.011	0.066
07/06/11	0.030	0.038	0.113	0.016	0.044
06/07/11	0.02	0.03	0.014	0.018	0.006
03/08/11	0.003	0.009	0.046	0.015	0.016
08/09/11	0.014	0.019	0.065	0.002	0.018
04/10/11	0.039	0.012	0.036	0.003	0.036
03/11/11	0.014	0.009	0.096	0.042	0.027
08/12/11	0.088	0.066	0.295	0.059	0.086
09/01/12	0.024	0.083	0.175	0.003	0.001

(1) End date of monthly sampling period.

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

Table A20: Monthly averaged gross β activity concentrations in air dust near the nuclear power plant at Borssele in 2011

Date [1]			**Gross β** $mBq \cdot m^{-3}$		
Location	**21**	**22**	**23**	**27**	**29**
01/02/11	0.20 ± 0.04	0.249 ± 0.015	0.14 ± 0.03	0.28 ± 0.02	0.301 ± 0.012
01/03/11	0.44 ± 0.04	0.579 ± 0.018	0.40 ± 0.03	0.27 ± 0.02	0.367 ± 0.015
06/04/11	0.47 ± 0.03	0.403 ± 0.012	0.46 ± 0.03	0.72 ± 0.02	0.610 ± 0.014
02/05/11	0.41 ± 0.04	0.437 ± 0.017	0.49 ± 0.04	0.37 ± 0.02	0.628 ± 0.017
07/06/11	0.35 ± 0.03	0.318 ± 0.013	0.29 ± 0.03	0.270 ± 0.017	0.373 ± 0.013
06/07/11	0.31 ± 0.05	0.20 ± 0.03	0.35 ± 0.04	0.21 ± 0.04	0.27 ± 0.03
03/08/11	0.40 ± 0.02	0.207 ± 0.014	0.310 ± 0.019	0.27 ± 0.02	0.258 ± 0.010
08/09/11	0.315 ± 0.018	0.220 ± 0.011	0.56 ± 0.03	0.264 ± 0.017	0.316 ± 0.008
04/10/11	0.83 ± 0.03	0.85 ± 0.03	0.63 ± 0.02	0.327 ± 0.016	0.676 ± 0.015
03/11/11	0.31 ± 0.02	0.131 ± 0.013	0.53 ± 0.02	0.46 ± 0.02	0.472 ± 0.013
08/12/11	0.98 ± 0.04	0.73 ± 0.04	0.90 ± 0.03	0.60 ± 0.03	0.811 ± 0.018
09/01/12	0.31 ± 0.02	0.208 ± 0.015	0.319 ± 0.017	0.240 ± 0.019	0.37 ± 0.03

[1] End date of monthly sampling period.

Table A21: Monthly averaged activity concentrations of γ-emitters in air dust near the nuclear power plant at Borssele in 2011

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

Date [1]	**^{60}Co** $mBq \cdot m^{-3}$	**$^{131}I_{el}$** [2] $mBq \cdot m^{-3}$	**$^{131}I_{or}$** [2] $mBq \cdot m^{-3}$	**^{137}Cs** $mBq \cdot m^{-3}$	**Nat.** [3] $mBq \cdot m^{-3}$
01/02/11	< 0.07	< 0.2	< 0.5	< 0.05	2.27 ± 0.10
01/03/11	< 0.07	< 0.4	< 0.3	< 0.06	2.11 ± 0.07
06/04/11	< 0.016	0.172 ± 0.008	0.42 ± 0.04	< 0.014	1.03 ± 0.06
02/05/11	< 0.06	< 0.1	< 0.3	< 0.05	1.5 ± 0.3
07/06/11	< 0.07	< 0.1	< 0.2	< 0.05	1.95 ± 0.10
06/07/11	< 0.06	< 0.1	< 0.2	< 0.05	1.58 ± 0.19
03/08/11	< 0.07	< 0.09	< 0.2	< 0.05	1.7 ± 0.2
08/09/11	< 0.06	< 0.1	< 0.3	< 0.05	1.24 ± 0.18
04/10/11	< 0.08	< 0.2	< 0.3	< 0.05	1.5 ± 0.2
03/11/11	< 0.04	< 0.2	< 0.4	< 0.03	1.17 ± 0.08
08/12/11	< 0.04	< 0.4	< 0.3	< 0.05	2.3 ± 0.3
09/01/12	< 0.06	< 0.1	< 0.2	< 0.04	0.9 ± 0.3

[1] End date of monthly sampling period.

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

[3] Naturally occurring γ-emitters.

Table A22: Activity concentrations of γ-emitters in grass near the nuclear power plant at Borssele in 2011

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

Date	Mass	^{60}Co	^{131}I	^{137}Cs
	kg·m^{-2}	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)
01/02/11	0.326	< 2	< 1	< 1
01/03/11	0.303	< 2	< 2	< 2
06/04/11	0.303	< 2	10.5 ± 0.7	< 2
02/05/11	0.319	< 2	< 2	< 2
07/06/11	0.376	< 2	< 2	< 1
06/07/11	0.128	< 5	< 4	< 4
03/08/11	0.175	< 4	< 4	< 3
08/09/11	0.224	< 3	< 3	< 2
04/10/11	0.232	< 3	< 2	< 2
03/11/11	0.197	< 3	< 3	< 2
08/12/11	0.548	< 1	< 0.9	< 0.9
09/01/12	0.209	< 3	< 2	< 2

(1) Dry weight.

Table A23: Activity concentrations of γ-emitters in soil near the nuclear power plant at Borssele in 2011

Analysis was performed on four samples taken near the outlet of the plant on 17 May 2011.

Location	Mass	^{54}Mn	^{60}Co	^{134}Cs	^{137}Cs
	kg·m^{-2}	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)
O1	71.2	< 0.2	< 0.2	< 0.2	1.95 ± 0.08
O2	74.0	< 0.2	< 0.2	< 0.2	0.93 ± 0.06
O3	76.8	< 0.2	< 0.2	< 0.2	0.72 ± 0.06
O4	77.0	< 0.2	< 0.2	< 0.2	0.86 ± 0.05

(1) Dry weight.

Table A24: Residual β activity concentrations in water from the Westerscheldt in 2011

Date		Residual β Bq·L^{-1}		
Location	1	2	3	4
01/02/11	0.135 ± 0.006	0.099 ± 0.004	0.089 ± 0.004	0.078 ± 0.005
01/03/11	0.102 ± 0.004	0.084 ± 0.005	0.064 ± 0.007	0.085 ± 0.005
06/04/11	0.096 ± 0.004	0.057 ± 0.006	0.081 ± 0.006	0.061 ± 0.007
02/05/11	0.071 ± 0.008	0.102 ± 0.007	0.069 ± 0.006	0.082 ± 0.007
07/06/11	0.078 ± 0.007	0.056 ± 0.007	0.061 ± 0.006	0.069 ± 0.006
06/07/11	0.059 ± 0.007	0.063 ± 0.009	0.091 ± 0.007	0.070 ± 0.006
03/08/11	0.141 ± 0.007	0.086 ± 0.006	0.056 ± 0.005	0.067 ± 0.006
08/09/11	0.121 ± 0.018	0.103 ± 0.007	0.107 ± 0.007	0.138 ± 0.010
04/10/11	0.108 ± 0.007	0.081 ± 0.006	0.062 ± 0.007	0.072 ± 0.007
03/11/11	0.051 ± 0.006	0.048 ± 0.006	0.043 ± 0.006	0.036 ± 0.006
08/12/11	0.100 ± 0.007	0.077 ± 0.010	0.085 ± 0.006	0.108 ± 0.008
09/01/12	0.043 ± 0.005	0.051 ± 0.005	0.065 ± 0.005	0.047 ± 0.004

Table A25: ^{3}H activity concentrations in water from the Westerscheldt in 2011

Date		**^{3}H Bq·L^{-1}**		
Location	**1**	**2**	**3**	**4**
01/02/11	8.3 ± 1.3	9.9 ± 1.3	9.4 ± 1.3	7.1 ± 1.1
01/03/11	8.3 ± 1.3	8.5 ± 1.3	8.6 ± 1.3	9.0 ± 1.1
06/04/11	8.9 ± 1.3	9.2 ± 1.3	9.8 ± 1.4	8.8 ± 1.1
02/05/11	7.4 ± 1.3	8.4 ± 1.3	7.2 ± 1.3	8.3 ± 1.1
07/06/11	9.8 ± 1.3	8.1 ± 1.3	8.3 ± 1.2	8.8 ± 1.1
06/07/11	8.9 ± 1.3	8.1 ± 1.3	7.8 ± 1.3	9.1 ± 1.1
03/08/11	8.9 ± 1.5	9.4 ± 1.5	9.1 ± 1.5	8.8 ± 1.3
08/09/11	8.3 ± 1.5	9.2 ± 1.5	8.6 ± 1.5	9.4 ± 1.3
04/10/11	8.8 ± 1.5	9.8 ± 1.5	9.1 ± 1.5	9.4 ± 1.3
03/11/11	8.3 ± 1.4	9.3 ± 1.4	9.5 ± 1.6	9.1 ± 1.2
08/12/11	8.5 ± 1.5	8.8 ± 1.5	9.6 ± 1.5	9.5 ± 1.3
09/01/12	8.3 ± 1.5	9.2 ± 1.5	8.6 ± 1.5	9.2 ± 1.3

Table A26: Gross β activity concentrations in suspended solids from the Westerscheldt in 2011

Date		**Gross β kBq·kg^{-1}**		
Location	**1**	**2**	**3**	**4**
01/02/11	1.07 ± 0.06	1.44 ± 0.09	0.81 ± 0.07	1.57 ± 0.08
01/03/11	0.81 ± 0.03	1.33 ± 0.09	1.64 ± 0.08	1.35 ± 0.08
06/04/11	0.59 ± 0.12	1.39 ± 0.13	0.74 ± 0.07	0.45 ± 0.05
02/05/11	0.49 ± 0.07	0.41 ± 0.09	0.51 ± 0.06	0.59 ± 0.05
07/06/11	0.30 ± 0.06	0.61 ± 0.13	0.59 ± 0.04	0.43 ± 0.07
06/07/11	0.80 ± 0.07	0.76 ± 0.03	0.56 ± 0.03	0.64 ± 0.03
03/08/11	0.70 ± 0.03	0.72 ± 0.08	0.58 ± 0.04	0.61 ± 0.03
08/09/11	0.77 ± 0.13	0.77 ± 0.10	0.67 ± 0.07	0.72 ± 0.08
04/10/11	0.67 ± 0.05	0.75 ± 0.08	0.72 ± 0.03	0.73 ± 0.04
03/11/11	0.71 ± 0.04	0.98 ± 0.07	0.70 ± 0.04	0.67 ± 0.04
08/12/11	0.73 ± 0.08	0.87 ± 0.07	0.63 ± 0.04	0.59 ± 0.06
09/01/12	0.86 ± 0.08	1.11 ± 0.07	0.85 ± 0.09	0.84 ± 0.04

Table A27: Activity concentrations of γ-emitters in seaweed from the Westerscheldt in 2011

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

Date	Mass	^{60}Co	^{131}I	^{137}Cs
	kg	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)
01/02/11	0.161	< 3	< 2	< 2
01/03/11	0.129	< 3	< 2	< 2
06/04/11	0.191	< 2	< 2	< 2
02/05/11	0.132	< 3	0.9 ± 0.3	< 2
07/06/11	0.162	< 3	< 2	< 2
06/07/11	0.107	< 3	< 3	< 3
03/08/11	0.132	< 3	< 2	< 2
08/09/11	0.119	< 3	< 2	< 2
04/10/11	0.141	< 3	< 2	< 2
03/11/11	0.086	< 4	< 3	< 3
08/12/11	0.097	< 4	< 3	< 3
09/01/12	0.100	< 4	< 3	< 3

(1) Dry weight.

Table A28: Activity concentrations of γ-emitters in sediment from the Westerscheldt in 2011

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

Location	Mass	^{60}Co	^{131}I	^{137}Cs
	kg·m^{-2}	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)	Bq·kg^{-1} (1)
01/02/11	65.4	< 0.4	< 0.3	1.36 ± 0.09
01/03/11	71.7	< 0.3	< 0.2	0.89 ± 0.08
06/04/11	67.3	< 0.3	< 0.2	0.97 ± 0.08
02/05/11	52.7	< 0.4	< 0.3	1.37 ± 0.14
07/06/11	50.4	< 0.4	< 0.3	0.70 ± 0.07
06/07/11	57.3	< 0.4	< 0.3	1.21 ± 0.09
03/08/11	59.6	< 0.3	< 0.2	0.75 ± 0.08
08/09/11	60.7	< 0.4	< 0.4	< 0.4
04/10/11	50.1	< 0.4	< 0.3	1.23 ± 0.10
03/11/11	57.5	< 0.3	< 0.2	0.62 ± 0.04
08/12/11	56.4	< 0.4	< 0.3	2.28 ± 0.10
09/01/12	57.7	< 0.3	< 0.3	0.34 ± 0.07

(1) Dry weight.

Appendix B – Presentation of data

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

B.1 Correction for radioactive decay

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

B.2 Calculation of sums and averages

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

The lower and upper limits are calculated as follows:

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

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

where

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

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

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

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

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

B.3 Calculation of uncertainties

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

Appendix C – Glossary

Ambient dose equivalent	An operational quantity used when monitoring radiation in the environment. The unit of ambient dose equivalent is the Sievert (Sv).
Becquerel (Bq)	One radioactive transformation per second.
Decay product	A decay product (also known as a daughter product, daughter isotope or daughter nuclide) is a nuclide resulting from the radioactive decay of a parent isotope or precursor nuclide. The daughter product may be stable or it may decay to form a daughter product of its own.
Dose rate	The radiation dose delivered per unit of time.
Effective dose	The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the Sievert (Sv).
Gross alpha activity	Gross α (or total α) activity is the total activity of nuclides emitting α radiation.
Gross beta activity	Gross β (or total β) activity is the total activity of nuclides emitting β-radiation. Depending on the measurement methodology, it might exclude tritium and/or radon daughters.
Radioactivity	The emission of α particles, β particles, neutrons and γ or X radiation from the disintegration of an atomic nucleus. The unit of radioactivity is the Becquerel (Bq).
Radionuclide	An unstable form of an element that undergoes radioactive decay.
Residual beta activity	The residual β activity is the gross β activity (total β activity) minus the β activity of naturally occurring 40K. For brackish and salt water, RWS uses a direct method to determine the residual β activity [46].

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