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

# Environmental radioactivity in the Netherlands

*Results in 2009*

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# Colophon



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# Abstract

**Environmental radioactivity in the Netherlands**
**Results in 2009**

In 2009 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. Euratom has provided guidelines for performing the measurements uniformly since 2000. However, Member States are not obliged to comply with these recommended guidelines. In the Netherlands, in 2009 strontium-90 was also determined (for the first time) in a mixed food package for which the above recommendations had been fulfilled.

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. Moreover, this information provides background values and/or amounts of radioactivity that are present under normal circumstances. These background values can be used as reference values, for instance, during a disaster.

**Radioactivity in air, food and milk.**
The measurements in the air and environment showed normal levels. The deposition of polonium-210 showed the highest level since 1993, and approximately the same level as in 2008.
Radioactivity levels in food and milk were well below the export and consumption limits set by the European Union.

**Radioactivity in surface water**
The activity concentration in surface water was in some locations above the target values from the Vierde Nota waterhuishouding (1998). However, these exceeded values do not pose a threat to public health. Target values are values that should preferably not be exceeded but they are not limits as such.

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

# Rapport in het kort

**Radioactiviteit in het Nederlandse milieu**
**Resultaten in 2009**

In 2009 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. Sinds 2000 bevat Euratom aanbevelingen om de metingen volgens een bepaald stramien uit te voeren, maar lidstaten zijn niet verplicht deze na te leven. In 2009 heeft Nederland voor het eerst ook strontium-90 bepaald in een gemengd voedselpakket, waarmee aan al deze aanbevelingen is voldaan.

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

**Radioactiviteit in lucht, voedsel en melk**
De metingen in lucht en omgeving lieten een normaal beeld zien. De depositie van polonium-210 is het hoogst sinds 1993, en ongeveer even hoog als in 2008. De radioactiviteitsniveaus in voedsel en melk zijn duidelijk beneden de Europese limieten voor consumptie en export.

**Radioactiviteit in oppervlaktewater**
In het oppervlaktewater ligt de activiteitsconcentratie op een aantal locaties boven de streefwaarden uit de Vierde Nota waterhuishouding (1998). De overschrijdingen zijn echter zodanig dat ze niet schadelijk zijn voor de volksgezondheid. Streefwaarden zijn waarden die bij voorkeur niet overschreden mogen worden, maar het zijn geen limieten.

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

# Preface

The following institutes have contributed to the report:

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

**RWS WD Centre for Water Management**
**Rijkswaterstaat Waterdienst (RWS WD)**
Data on seawater and surface water from the main inland waters.
C. Engeler, ing. M van der Weijden.

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

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

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

# Contents

# Summary

The Dutch government has the obligation to measure radioactivity in air, water and soil under the terms of the Euratom Treaty of 1957. In 2000, the European Union specified this treaty by means of recommendations describing the matrices to be measured (air dust, ambient dose, surface water, drinking water, milk and food) and the frequency of the measurements. The results should be published yearly. This report presents the results of radioactivity measurements in the Dutch environment in 2009. The measurements were carried out by RIVM, Centre for Water Management, RIKILT, VWA, and (tasked by EPZ) NRG.

The yearly averaged activity concentration in air dust was determined for gross α, gross β, $^{7}$Be, $^{137}$Cs and $^{210}$Pb. The yearly total activity in deposition was determined for gross α, gross β, $^{3}$H, $^{7}$Be, $^{137}$Cs, $^{210}$Pb and $^{210}$Po. Gross α and gross β is the total activity of nuclides emitting α- and β-radiation, respectively. The results are presented in Table S1 and are within the range of those in previous years, except for the yearly total activity in deposition from $^{210}$Po (32.5 Bq·m$^{-2}$) which is the highest since 1993.

The National Radioactivity Monitoring Network (NMR) was used to determine the activity concentrations in air dust of gross α and artificial β (β-radiation emitted by man-made nuclides). The difference between the NMR data and those mentioned above is due to the contribution of short-lived natural radionuclides (radon daughters). The yearly averaged gross α-activity concentration in air dust was 3.3 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 74.1 nSv·h$^{-1}$.

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

The gross α-activity concentration in the Noordzeekanaal, Nieuwe Waterweg and Scheldt exceeds the target value (100 mBq·L$^{-1}$) in 6 out of 6, 6 out of 13 and 13 out of 13 samples taken, respectively. The yearly averaged gross α-activity concentrations in the Noordzeekanaal, Nieuwe Waterweg and Scheldt (220, 113 and 380 mBq·L$^{-1}$, respectively) are above the target value, but within the range of those in previous years.

The residual β- and $^{90}$Sr-activity concentrations (of both individual samples and yearly average) in surface water are below the target value (200 and 10 mBq·L$^{-1}$ respectively).

The $^{3}$H-activity concentration in the Scheldt and Meuse exceeds the target value (10 Bq·L$^{-1}$) in 4 out of 7 and 4 out of 13 samples taken, respectively. The yearly averaged $^{3}$H-activity concentrations in the Scheldt and Meuse (11.9 and 14.0 Bq·L$^{-1}$, respectively) are above the target value of 10 Bq·L$^{-1}$, but within the range of those in previous years.

The $^{226}$Ra-activity concentration in the Scheldt exceeds the target value (5 mBq·L$^{-1}$) in 7 out of 7 samples taken. The yearly averaged $^{226}$Ra-activity concentration in the Scheldt (12.4 mBq·L$^{-1}$) is above the target value of 5 mBq·L$^{-1}$, but within the range of those in previous years.

The $^{60}$Co-activity concentration in suspended solids in the Meuse exceeds the target value (10 Bq·kg$^{-1}$) in 6 out of 45 samples taken, but the yearly averaged $^{60}$Co-activity concentration is below the target value.

The $^{131}$I-activity concentration in suspended solids in the Noordzeekanaal and Meuse exceeds the target value (20 Bq·kg$^{-1}$) in 6 out of 6 and 10 out of 45 samples taken, respectively. The yearly averaged $^{131}$I-activity concentration in the Meuse is below the target value. The yearly averaged $^{131}$I-activity concentration in the Noordzeekanaal (29 Bq·kg$^{-1}$) is higher than those in previous years, and exceeds the target value.

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

The $^{210}$Pb-activity concentration in suspended solids in the Nieuwe Waterweg, Rhine and Meuse exceeds the target value (100 Bq·kg$^{-1}$) in 4 out of 7, 6 out of 6 and 5 out of 6 samples taken, respectively. The yearly averaged $^{210}$Pb-activity concentrations in the Nieuwe Waterweg, Rhine and Meuse (112, 120 and 153 Bq·kg$^{-1}$, respectively) are above the target value, but within the range of those in previous years.

The yearly averaged gross α-, and residual β-activity concentrations in seawater are in some areas higher than in previous years.

The yearly averaged $^{3}$H-, $^{90}$Sr-, and $^{137}$Cs-activity concentrations in seawater are within the range of those in previous years.
Since 2009, for seawater $^{210}$Pb is reported instead of $^{210}$Po. The yearly averaged $^{210}$Pb-activity concentrations in seawater are within the range of those in previous years.

Typical activities found in raw input water for drinking water production are presented in Table S1. There is little potassium, and thus $^{40}$K, present in this water. In 2009, the gross α-activity concentration averaged per production station did not exceed the screening value (0.1 Bq·L$^{-1}$) at any of the 187 production stations.

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

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

In 2009, the Netherlands complied with the Euratom recommendations, including the determination of $^{90}$Sr in mixed diet, which was performed by RIKILT – Institute of Food Safety.

# 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 2009. De metingen zijn verricht door RIVM, RWS Waterdienst, RIKILT, VWA en (in opdracht van EPZ) NRG.

In luchtstof werd de jaargemiddelde activiteitsconcentratie bepaald van totaal-α, totaal-β, $^{7}$Be, $^{137}$Cs en $^{210}$Pb. In depositie werd de totale jaarlijkse activiteit bepaald van totaal-α, totaal-β, $^{3}$H, $^{7}$Be, $^{137}$Cs, $^{210}$Pb en $^{210}$Po. Totaal-α respectievelijk totaal-β is de totale activiteit aan α- dan wel β-straling uitzendende nucliden. De resultaten zijn weergegeven in Tabel S1 en vallen binnen het bereik van voorgaande jaren, met uitzondering van de depositie van $^{210}$Po (32,5 Bq·m$^{-2}$) die het hoogst sinds 1993 is.

Met het Nationaal Meetnet Radioactiviteit (NMR) werden activiteitsconcentraties bepaald in luchtstof voor totaal-α en kunstmatige β (β-straling uitgezonden door nucliden ontstaan door menselijk handelen). Het verschil tussen de NMR-metingen en bovenstaande metingen wordt veroorzaakt door de bijdrage van kortlevende natuurlijke radionucliden (radondochters). Het jaargemiddelde voor de totaal-α-activiteitsconcentratie in luchtstof was 3,3 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 74,1 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 Noordzeekanaal, de Nieuwe Waterweg en de Schelde overschrijdt de streefwaarde (100 mBq·L$^{-1}$) in respectievelijk 6 van de 6, 6 van de 13 en 13 van de 13 genomen monsters. De jaargemiddelde totaal α-activiteitsconcentraties in het Noordzeekanaal, de Nieuwe Waterweg en de Schelde (respectievelijk 220, 113 en 380 mBq·L$^{-1}$) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

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

De $^{3}$H-activiteitsconcentratie in de Schelde en de Maas overschrijdt de streefwaarde (10 Bq·L$^{-1}$) in respectievelijk 4 van de 7 en 4 van de 13 genomen monsters. De jaargemiddelde $^{3}$H-activiteitsconcentraties in de Schelde en de Maas

(respectievelijk 11,9 en 14,0 Bq·L$^{-1}$) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De $^{226}$Ra-activiteitsconcentratie in de Schelde overschrijdt de streefwaarde (5 mBq·L$^{-1}$) in 7 van de 7 genomen monsters. De jaargemiddelde $^{226}$Ra-activiteitsconcentratie in de Schelde (12,4 mBq·L$^{-1}$) is boven de streefwaarde, maar valt binnen het bereik van voorgaande jaren.

De $^{60}$Co-activiteitsconcentratie in zwevend stof in de Maas overschrijdt de streefwaarde (10 Bq·kg$^{-1}$) in 6 van de 45 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 10 van de 45 genomen monsters. De jaargemiddelde $^{131}$I-activiteitsconcentratie in de Maas is echter beneden de streefwaarde. De jaargemiddelde $^{131}$I-activiteitsconcentratie in het Noordzeekanaal (29 Bq·kg$^{-1}$) is hoger dan in voorgaande jaren en overschrijdt de streefwaarde.

De $^{137}$Cs-activiteitsconcentraties (van zowel de individuele monsters als het jaargemiddelde) in zwevend stof in oppervlaktewater zijn beneden de streefwaarde (40 Bq·kg$^{-1}$).

De $^{210}$Pb-activiteitsconcentratie in zwevend stof in de Nieuwe Waterweg, de Rijn en de Maas overschrijdt de streefwaarde (100 Bq·kg$^{-1}$) in respectievelijk 4 van de 7, 6 van de 6 en 5 van de 6 genomen monsters. De jaargemiddelde $^{210}$Pb-activiteitsconcentraties in de Nieuwe Waterweg, de Rijn en de Maas (respectievelijk 112, 120 en 153 Bq·kg$^{-1}$) zijn boven de streefwaarde, maar vallen binnen het bereik van voorgaande jaren.

De jaargemiddelde totaal α- en rest β-activiteitsconcentraties in zeewater zijn voor sommige gebieden hoger dan in voorgaande jaren.

De jaargemiddelde $^{3}$H-, $^{90}$Sr- en $^{137}$Cs-activiteitsconcentraties in zeewater vallen binnen het bereik van voorgaande jaren.
Sinds 2009 wordt in zeewater $^{210}$Pb in plaats van $^{210}$Po gerapporteerd. De jaargemiddelde $^{210}$Pb-activiteitsconcentraties 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. De totaal α-activiteitsconcentratie gemiddeld per productiestation overschrijdt de grenswaarde van 0,1 Bq·L$^{-1}$ bij geen van de 187 productiestations.

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

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

Nederland voldeed in 2009 aan alle Europese aanbevelingen, inclusief de bepaling van $^{90}$Sr in voedsel uitgevoerd door RIKILT – Instituut voor Voedselveiligheid.

*Table S1: Summary of the results of the Dutch monitoring program in 2009.*
*Tabel S1: Overzicht van de resultaten van het Nederlandse monitoringsprogramma in 2009.*

| Matrix | Parameter | Locations | Values | Frequency (per year) |
|---|---|---|---|---|
| Air dust [1] | Gross α | 1 | 0.029 mBq·m$^{-3}$ | 52 |
| | Gross β | 1 | 0.421 mBq·m$^{-3}$ | 52 |
| | $^{7}$Be | 1 | 4.060 mBq·m$^{-3}$ | 52 |
| | $^{137}$Cs | 1 | 0.00074 mBq·m$^{-3}$ | 52 |
| | $^{210}$Pb | 1 | 0.363 mBq·m$^{-3}$ | 52 |
| Deposition [2] | Gross α | 1 | 36.9 Bq·m$^{-2}$ | 12 |
| | Gross β | 1 | 95 Bq·m$^{-2}$ | 12 |
| | $^{3}$H | 1 | 0 - 1330 Bq·m$^{-2}$ [3] | 12 |
| | $^{7}$Be | 1 | 1410 Bq·m$^{-2}$ | 52 |
| | $^{137}$Cs | 1 | 0 - 4.3 Bq·m$^{-2}$ [3] | 52 |
| | $^{210}$Pb | 1 | 82 - 125 Bq·m$^{-2}$ [3] | 52 |
| | $^{210}$Po | 1 | 32.5 Bq·m$^{-2}$ | 12 |
| Surface water [1] | Gross α | 6 | 36 - 380 mBq·L$^{-1}$ | 6 or 13 [4] |
| | Residual β | 6 | 27 - 120 mBq·L$^{-1}$ | 6 or 13 [4] |
| | $^{3}$H | 6 | 3200 - 14000 mBq·L$^{-1}$ | 6, 7 or 13 [4] |
| | $^{90}$Sr | 3 | 1.8 - 3 mBq·L$^{-1}$ | 6 or 7 [4] |
| | $^{226}$Ra | 4 | 2.7 - 12.4 mBq·L$^{-1}$ | 6 or 7 [4] |
| Suspended solids in surface water [1] | $^{60}$Co | 6 | < 1 - 6.6 Bq·kg$^{-1}$ | 6, 12, 13 or 45 [4] |
| | $^{131}$I | 6 | < 1 - 29 Bq·kg$^{-1}$ | 6, 12, 13 or 45 [4] |
| | $^{137}$Cs | 6 | 2.9 - 13.8 Bq·kg$^{-1}$ | 6, 12, 13 or 45 [4] |
| | $^{210}$Pb | 4 | 92 - 153 Bq·kg$^{-1}$ | 6 or 7 [4] |
| Seawater [1] | Gross α | 8 | 500 - 880 mBq·L$^{-1}$ | 4, 5, 12 or 13 [4] |
| | Residual β | 8 | 64 - 150 mBq·L$^{-1}$ | 4, 5, 12 or 13 [4] |
| | $^{3}$H | 8 | 390 - 4430 mBq·L$^{-1}$ | 4, 5, 11 or 13 [4] |
| | $^{90}$Sr | 4 | 2.2 - 2.5 mBq·L$^{-1}$ | 4, 5 or 13 [4] |
| Suspended solids in seawater [1] | $^{137}$Cs | 4 | 5 - 6.5 Bq·kg$^{-1}$ | 3, 4 [4] |
| | $^{210}$Pb | 4 | 64 - 89 Bq·kg$^{-1}$ | 3, 4 [4] |
| Drinking water [1] | Gross α | 187 | < 0.1 Bq·L$^{-1}$ | 350 [5] |
| | Gross β | 195 | < 0.3 Bq·L$^{-1}$ | 436 [5] |
| | Residual β | 174 | < 0.3 Bq·L$^{-1}$ | 392 [5] |
| | $^{3}$H | 191 | < 4.0 Bq·L$^{-1}$ | 407 [5] |
| Milk [1] | $^{40}$K | 26 | 51.7 Bq·L$^{-1}$ | 827[5] |
| | $^{60}$Co | 26 | < 1.4 Bq·L$^{-1}$ | 827 [5] |
| | $^{90}$Sr | 26 | < 5 Bq·L$^{-1}$ | 47 [5] |
| | $^{131}$I | 26 | < 0.6 Bq·L$^{-1}$ | 827 [5] |
| | $^{134}$Cs | 26 | < 0.6 Bq·L$^{-1}$ | 827 [5] |
| | $^{137}$Cs | 26 | < 0.5 Bq·L$^{-1}$ | 827 [5] |

*Table S1: Continued.*
*Tabel S1: Vervolg.*

| Matrix | Parameter | Locations | Values | Frequency (per year) |
|---|---|---|---|---|
| Food [6, 7, 8] | | | | |
| Grain and grain products | $^{137}$Cs | - | < 6.0 Bq·kg$^{-1}$ | 75 (1) [9] |
| Vegetables | $^{137}$Cs | - | < 6.0 Bq·kg$^{-1}$ | 125 (1) [9] |
| Fruit and fruit products | $^{137}$Cs | - | < 6.0 Bq·kg$^{-1}$ | 44 (0) [9] |
| Milk and dairy products | $^{137}$Cs | - | < 6.0 Bq·kg$^{-1}$ | 57 (0) [9] |
| Meat and meat products | $^{137}$Cs | - | < 6.0 Bq·kg$^{-1}$ | 84 (2) [9] |
| Game and poultry | $^{137}$Cs | - | < 6.0 Bq·kg$^{-1}$ | 39 (0) [9] |
| Salads | $^{137}$Cs | - | < 6.0 Bq·kg$^{-1}$ | 28 (0) [9] |
| Oil and butter | $^{137}$Cs | - | < 6.0 Bq·kg$^{-1}$ | 39 (1) [9] |
| Honey | $^{137}$Cs | - | 11.6 - 347 Bq·kg$^{-1}$ | 101 (15) [9] |
| Food [6, 7, 10] | | | | |
| Vegetables | $^{137}$Cs | - | < 0.5 Bq·kg$^{-1}$ | 54 (0) [9] |
| Meat and meat products | $^{137}$Cs | - | < 0.5 Bq·kg$^{-1}$ | 492 (0) [9] |
| Game and poultry | $^{137}$Cs | - | 3.0 - 266 Bq·kg$^{-1}$ | 200 (30) [9] |
| Eggs | $^{137}$Cs | - | < 0.5 Bq·kg$^{-1}$ | 118 (0) [9] |
| Fish and seafood products | $^{137}$Cs | - | < 0.5 Bq·kg$^{-1}$ | 63 (0) [9] |
| Mixed diet | $^{90}$Sr | - | < 10.0 Bq·kg$^{-1}$ | 12 (0) [9] |

*[1] = Yearly average is shown.*

*[2] = Yearly total is shown.*

*[3] = A 68% confidence range is shown.*

*[4] = Frequency depends on location.*

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

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

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

*[8] = As measured by Food and Consumer Product Safety Authority.*

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

*[10] = As measured by RIKILT – Institute of Food Safety.*

*Table S2: Summary of the results of the monitoring program in the vicinity of the nuclear power plant at Borssele in 2009.*
*Tabel S2: Overzicht van de resultaten van het monitoringsprogramma in de nabijheid van Kerncentrale Borssele in 2009.*

| Matrix | Parameter | Locations | Values [1] | Frequency (per year) |
|---|---|---|---|---|
| Air dust | Gross α | 5 | 0.013 - 0.30 mBq·m$^{-3}$ | 12 |
| | Gross β | 5 | 0.10 - 0.56 mBq·m$^{-3}$ | 12 |
| | $^{60}$Co | 5 [2] | < 0.04 - < 0.10 mBq·m$^{-3}$ | 12 |
| | $^{131}I_{el}$ [3] | 5 [2] | < 0.1 - < 0.2 mBq·m$^{-3}$ | 12 |
| | $^{131}I_{or}$ [3] | 5 [2] | < 0.2 - < 0.4 mBq·m$^{-3}$ | 12 |
| | $^{137}$Cs | 5 [2] | < 0.04 - < 0.06 mBq·m$^{-3}$ | 12 |
| | Nat. [4] | 5 [2] | < 0.9 - 2.6 mBq·m$^{-3}$ | 12 |
| Grass | $^{60}$Co | 5 [2] | < 1 - < 6 Bq·kg$^{-1}$ | 12 |
| | $^{131}$I | 5 [2] | < 1 - < 6 Bq·kg$^{-1}$ | 12 |
| | $^{137}$Cs | 5 [2] | 0.3 - < 4 Bq·kg$^{-1}$ | 12 |
| Soil | $^{54}$Mn | 4 | < 0.2 - < 0.4 Bq·kg$^{-1}$ | 1 |
| | $^{60}$Co | 4 | < 0.3 - < 0.4 Bq·kg$^{-1}$ | 1 |
| | $^{134}$Cs | 4 | < 0.3 - < 0.4 Bq·kg$^{-1}$ | 1 |
| | $^{137}$Cs | 4 | 1.18 - 1.88 Bq·kg$^{-1}$ | 1 |
| Water | Residual β | 4 | 0.031 - 0.178 Bq·L$^{-1}$ | 12 |
| | $^{3}$H | 4 | 7.2 - 10.4 Bq·L$^{-1}$ | 12 |
| Suspended solids | Gross β | 4 | 0.20 - 1.33 kBq·kg$^{-1}$ | 12 |
| Seaweed | $^{60}$Co | 4 [2] | < 2 - < 6 Bq·kg$^{-1}$ | 12 |
| | $^{131}$I | 4 [2] | < 0.8 - < 5 Bq·kg$^{-1}$ | 12 |
| | $^{137}$Cs | 4 [2] | 1.2 - < 4 Bq·kg$^{-1}$ | 12 |
| Sediment | $^{60}$Co | 4 [2] | < 0.3 - < 0.4 Bq·kg$^{-1}$ | 12 |
| | $^{131}$I | 4 [2] | < 0.2 - < 0.5 Bq·kg$^{-1}$ | 12 |
| | $^{137}$Cs | 4 [2] | < 0.3 - 1.33 Bq·kg$^{-1}$ | 12 |

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

# 1 Introduction

Levels of radioactive nuclides of natural origin, such as $^{40}K$ and daughters from the uranium and thorium series may be enhanced as a result of human activities, e.g. emissions from factories processing ores. Man-made radionuclides are found in the environment due to, for example, nuclear weapons tests or discharges from nuclear installations. Monitoring radiation in the environment provides knowledge of levels of radiation under normal circumstances and enables the confirmation of abnormal levels. In this report results are presented of radioactivity measurements in the environment in the Netherlands. The aim of this report is threefold. Firstly, it presents a survey of measurements on radioactivity in the Dutch environment under normal circumstances in 2009. Secondly, it is aimed at determining compliance of monitoring programs in the Netherlands with the EU recommendation and at reporting omissions. Thirdly, it is the Dutch national report on radioactivity in the environment to the EU and to other Member States.

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

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

# 2 Airborne particles

The monitoring program for determining radioactive nuclides in air dust is given in Table 2.1. The sampling was done on the RIVM premises in Bilthoven. Air dust samples for the measurement of gross α-, gross β- and γ-emitters were collected weekly with a High Volume Sampler (HVS).
A detailed description of sampling, sample treatment and the analytical method is given in previous reports [2, 3, 4]. The data from 1991 to 2004 were reanalysed to determine the yearly averages by the method described in Appendix B [5]. This can lead to small differences between data presented in this report and data reported prior to 2005.

*Table 2.1: Monitoring program for the determination of radioactive nuclides in air dust.*

| Matrix | Location | Parameter | Sample period | Sample volume | Analysis frequency |
|---|---|---|---|---|---|
| Air dust | Bilthoven | gross α, gross β | week | 500 $m^3$ (1) | weekly |
| | Bilthoven | γ-emitters (2) | week | 50000 $m^3$ | weekly |

(1) *A sub sample of 1% from the filter through which about 50000 $m^3$ is sampled.*
(2) *γ-spectroscopic analysis of specific γ-emitting nuclides.*

## 2.1 Long-lived α- and β-activity

The weekly results of gross α- and β-activity concentrations in air dust are given in Figure 2.1 and Table A1 (see Appendix A). Due to large uncertainties caused by variations in dust thickness on the filters, gross α-activity concentrations in air dust should be regarded as indicative values [6]. The period between sampling and analysis is five to ten days, which is long compared to the decay time of the short-lived decay products of $^{222}Rn$ and $^{220}Rn$. This is to ensure that these naturally occurring decay-products do not contribute to the measured α- and β-activity concentrations. The frequency distributions of gross α-activity and gross β-activity concentrations in air dust are given in Figures 2.2 and 2.3, respectively.

The yearly averages of the gross α- and β-activity concentrations of long-lived nuclides in 2009 are within the range of the results from the period 1992-2008 as is illustrated in Figure 2.4. Since 2007 a new (more realistic) calibration for gross α has been implemented. This new calibration is 1.4 times higher than the one for previous years, which results in lower reported gross α-activities.

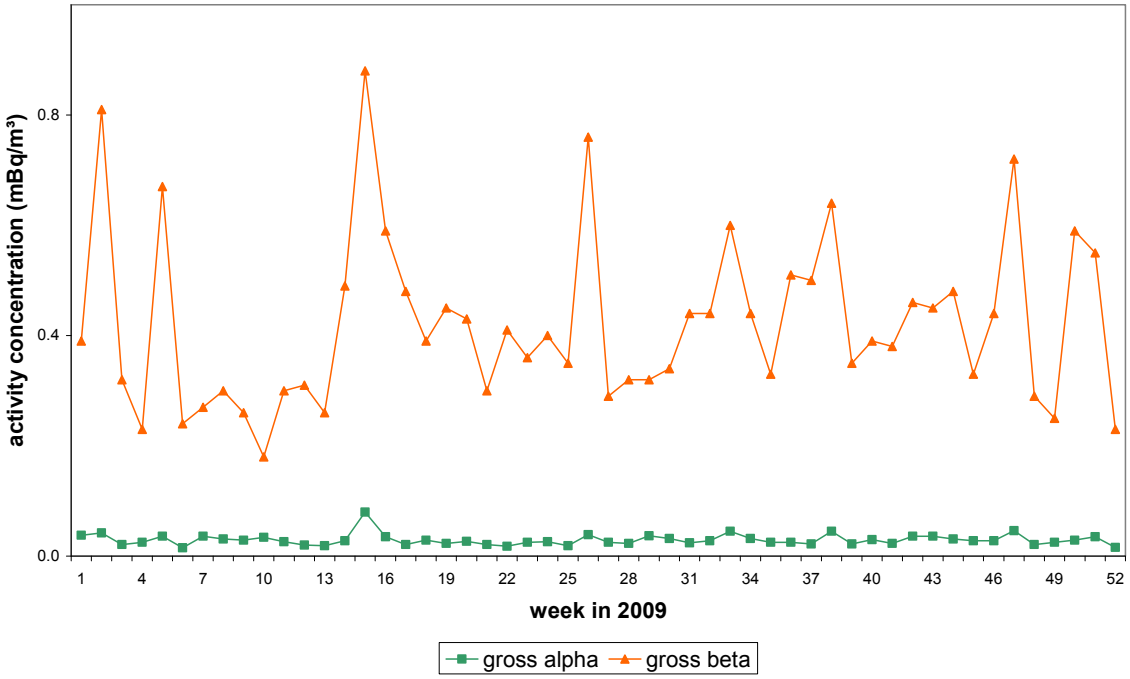



*Figure 2.1: Weekly averaged gross α- and β-activity concentrations of long-lived nuclides in air dust sampled at RIVM.*

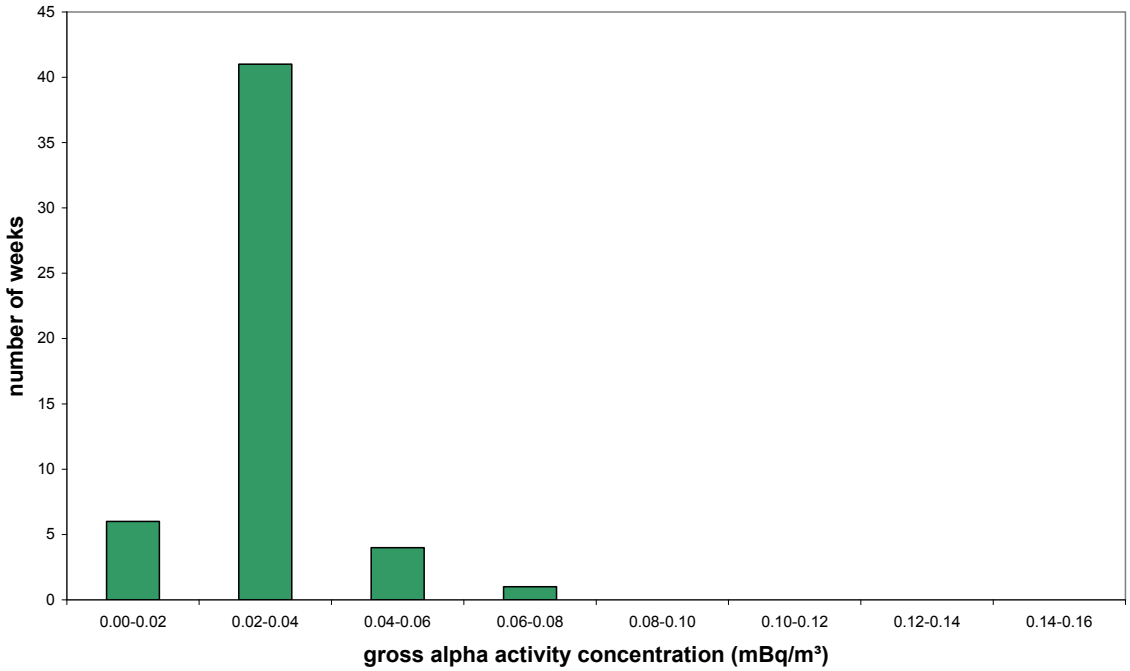



*Figure 2.2: Frequency distribution of gross α-activity concentration of long-lived nuclides in air dust collected weekly in 2009. The yearly average is 0.029 (SD=0.010) mBq·m$^{-3}$. SD is the standard deviation and illustrates the variation in weekly averages during the year.*

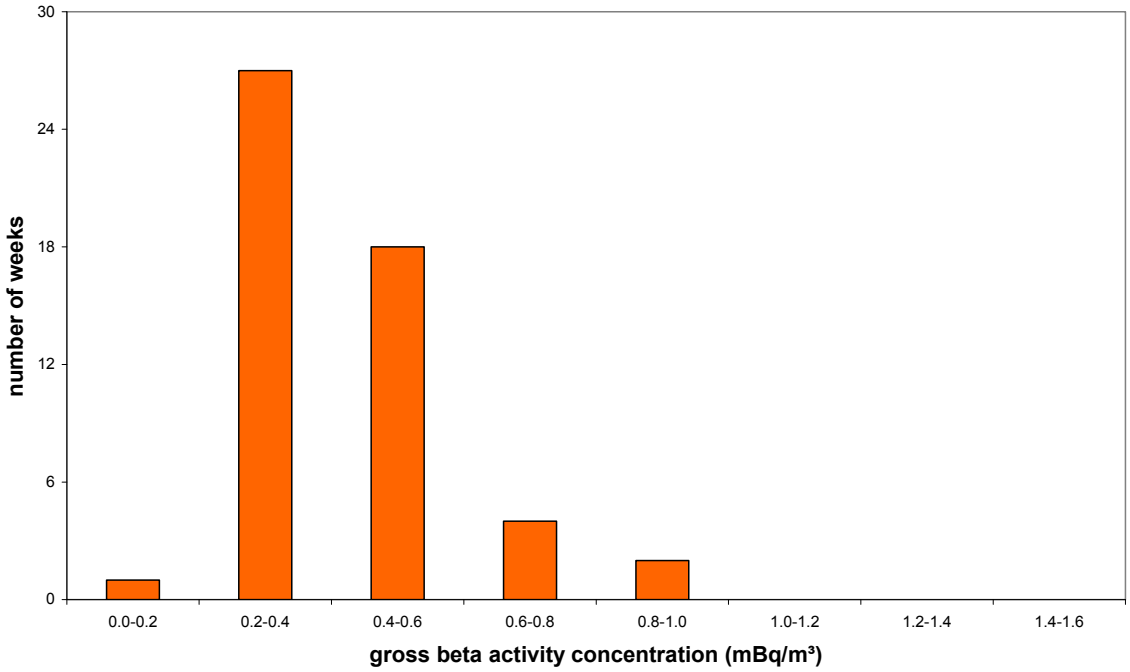



*Figure 2.3: Frequency distribution of gross β-activity concentration of long-lived nuclides in air dust collected weekly in 2009. The yearly average is 0.421 ± 0.007 (SD=0.15) mBq·m$^{-3}$.*

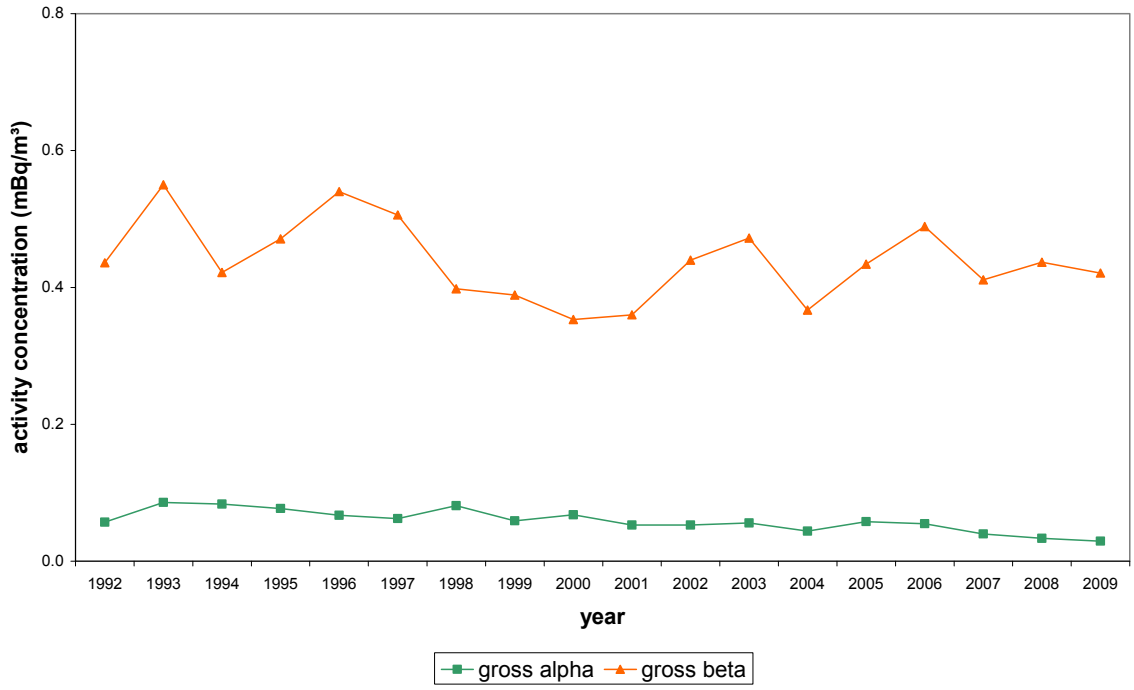



*Figure 2.4: Yearly averaged gross α- and gross β-activity concentrations of long-lived nuclides in air dust at RIVM in 1992-2009.*

## 2.2 γ-emitting nuclides

The only nuclides that could be detected were $^{7}$Be (52 times), $^{210}$Pb (52 times) and $^{137}$Cs (2 times). The results are presented in Table A3, 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 half 2009, the detection limit of $^{137}$Cs is higher than during 1991-1999, due to a different detector set-up. Since July 2009, a new detector set up is used, which results in lower detection limits.

The behaviour of $^{7}$Be in the atmosphere has been studied world-wide [7, 8, 9, 10, 11, 12, 13]. Natural $^{7}$Be (half-life 53.3 days) is formed by spallation reactions of cosmogenic radiation with atmospheric nuclei, such as carbon, nitrogen and oxygen resulting in the formation of BeO or $Be(OH)_2$ molecules. Approximately 70% of $^{7}$Be is produced in the stratosphere, with the remaining 30% being produced in the troposphere. A residence time is estimated at about 1 year in the stratosphere and about 6 weeks in the troposphere. Most of the $^{7}$Be produced in the stratosphere does not reach the troposphere, except during spring when seasonal thinning of the tropopause takes place at midlatitudes resulting in air exchange between stratosphere and troposphere. In the troposphere, $^{7}$Be rapidly associates mainly with submicron-sized aerosol particles. Gravitational settling and precipitation processes accomplish transfer to the earth's surface. Seasonal variations in the concentration of $^{7}$Be in surface air is influenced by the following main atmospheric processes: wet and dry deposition, mass exchange between stratosphere and troposphere, vertical transport in the troposphere and horizontal transport of air masses from the subtropics and midlatitudes into the tropics and polar regions.

The red line in Figure 2.5 shows the seasonal variation of the $^{7}$Be-activity concentration, with peaks during the spring and summer periods, reflecting the seasonal variations in the transport rate of air from stratosphere to troposphere. Figure 2.5 further shows the influence of the solar cycle. The maximum at 1997 and the minimum at 2000-2002 are consistent with the solar minimum (measured by radio flux and sunspot count) of 1996-1997 and the solar maximum of 2000-2002 [14]. In the summer of 1991 two severe geomagnetic storms caused a significant world-wide disturbance of earth's geomagnetic field. This resulted in a considerable decrease in cosmogenic radiation, unprecedented in at least the previous four decades [15]. The absence of a 1991 summer peak in the $^{7}$Be-activity concentration can be explained by the decrease in cosmogenic radiation. The concentrations found for $^{7}$Be in 2009 fit in the pattern described above.

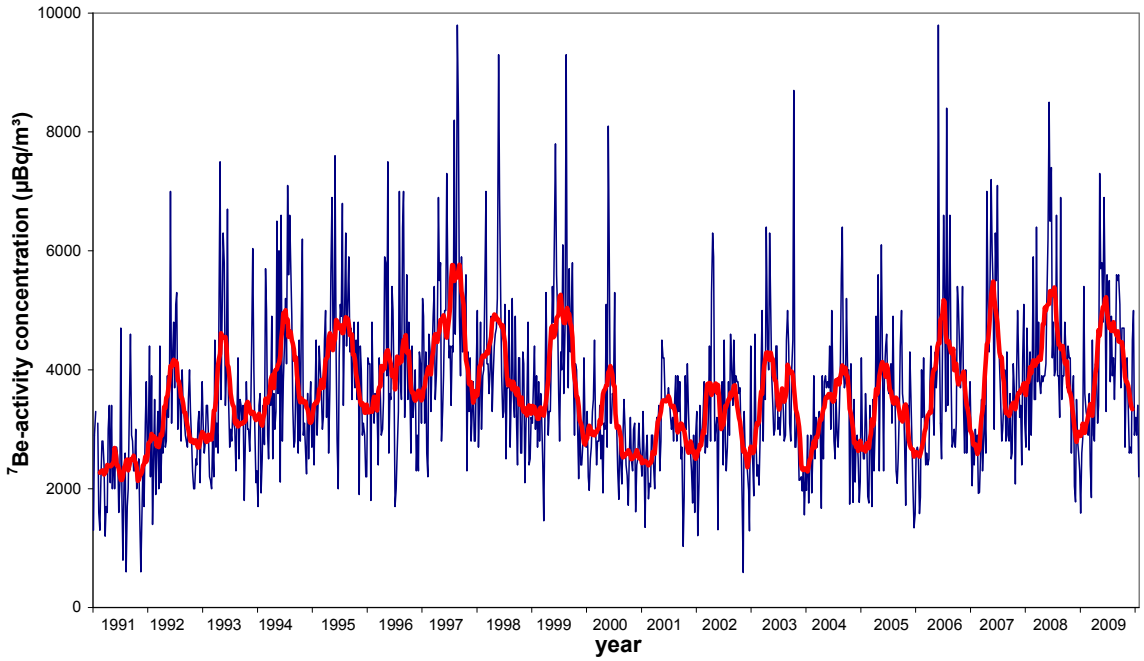



*Figure 2.5: Weekly averaged $^{7}$Be-activity concentrations (blue) in air dust at RIVM in 1991-2009. The red line is a moving average of 13 weeks. The yearly average for 2009 is 4060 ± 50 (SD=1200) µBq·m$^{-3}$.*

The nuclide $^{137}$Cs (half-life 30.2 years) is of anthropogenic origin. The two main sources of $^{137}$Cs in the environment are nuclear weapons tests and the Chernobyl accident. Nowadays resuspension of already deposited activity is the main source of airborne $^{137}$Cs-activity.
Figure 2.6 shows a peak during May 1992. During the same period several wildfires occurred near the Chernobyl area [16]. The level of airborne $^{137}$Cs-activity increased ten times in the 30 km exclusion zone around Chernobyl. It is plausible that the airborne $^{137}$Cs was transported to Western Europe due to the weather conditions in the same period, dry and a strong eastern wind [17]. On the 29$^{th}$ of May 1998 an incident occurred at Algeciras (Spain), an iron foundry melted a $^{137}$Cs-source concealed in scrap metal [18]. As a result elevated levels of airborne $^{137}$Cs-activity were measured in France, Germany, Italy and Switzerland during late May and early June. Figure 2.6 shows a slightly elevated level of $^{137}$Cs-activity (second peak) around the same period (29$^{th}$ of May until 5$^{th}$ of June 1998). Such slightly elevated levels are not uncommon as can be seen in Figure 2.6. These elevations may be related to resuspension of already deposited dust especially during a strong wind from the continent [18].

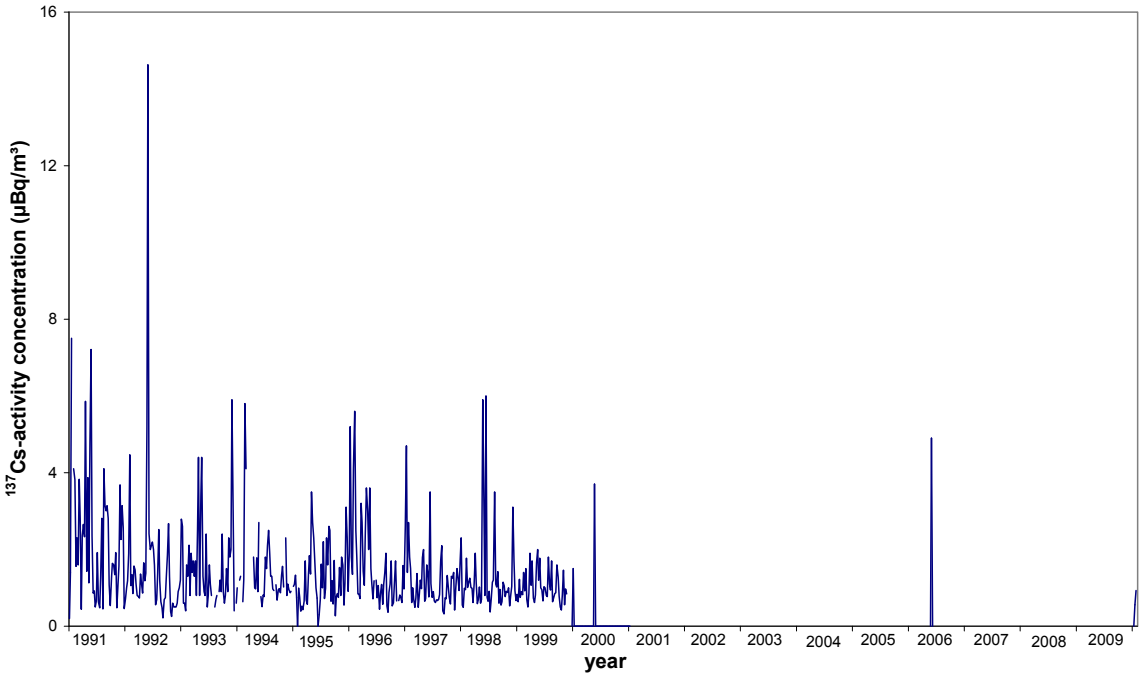



*Figure 2.6: Weekly averaged $^{137}$Cs-activity concentrations in air dust at RIVM in 1991-2009. 50 out of 52 measurements were below the detection limit in 2009. Between 2000 and half 2009 the detection limit was higher than during 1991-1999, due to a different detector set up. Since July 2009, a new detector set up is used, which results in lower detection limits (see Table A2).*

The primary source of atmospheric $^{210}$Pb (half-life 22.3 years) is the decay of $^{222}$Rn exhaled from continental surfaces. Therefore, the atmospheric concentration of $^{210}$Pb over the continental areas is in general higher than that over the oceanic ones ($^{222}$Rn exhalation from the ocean is 1000 times less than that from the continents). The reported reference value of $^{210}$Pb in air dust is 500 µBq·m$^{-3}$ [19]. In the atmosphere this radionuclide is predominantly associated with submicron-sized aerosols [20, 21]. The mean aerosol (carrying $^{210}$Pb) residence time in the troposphere is approximately five days [22].

Other sources of $^{210}$Pb in air dust are volcanic activity and industrial emissions [23, 24, 25, 26, 27]. Examples of industrial emissions are discharges of power plants using fossil fuels, fertiliser and phosphorus industries, and exhaust gases of traffic. In the Netherlands the emission of power plants is only of local importance regarding $^{210}$Pb deposition. The emission by other industries contributes a significant part of the yearly total $^{210}$Pb deposition [25]. Volcanic eruptions bring uranium decay products in the atmosphere like $^{226}$Ra, $^{222}$Rn, $^{210}$Pb and $^{210}$Po. Beks et al. [25] estimate that volcanoes contribute 60 TBq·year$^{-1}$ to the atmospheric $^{210}$Pb stock. If the volcanic deposition is evenly distributed world-wide, the contribution to the yearly total $^{210}$Pb deposition would be negligible.

Unusual $^{210}$Pb values might be explained by natural phenomena such as an explosive volcanic eruption, Saharan dust [28, 29, 30] and resuspension of (local) dust. The unusual value of week 45 in 2002 (3000 ± 300 µBq·m$^{-3}$) can not be explained by these natural sources [31].

Except for week 45 in 2002 there is a good correlation between activity concentrations of $^{210}$Pb and activity concentrations of gross β, as is the case in 2009 (Figure 2.8). The weekly averaged activity concentrations of $^{210}$Pb in 2009 are within range of those found in previous years (Figure 2.7).

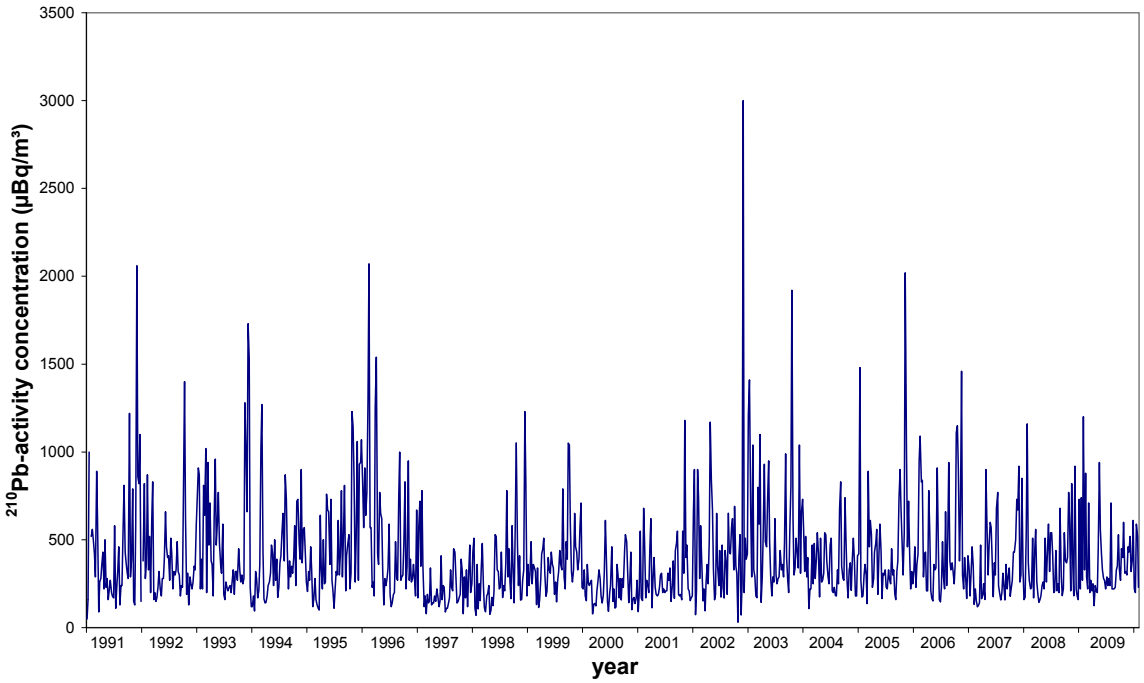



*Figure 2.7: Weekly averaged $^{210}$Pb-activity concentrations in air dust at RIVM in 1991-2009. The yearly average for 2009 is 363 ± 5 (SD=180) µBq·m$^{-3}$.*

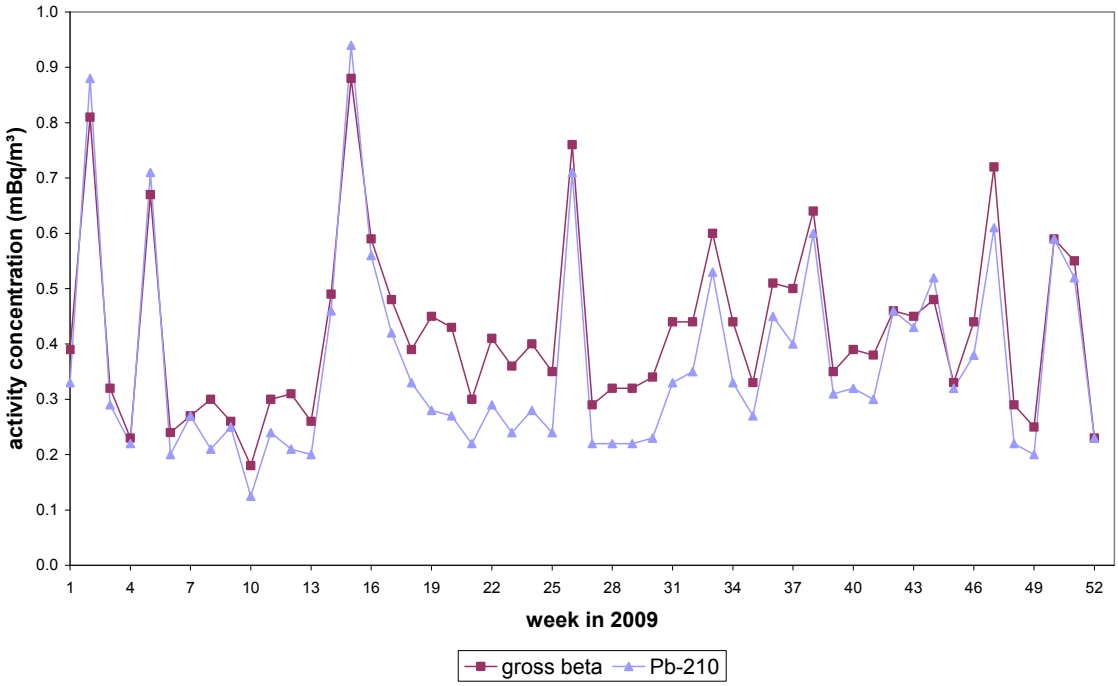



*Figure 2.8: Figure illustrating the correlation between weekly averaged gross β- and $^{210}$Pb-activity concentrations in air dust at RIVM.*

# 3 Deposition

The monitoring program for determining radioactive nuclides in deposition is given in Table 3.1. Sampling was done on the RIVM premises in Bilthoven. Samples were collected weekly for γ-emitters and monthly in case of gross α, gross β, $^{3}H$ and $^{210}Po$. The data from 1993 to 2004 were reanalysed to determine the yearly totals by the method described in Appendix B [5]. This can lead to small differences between data presented in this report and data reported prior to 2005.

*Table 3.1: The monitoring program for the determination of radioactive nuclides in deposition.*

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

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

## 3.1 Long-lived α- and β-activity

The monthly deposited gross α- and gross β-activities of long-lived nuclides are given in Figure 3.1, Figure 3.3 and Table A4. The yearly total deposition of gross α and gross β was 36.9 ± 1.3 and 95 ± 2 $Bq \cdot m^{-2}$, respectively. These values are within range of those from previous years, as illustrated in Figure 3.2, Figure 3.4 and Table A5.

The monthly deposition of $^{3}H$ is given in Table A4. In 2009, the yearly total deposition of $^{3}H$ ranged between 0 and 1300 $Bq \cdot m^{-2}$ (68% confidence level). The yearly total consists of 12 samples. All measurements were below the detection limit. Therefore, detection limits were used for the contribution to the yearly total. The range of 2009 does not differ significantly from those measured since 1993, as illustrated in Figure 3.5 and Table A5. Until 1998, samples were electrolytically enriched before counting, which resulted in a much lower detection limit than that after 1997.

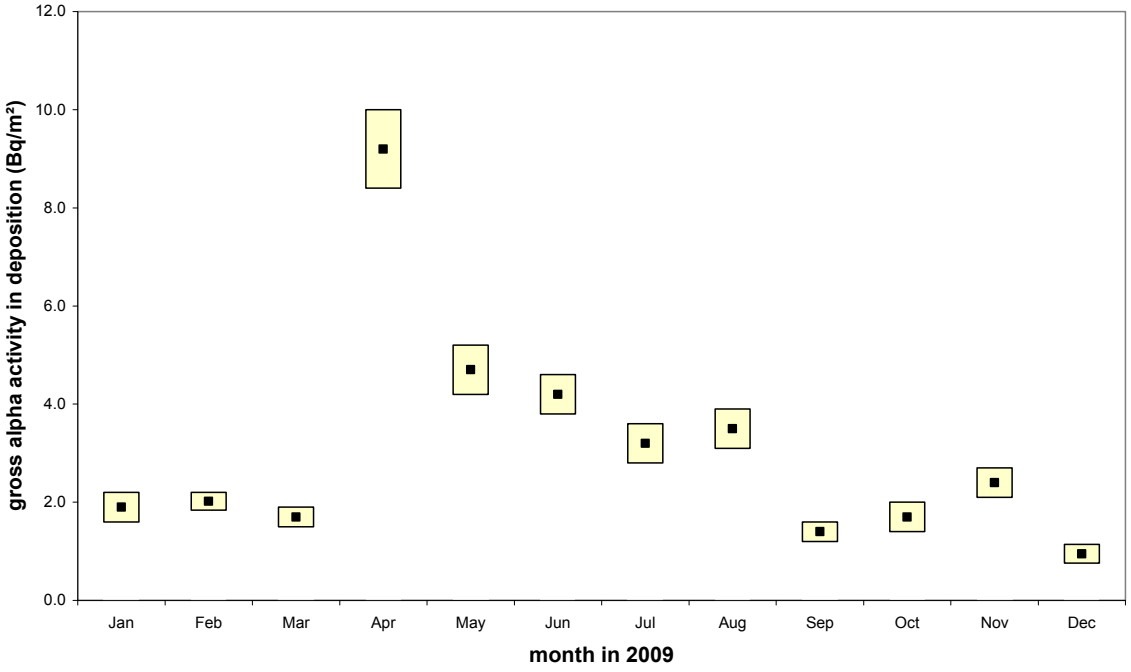



*Figure 3.1: Monthly deposited gross α-activity of long-lived nuclides at RIVM. Given are monthly totals (black dot) with a 68% confidence range (coloured bar).*

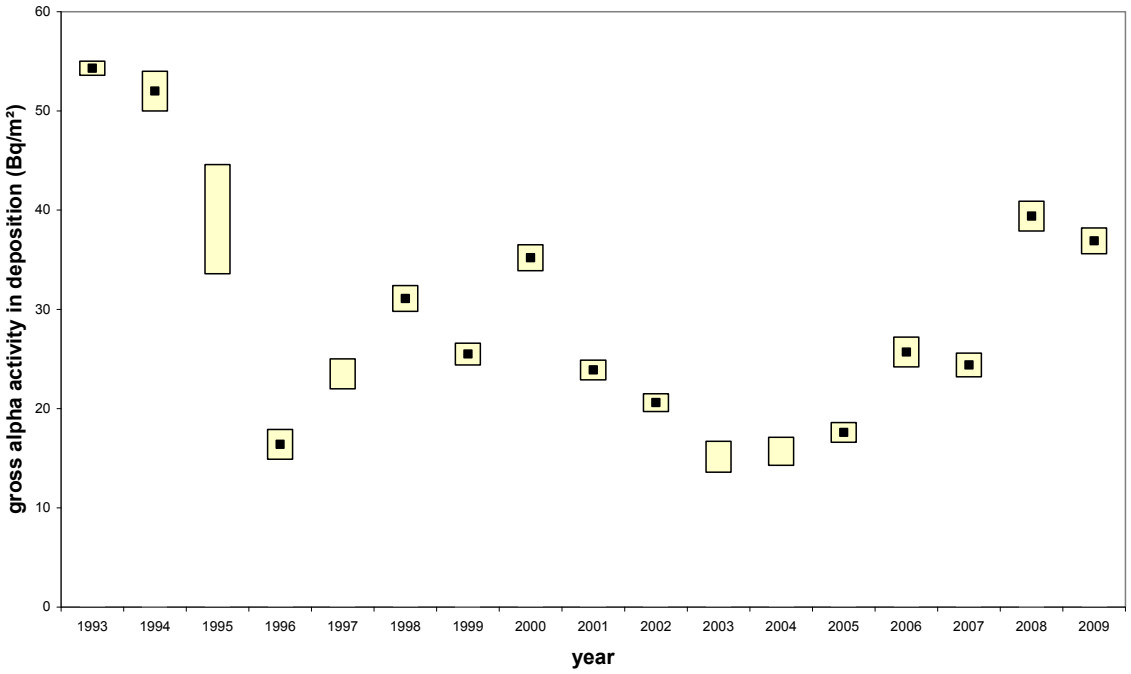



*Figure 3.2: Yearly gross α-activity of long-lived nuclides deposited at RIVM from 1993 to 2009. Given are yearly totals (black dot) with a 68% confidence range (coloured bar). Solely a 68% confidence range is given if the yearly result is made up of at least one detection limit.*

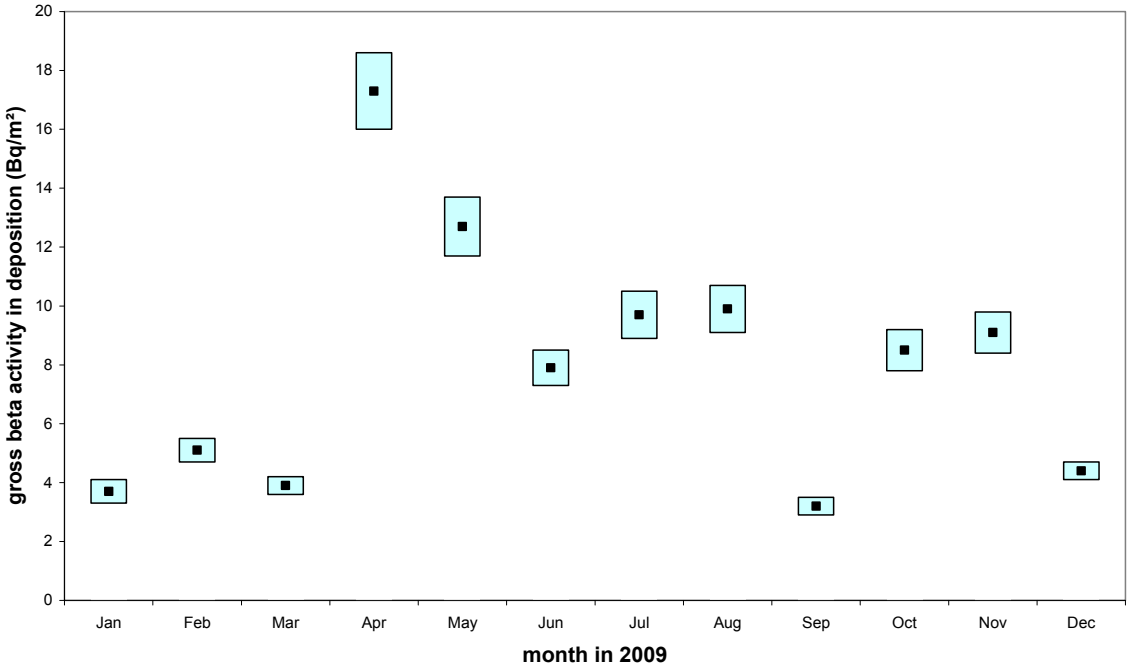



*Figure 3.3: Monthly deposited gross β-activity of long-lived nuclides at RIVM. Given are monthly totals (black dot) with a 68% confidence range (coloured bar).*

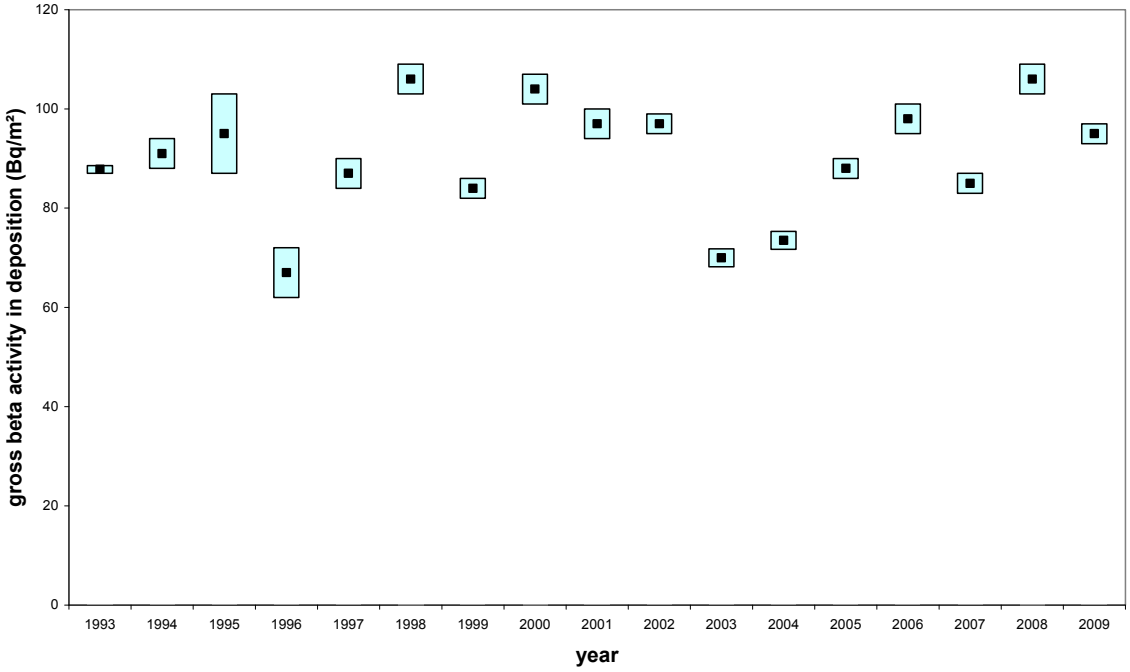



*Figure 3.4: Yearly gross β-activity of long-lived nuclides deposited at RIVM from 1993 to 2009. Given are yearly totals (black dot) with a 68% confidence range (coloured bar).*

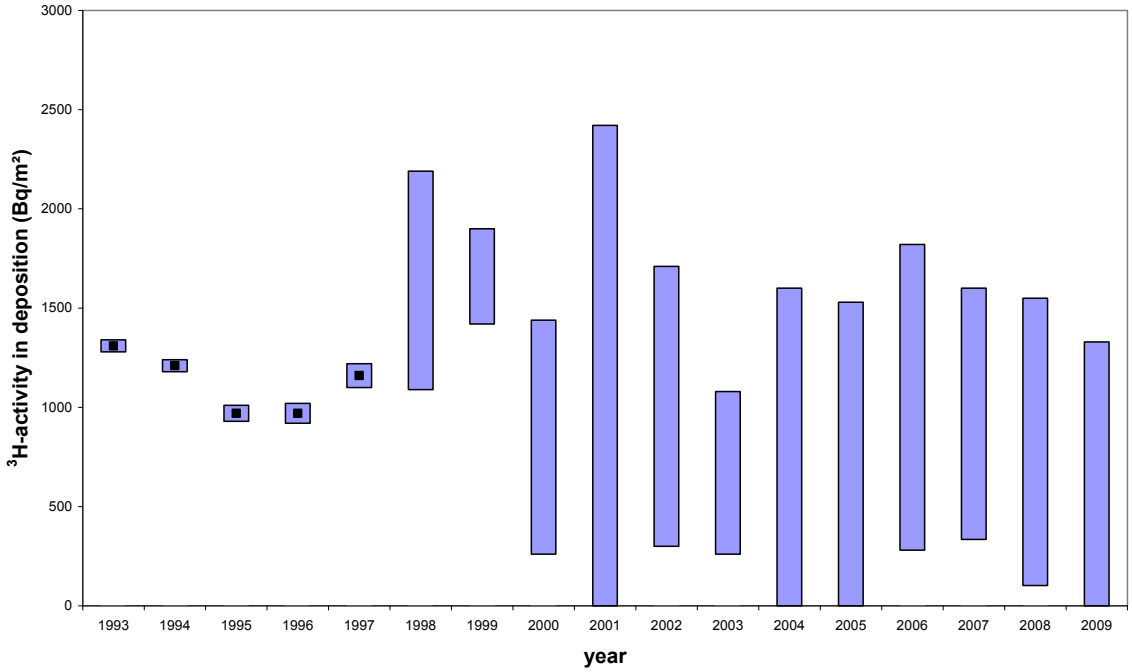



*Figure 3.5: Yearly deposition of $^3$H at RIVM from 1993 to 2009. Given are yearly totals (black dot) with a 68% confidence range (coloured bar). Solely a 68% confidence range is given if the yearly result is made up of at least 1 detection limit.*

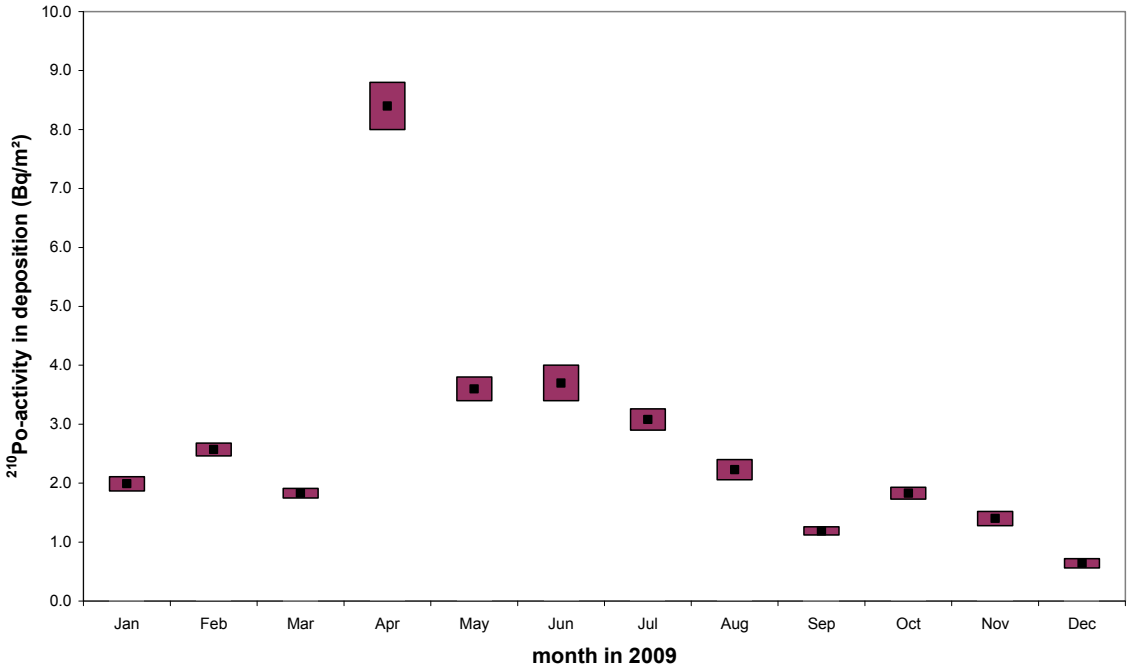



*Figure 3.6: Monthly deposited $^{210}$Po-activity at RIVM. Given are monthly totals (black dot) with a 68% confidence range (coloured bar).*

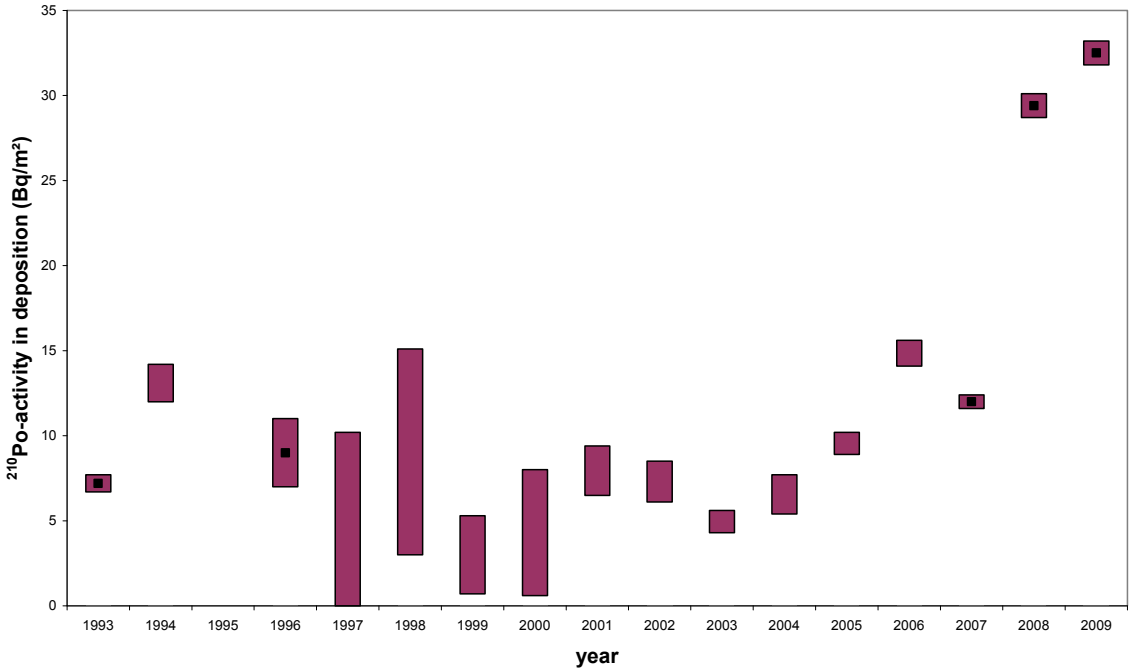



*Figure 3.7: Yearly $^{210}$Po-activity deposited at RIVM from 1993 to 2009. Given are yearly totals (black dot) with a 68% confidence range (coloured bar). Solely a 68% confidence range is given if the yearly result is made up of at least one detection limit.*

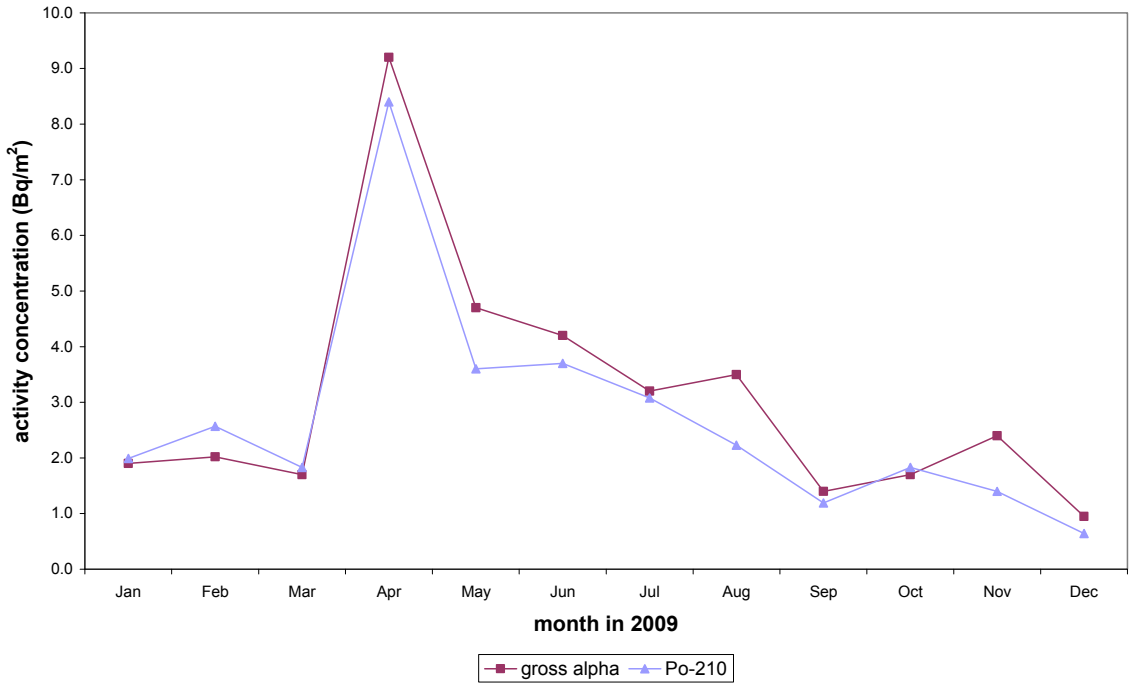



*Figure 3.8: Figure illustrating the correlation between monthly total gross α- and $^{210}$Po-activity in deposition at RIVM.*

The monthly α-spectroscopy results for $^{210}$Po are given in Figure 3.6 and Table A6. The results for previous years are given in Figure 3.7 and Table A7. The yearly total deposition of $^{210}$Po deposited in 2009 was 32.5 ± 0.7 Bq·m$^{-2}$ (68% confidence level). This is the highest yearly total since 1993, and approximately the same level as in 2008. The elevated level of $^{210}$Po in April is in good correlation with the elevated level of gross α as can be seen in Figure 3.8.

## 3.2 γ-emitting nuclides

Detectable quantities of the naturally occurring nuclides $^{7}$Be and $^{210}$Pb were found in 52 and respectively 36 out of 52 samples. Due to a new detector set up the detection limit for $^{210}$Pb is lower in the second half year of 2009; all non detectable results are from the first half of the year. The yearly total deposition of $^{7}$Be is 1410 ± 30 Bq·m$^{-2}$. The yearly total deposition of $^{210}$Pb ranged between 82 and 125 Bq·m$^{-2}$ (68% confidence level). The nuclide $^{137}$Cs was detected in none of 52 samples. The detection limit for $^{137}$Cs during the first half of the year is 0.1 Bq·m$^{-2}$. The detection limit for the second half of the year is 0.02 Bq·m$^{-2}$. The yearly total deposition of $^{137}$Cs ranged between 0 and 4.3 Bq·m$^{-2}$ (68% confidence level). The weekly results for deposition of $^{7}$Be, $^{137}$Cs and $^{210}$Pb are given in Table A8 and Figures 3.9 and 3.12. The results for previous years are given in Table A7, Figure 3.10, 3.11 and 3.13.

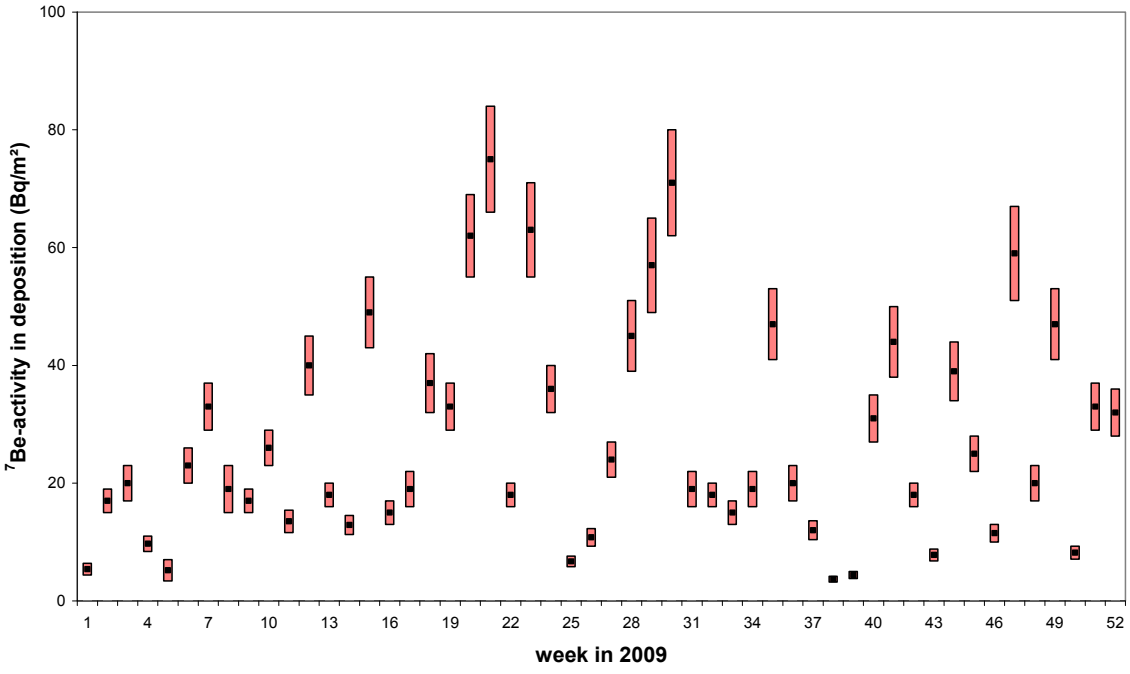



*Figure 3.9: Weekly deposited $^{7}$Be-activity at RIVM. Given are weekly totals (black dot) with a 68% confidence range (coloured bar).*

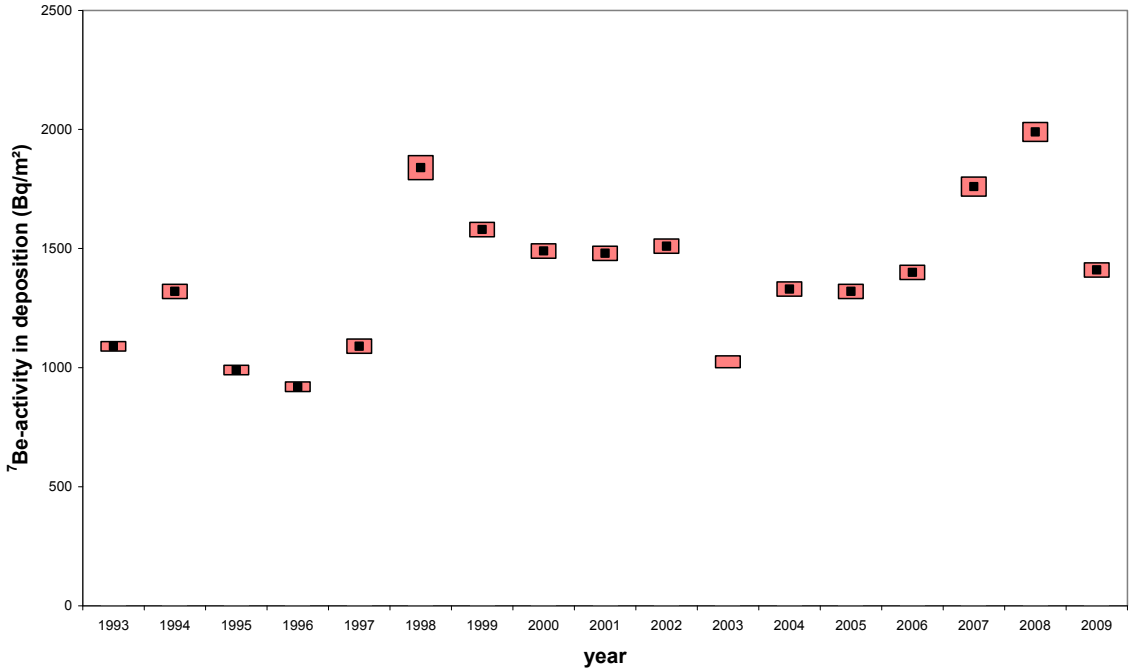



*Figure 3.10: Yearly $^{7}$Be-activity deposited at RIVM from 1993 to 2009. Given are yearly totals (black dot) with a 68% confidence range (coloured bar). Solely a 68% confidence range is given if the yearly result is made up of at least one detection limit.*

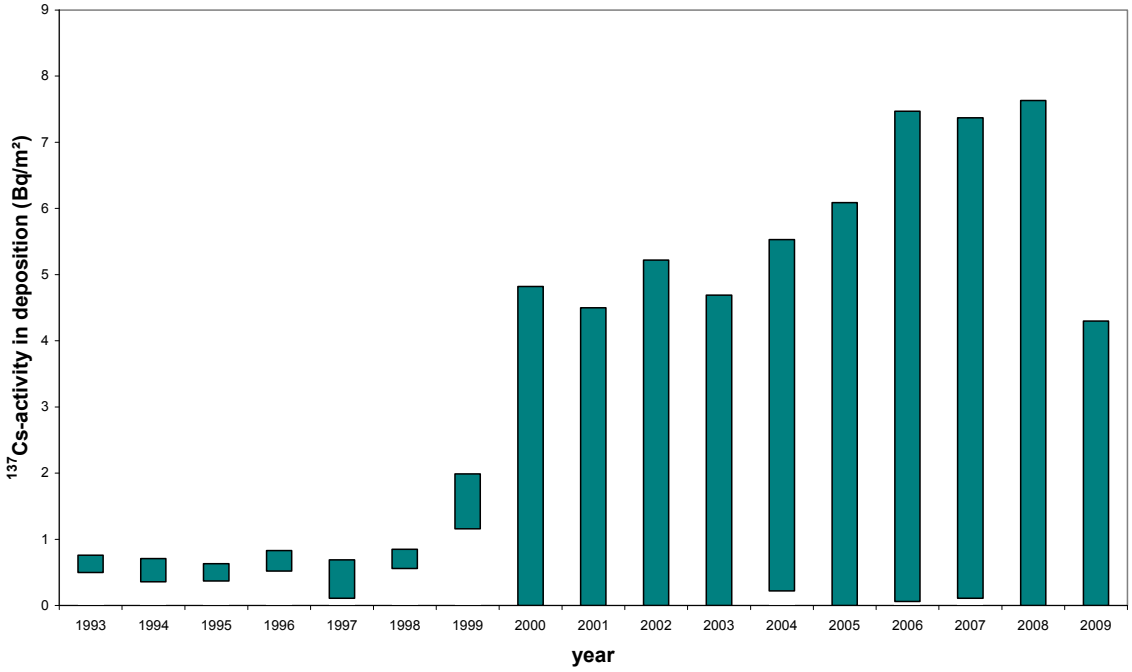



*Figure 3.11: Yearly $^{137}$Cs-activity deposited at RIVM from 1993 to 2009. Given are yearly averages, solely a 68% confidence range is given since the yearly result is made up of at least one detection limit. Since 2000 the detection limit is higher than during 1993-1999, due to a different detector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

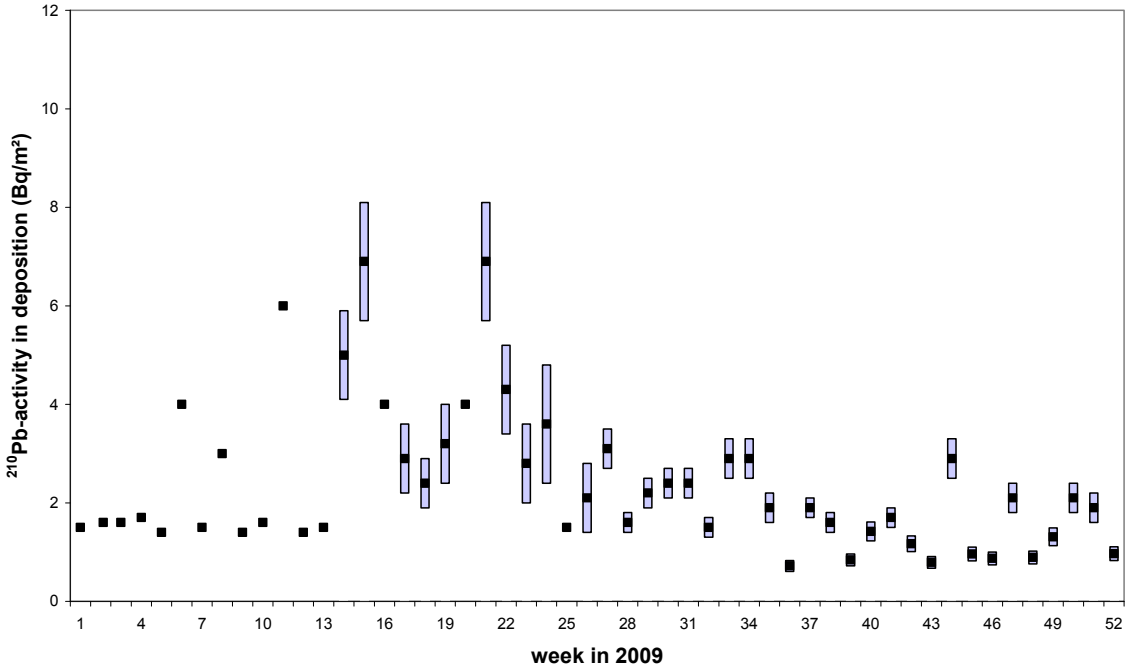



*Figure 3.12: Weekly deposited $^{210}$Pb-activity at RIVM. Given are weekly averages (black dot) with a 68% confidence range (coloured bar). Solely a black dot is given if the result is a detection limit.*

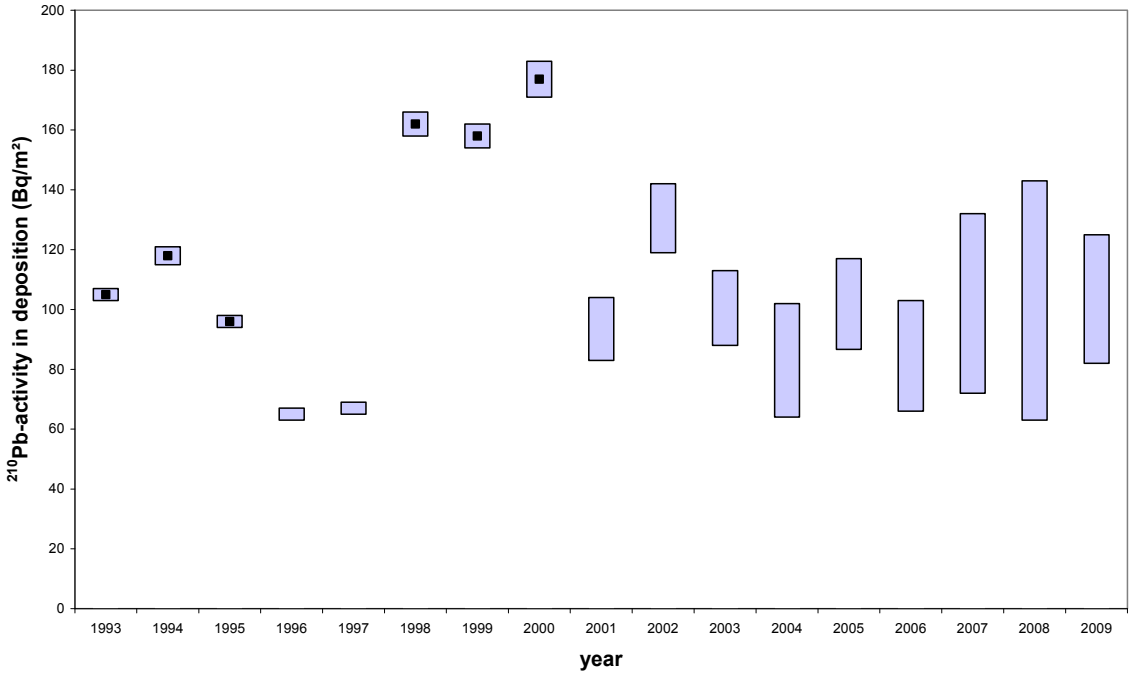



*Figure 3.13: Yearly $^{210}$Pb-activity deposited at RIVM from 1993 to 2009. Given are yearly averages (black dot) with a 68% confidence range (coloured bar). Solely a 68% confidence range is given if the yearly result is made up of at least 1 detection limit.*

# 4 National Radioactivity Monitoring Network

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

The NMR consists of 14 measuring sites at which gross α- and artificial β-activity concentrations are determined as well as the ambient dose equivalent rate [32]. At another 153 measuring sites only the ambient dose equivalent rate is determined. The dose equivalent rate monitors at the previously mentioned 14 sites are differently placed from the 153 dose equivalent rate monitors with regard to height (3.5 meter versus 1 meter above ground level) and surface covering. Therefore, results can differ between the two types of measuring sites [33]. Hence, these 14 dose equivalent rate monitors are not taken into account for calculating the yearly averaged ambient dose equivalent. The reported artificial β-activity concentrations are calculated from the difference between the measured gross β-activity concentration and the natural gross β-activity derived from the measured gross α-activity concentration.

During the second half of 2002 the 14 aerosol FAG FHT59S monitors were gradually replaced by 14 new Berthold BAI 9128 monitors. Due to differences in detection method, filter transport, calibration nuclides and algorithms the results for the activity concentrations are not exactly the same. By running both monitors simultaneously at the same location, the measured gross α-activity concentration was compared. On average the Berthold monitor systematically reports about 20% higher values than the FAG monitor [34]. The estimated random uncertainty for both types of monitor is about 20%. No correction is applied for the difference in the gross α-activity concentration between the Berthold and FAG monitor.

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

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

Figure 4.2 presents the yearly averages of gross α-activity concentration from 1990 to 2009, while Figure 4.4 presents the yearly averages of ambient dose equivalent rate from 1996 to 2009. In 2009 the yearly averaged gross α-activity concentration in air dust was 3.3 $Bq \cdot m^{-3}$ (based on the yearly averages of the 14 measurement locations). To compare this value with data before 2002 it should be noted that the Berthold values are 20% higher than FAG values, and

the value can be corrected to 2.7 $Bq \cdot m^{-3}$. This value is within the range of those in previous years. The yearly average of the artificial β-activity concentration does not deviate significantly from zero.
Between 1996 and 2003 the analysis of the ambient dose equivalent rate has been based on a set of 163 stations. From 2004 onwards, the analysis of the ambient dose equivalent rate has been based on the set of 153 stations, 10 stations have been dismantled. The yearly averaged ambient dose equivalent rate in 2009 is calculated using 146 stations. The remaining 7 stations were not operational.

For the ambient dose equivalent rate the yearly averaged measured value was 74.1 nSv $h^{-1}$ in 2009. Figure 4.5 shows the influence of the 11-year solar cycle on the cosmogenic contribution to the effective dose rate, which is related to the ambient dose equivalent rate. The decrease in the ambient dose equivalent rate (as given by the NMR) during 1996 to 2003 (Figure 4.4) might be related to the decrease in the cosmogenic contribution. However, the correlation between the increase in the cosmogenic contribution since 2004 and the measured ambient dose equivalent rate is less evident (Figure 4.4).

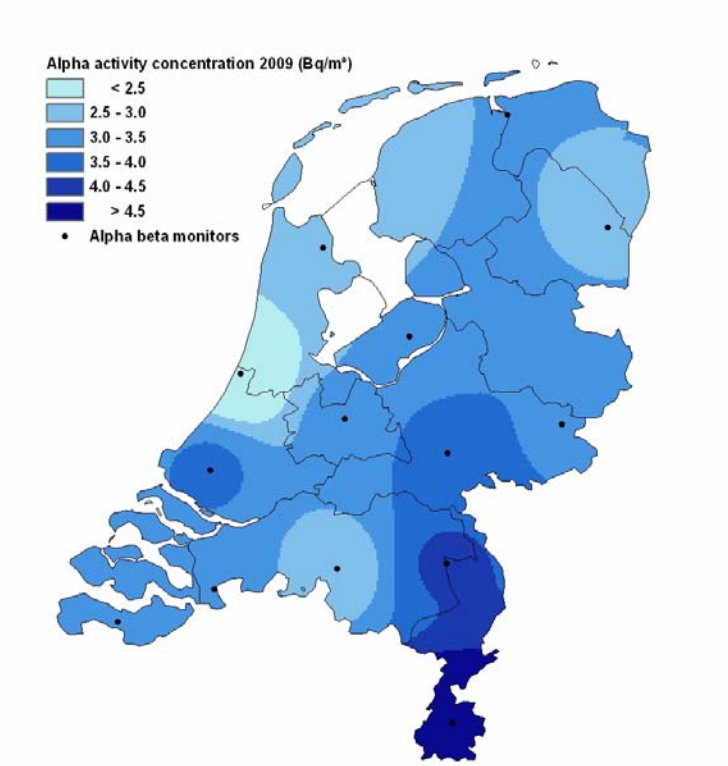



*Figure 4.1: Spatial variation in the average gross α-activity concentration of (mainly) short-lived nuclides in air dust. The dots represent the locations of the aerosol monitors.*

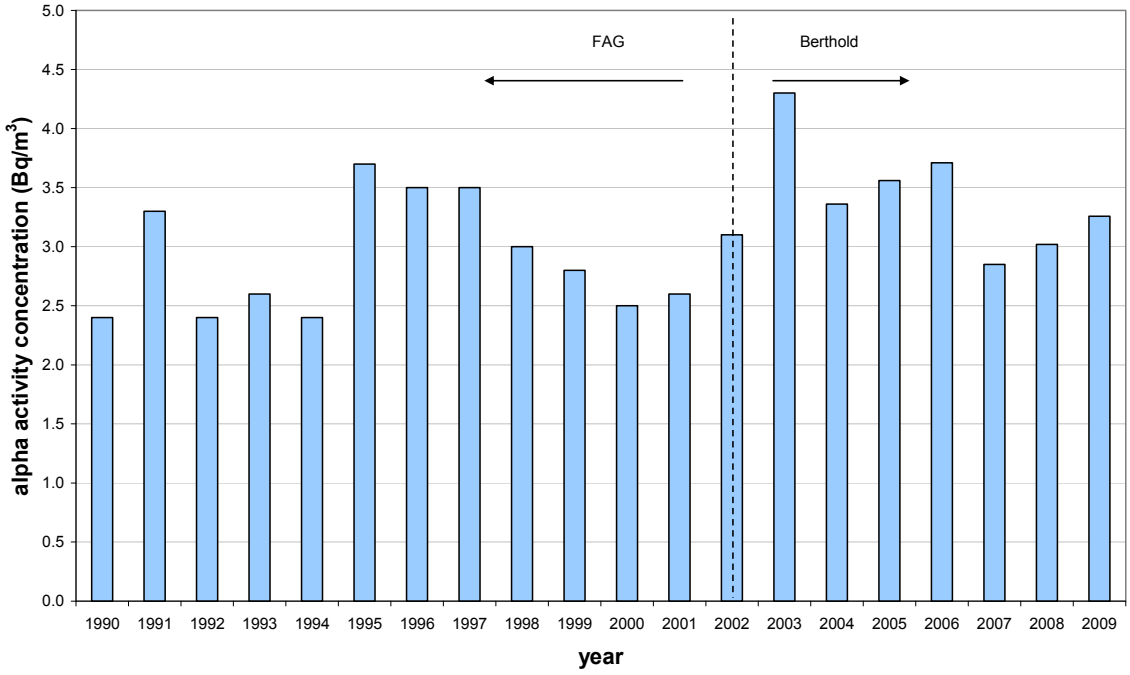



*Figure 4.2: Yearly averaged gross α-activity concentration of (mainly) short-lived nuclides in air dust. During the second half of 2002 the FAG monitors were gradually replaced by the Berthold monitors.*

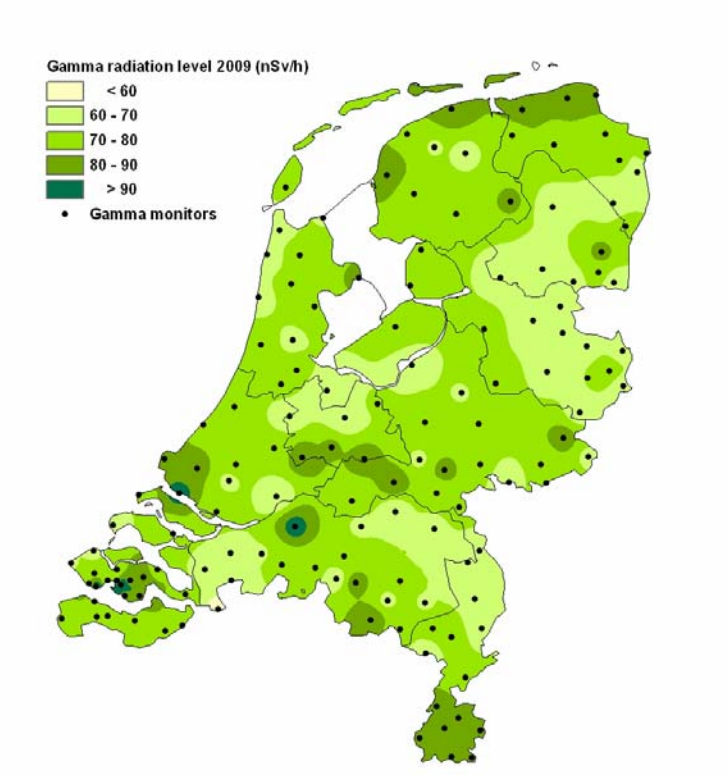



*Figure 4.3: Spatial variation in the average ambient dose equivalent rate. The dots represent the locations of the dose equivalent rate monitors.*

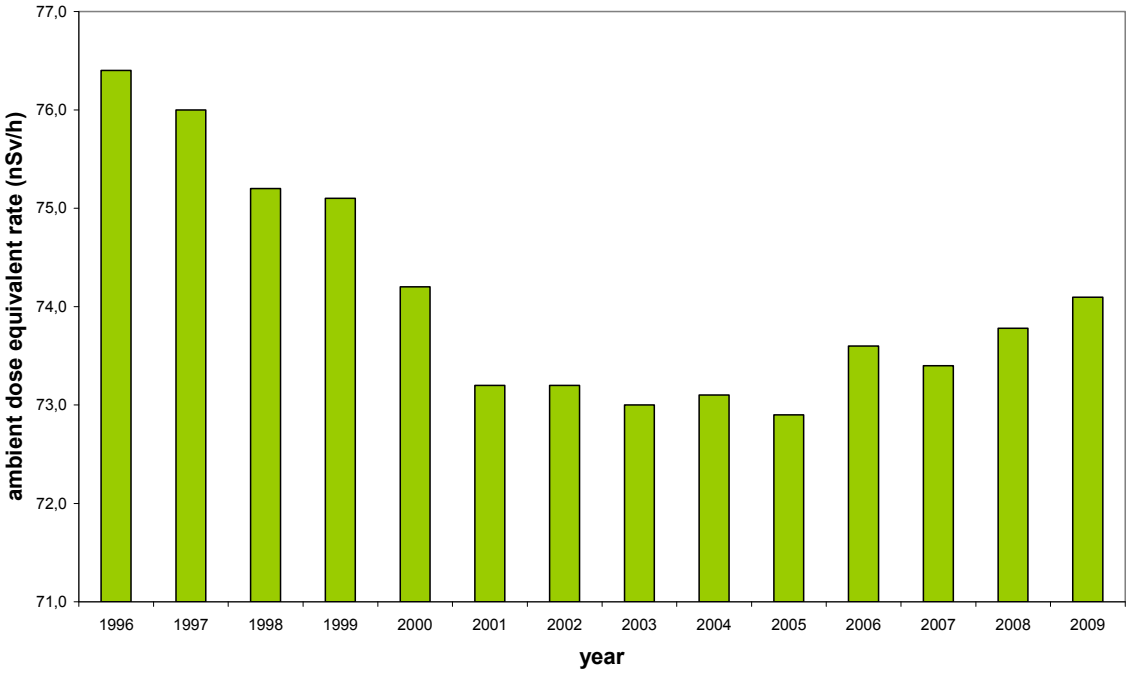



*Figure 4.4: The yearly averaged ambient dose equivalent rate.*

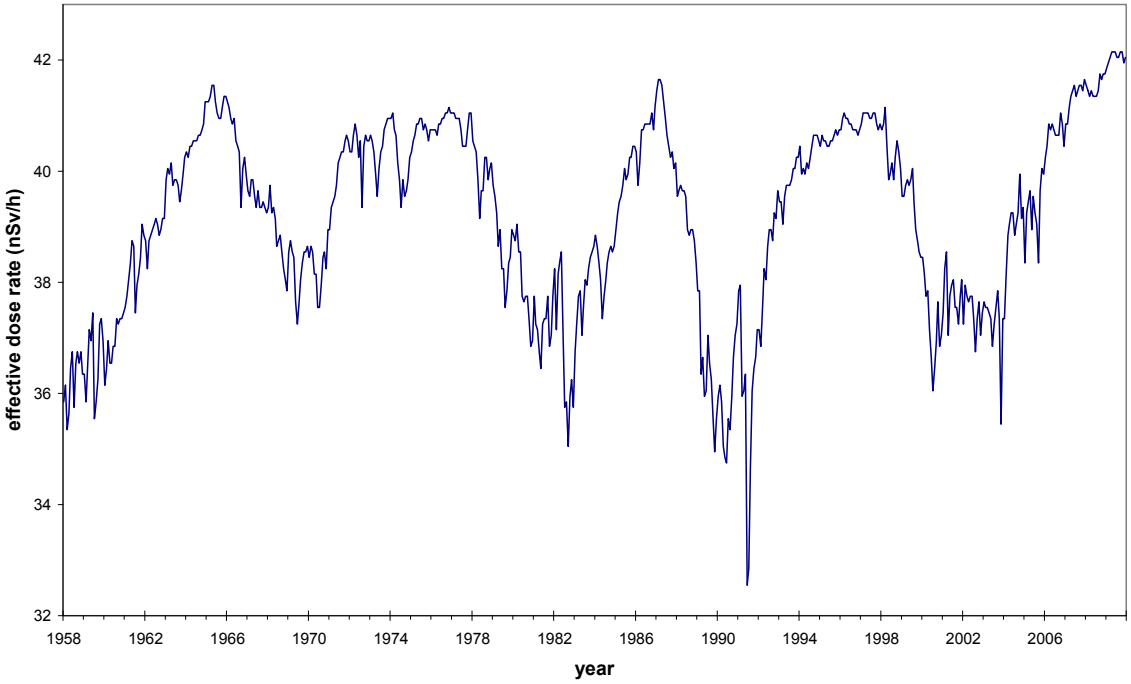



*Figure 4.5: Cosmogenic contribution to the effective dose rate (at sea level), influenced by the solar cycle. Location 51° 26′ north latitude and 3° 43′ eastern longitude (in the south-west of the Netherlands), air pressure 1019 hPa. Figure derived from data supplied by Federal Aviation Administration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

# 5 Surface water and seawater

## 5.1 Introduction

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

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

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

| Location | Parameter | Matrix | Monitoring frequency (per year) |
|---|---|---|---|
| IJsselmeer (Vrouwezand) | Gross α | Water | 13 |
| | Residual β | Water | 13 |
| | $^{3}H$ | Water | 6 |
| | $^{60}Co$ | Suspended solids | 12 (1) |
| | $^{131}I$ | Suspended solids | 12 (1) |
| | $^{137}Cs$ | Suspended solids | 12 (1) |
| Ketelmeer (Ketelmeer West) | $^{60}Co$ | Suspended solids | - (2) |
| | $^{131}I$ | Suspended solids | - (2) |
| | $^{137}Cs$ | Suspended solids | - (2) |
| Noordzeekanaal (IJmuiden) | Gross α | Water | 6 |
| | Residual β | Water | 6 |
| | $^{3}H$ | Water | 6 |
| | $^{60}Co$ | 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 | 13 |
| | $^{131}I$ | Suspended solids | 13 |
| | $^{137}Cs$ | Suspended solids | 13 |
| | $^{210}Pb$ | 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 | 45 (3) |
| | $^{131}I$ | Suspended solids | 45 (3) |
| | $^{137}Cs$ | Suspended solids | 45 (3) |
| | $^{210}Pb$ | Suspended solids | 6 |

*(1) Normally 13 times per year. Sampling in January could not be performed due to floating ice.*

*(2) In 2009, Ketelmeer was not monitored for radioactivity.*

*(3) Normally 52 times per year. Sampling frequency was reduced (halved) in April, May and June because of instrument problems.*

The radioactive nuclides were determined according to standard procedures [36] and [39]. In the Netherlands target values are in use for radioactive materials in surface water, which are given in the Fourth memorandum on water management (Vierde Nota waterhuishouding) [40]. The yearly averages are compared with these target values.

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

| Area | Location | Parameter | Matrix | Monitoring frequency (per year) |
|---|---|---|---|---|
| Coastal area (KZ) | Noordwijk 2 (1) | Gross α | Water | 4 |
| | | Residual β | Water | 4 |
| | | $^{3}H$ | Water | 4 |
| | | $^{137}Cs$ | Suspended solids | 3 (2) |
| | | $^{210}Po$ | Suspended solids | 3 (2) |
| Southern North Sea (ZN) | Noordwijk 70 (1) | Gross α | Water | 4 |
| | | Residual β | Water | 4 |
| | | $^{3}H$ | Water | 4 |
| | | $^{90}Sr$ | Water | 4 |
| Central North Sea (CN) | Terschelling 235 (1) | Gross α | Water | 4 |
| | | Residual β | Water | 4 |
| | | $^{3}H$ | Water | 4 |
| | | $^{90}Sr$ | Water | 4 |
| Delta Coastal Waters (VD) | Schouwen 10 (1) | Gross α | Water | 12 |
| | | Residual β | Water | 12 |
| | | $^{3}H$ | Water | 11 (3) |
| | | $^{90}Sr$ | Water | 5 |
| Westerscheldt (WS) | Vlissingen Boei | Gross α | Water | 13 |
| | | Residual β | Water | 13 |
| | | $^{3}H$ | Water | 13 |
| | | $^{90}Sr$ | Water | 13 |
| | | $^{137}Cs$ | Suspended solids | 4 |
| | | $^{210}Po$ | Suspended solids | 4 |
| Eems-Dollard (ED) | Huibergat Oost | Gross α | Water | 5 |
| | | Residual β | Water | 5 |
| | | $^{3}H$ | Water | 5 |
| | Bocht van Watum | $^{137}Cs$ | Suspended solids | 4 |
| | | $^{210}Po$ | Suspended solids | 4 |
| Wadden Sea West (4) (WW) | Marsdiep Noord | Gross α | Water | 5 |
| | | Residual β | Water | 5 |
| | | $^{3}H$ | Water | 5 |
| | Doove Balg West | $^{137}Cs$ | Suspended solids | 3 (2) |
| | | $^{210}Po$ | Suspended solids | 3 (2) |
| Wadden Sea East (5) (WO) | Dantziggat | Gross α | Water | 5 |
| | | Residual β | Water | 5 |
| | | $^{3}H$ | Water | 5 |

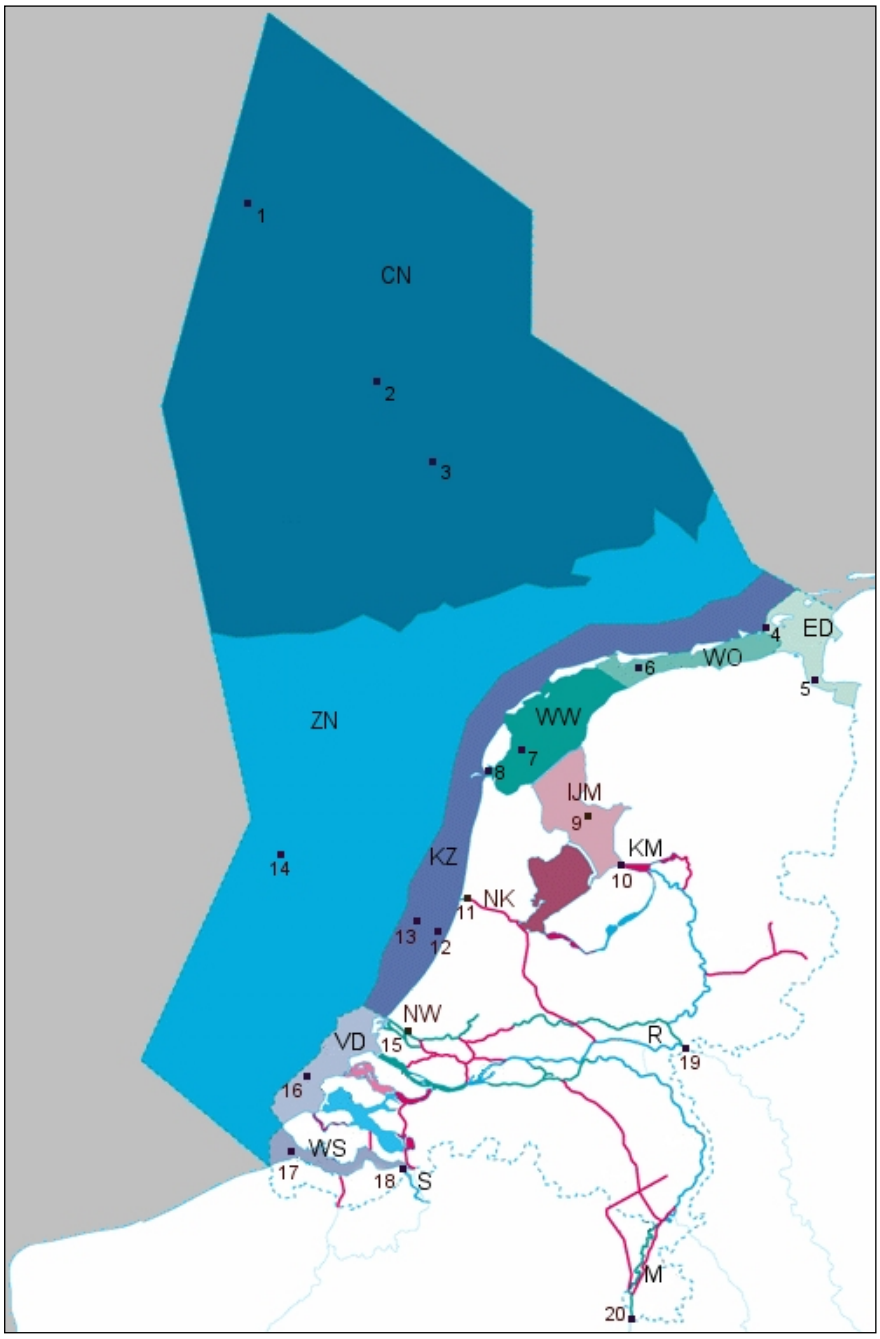
*(1) Number indicates distance from shore. For example, Noordwijk 2 means Noordwijk 2 km offshore.*

*(2) Normally 4 times per year. Sampling did not occur on one occasion.*

*(3) Normally 12 times per year. Sampling did not occur on one occasion.*

*(4) Since 2009 $^{137}Cs$ and $^{210}Pb$ (in suspended solids) are determined at Doove Balg West again.*

*(5) Since 2009 $^{137}Cs$ and $^{210}Pb$ (in suspended solids) are no longer determined at Dantziggat.*




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

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

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

*Figure 5.1: Overview of monitoring locations for the monitoring program in surface water and in seawater.*
*Terschelling 135 km offshore and Terschelling 100 km offshore were the old monitoring locations for the Central North Sea during 1989 and 1988-1994 (except 1989), respectively. Terschelling 235 km offshore is the monitoring location for the Central North Sea from 1995 and onwards. Noordwijk 10 km offshore was the old monitoring location for the Coastal area during 1988-1998. Noordwijk 2 km offshore is the monitoring location for the Coastal area from 1999 and onwards [36].*

## 5.2 The results for surface water

The general monitoring strategy for surface water is to monitor the inland and border crossing waters of the Netherlands. Therefore, the locations mentioned in Table 5.1 are used for monitoring as they represent the major inland, incoming and outgoing waters of the Netherlands. The results for surface water are presented in Tables A11 and A12 and in Figures 5.2 to 5.19.

Gross α and residual β are indicative parameters. The yearly averaged activity concentrations of gross α and residual β in 2009 are within the range of those in previous years. The gross α -activity concentration in the Noordzeekanaal, Nieuwe Waterweg and Scheldt exceeds the target value (100 $mBq \cdot L^{-1}$) in 6 out of 6, 6 out of 13 and 13 out of 13 samples taken, respectively. In 2009 the yearly averaged gross α -activity concentrations in the Noordzeekanaal, Nieuwe Waterweg and Scheldt (220, 113 and 380 $mBq \cdot L^{-1}$, respectively) are above the target value of 100 $mBq \cdot L^{-1}$.

The yearly averaged residual β-activity concentrations are below the target value of 200 $mBq \cdot L^{-1}$. Residual β in the Noordzeekanaal, Nieuwe Waterweg and Scheldt shows a change in the trend since 1994. This is caused by a change in measuring technique, which only applies to salt and brackish water [36]. Therefore, this change in trend is not seen for the IJsselmeer, Rhine and Meuse.

The $^{3}H$-activity concentration in the Scheldt and Meuse exceeds the target value (10 $Bq \cdot L^{-1}$) in 4 out of 7 and 4 out of 13 samples taken, respectively. The elevated levels of $^{3}H$ in the Meuse (Figure 5.6) could originate from the nuclear power plants at Tihange (Belgium) or Chooz (France). The elevated levels of $^{3}H$ in the Scheldt could originate from the nuclear power plant at Doel (Belgium). The yearly averaged $^{3}H$-activity concentrations in 2009 are within the range of those in previous years. In 2009, the yearly averaged $^{3}H$-activity concentration in the Scheldt and Meuse (11.9 and 14.0 $Bq \cdot L^{-1}$, respectively) are 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 2009 are within the range of those in previous years. The yearly averaged $^{90}Sr$-activity concentrations are below the target value of 10 $mBq \cdot L^{-1}$.

The nuclide $^{226}Ra$ is released into the environment by the ore processing industry. The $^{226}Ra$-activity concentration in the Scheldt exceeds the target value (5 $mBq \cdot L^{-1}$) in 7 out of 7 samples taken. The yearly averaged $^{226}Ra$-activity concentrations in 2009 are within the range of those in previous years. In 2009 the yearly averaged $^{226}Ra$-activity concentration in the Scheldt (12.4 $mBq \cdot L^{-1}$) is above the target value of 5 $mBq \cdot L^{-1}$.

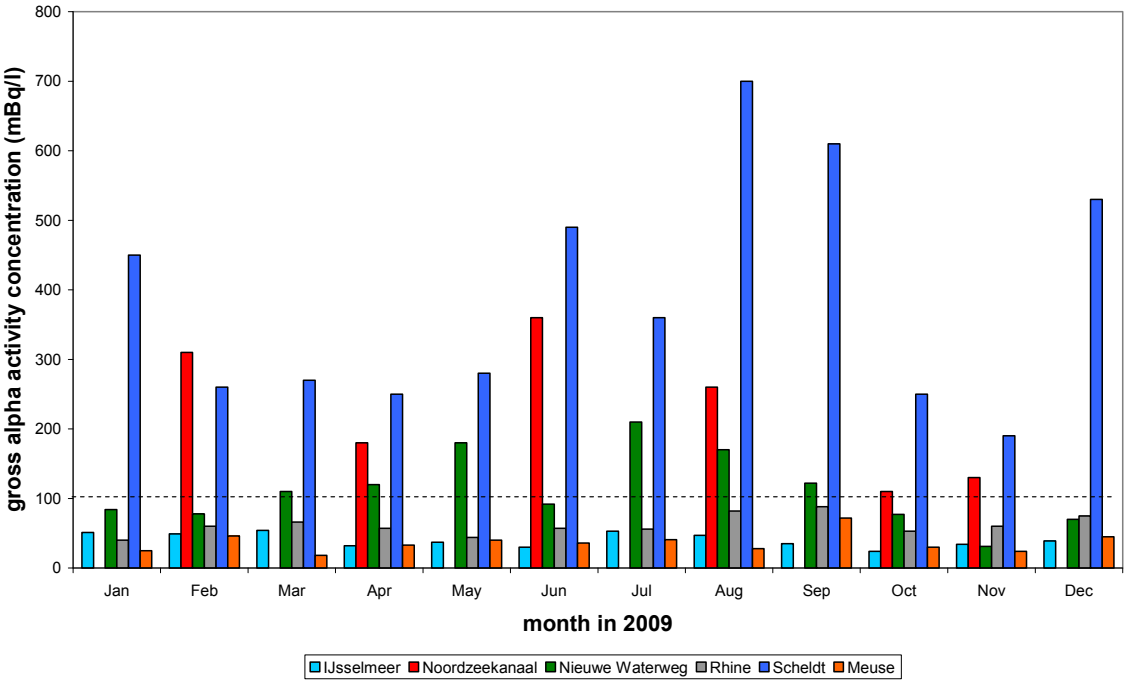



*Figure 5.2: The gross α-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 40, 220, 113, 61, 380 and 36 mBq·L$^{-1}$, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 100 mBq·L$^{-1}$ [40].*

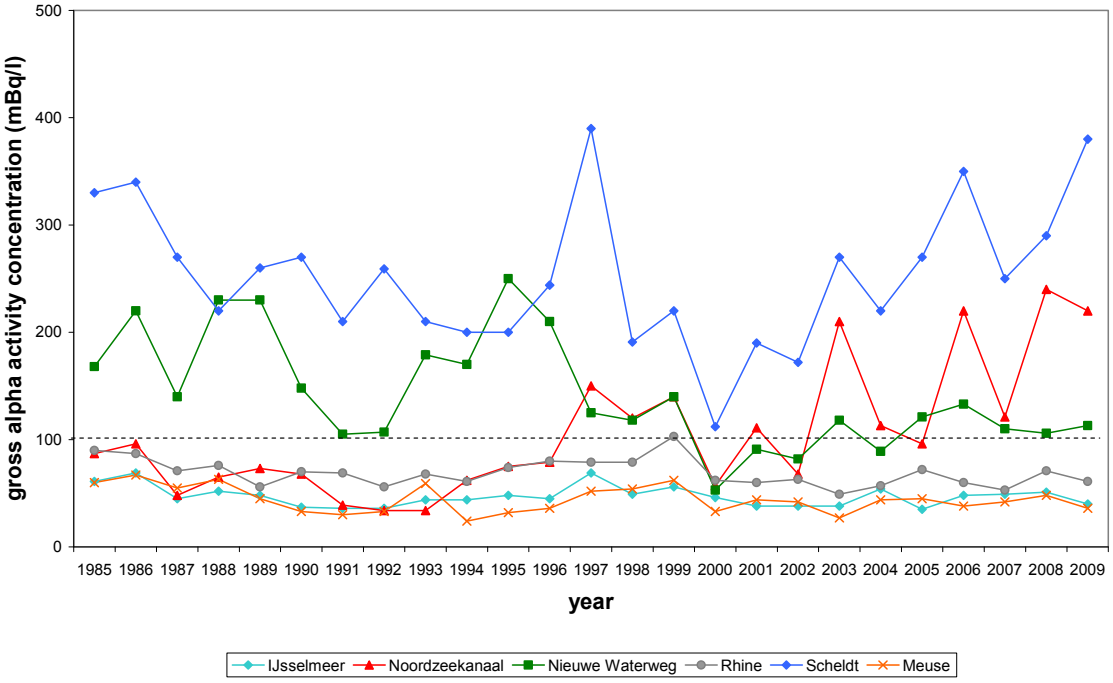



*Figure 5.3: Yearly averaged gross α-activity concentrations.*

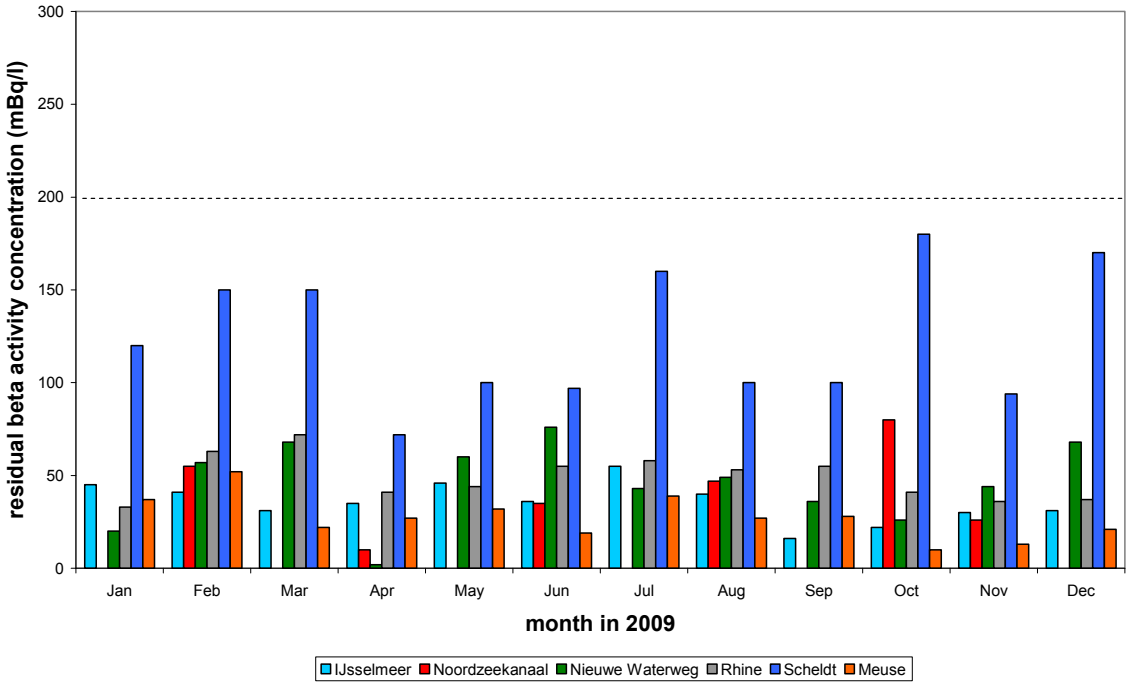



*Figure 5.4: The residual β-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 36, 42, 45, 50, 120 and 27 mBq·L$^{-1}$, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 200 mBq·L$^{-1}$ [40].*

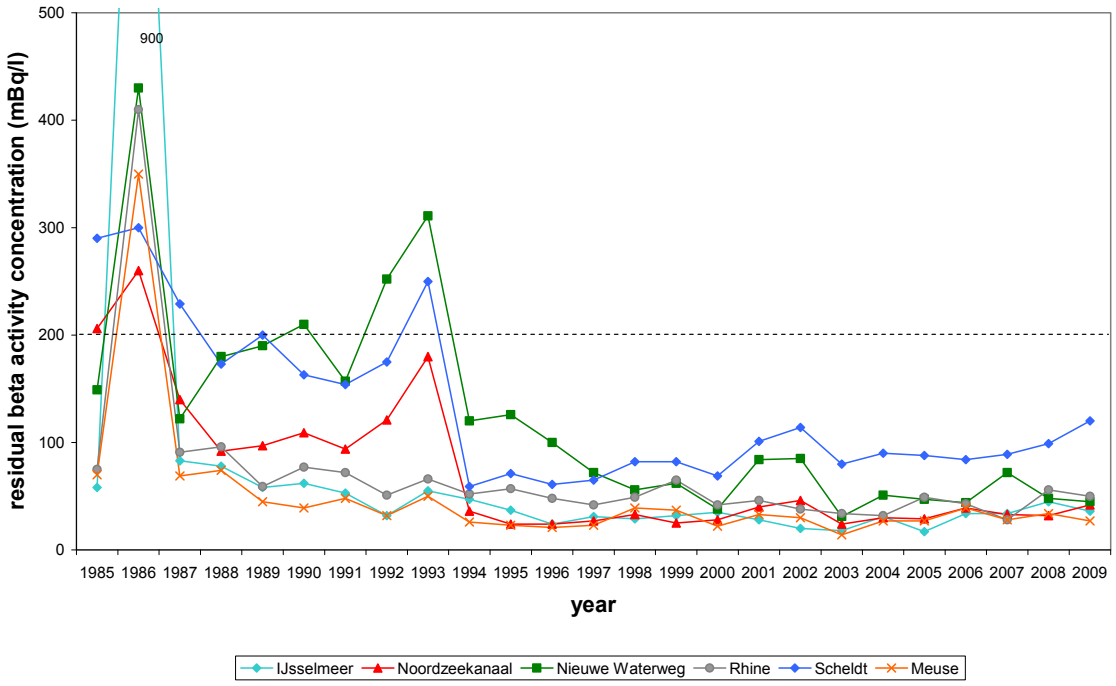



*Figure 5.5: Yearly averaged residual β-activity concentrations.*

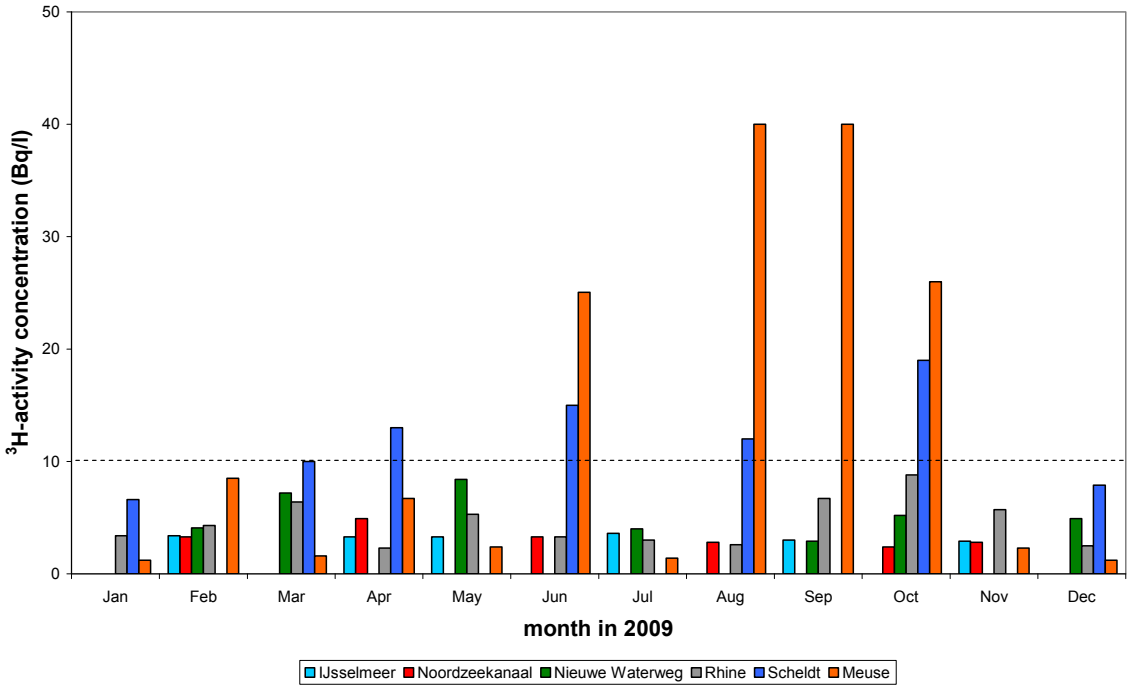



*Figure 5.6: The $^3$H-activity concentration for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 3.3, 3.2, 5.2, 4.4, 11.9 and 14.0 Bq·L$^{-1}$, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 Bq·L$^{-1}$ [40].*

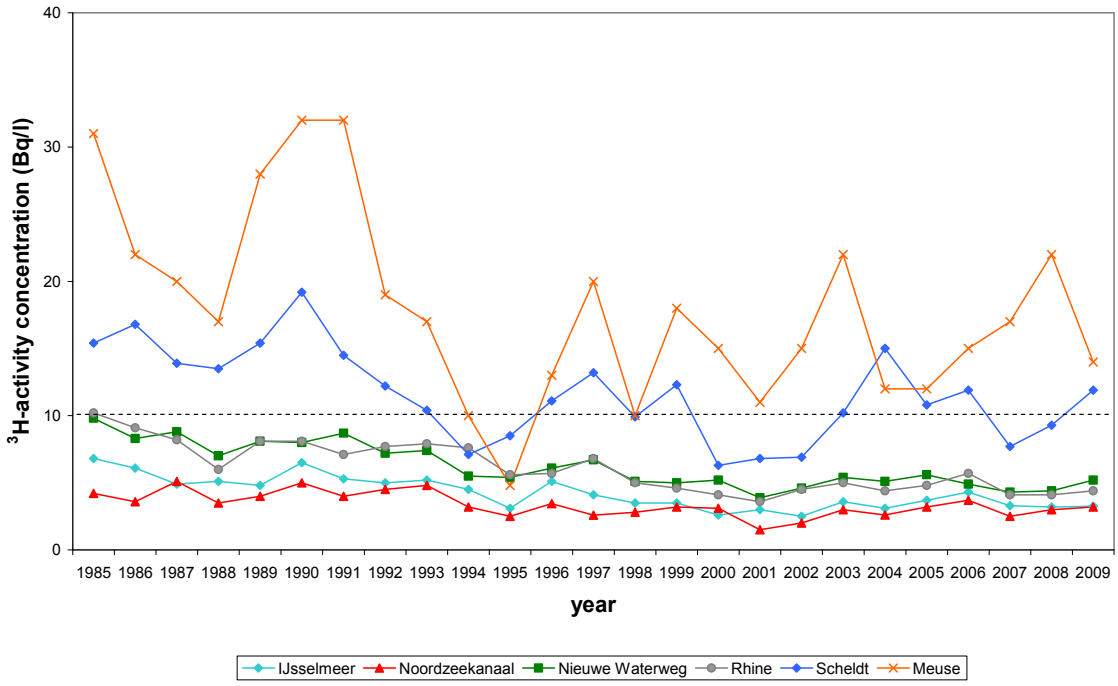



*Figure 5.7: Yearly averaged $^3$H-activity concentrations.*

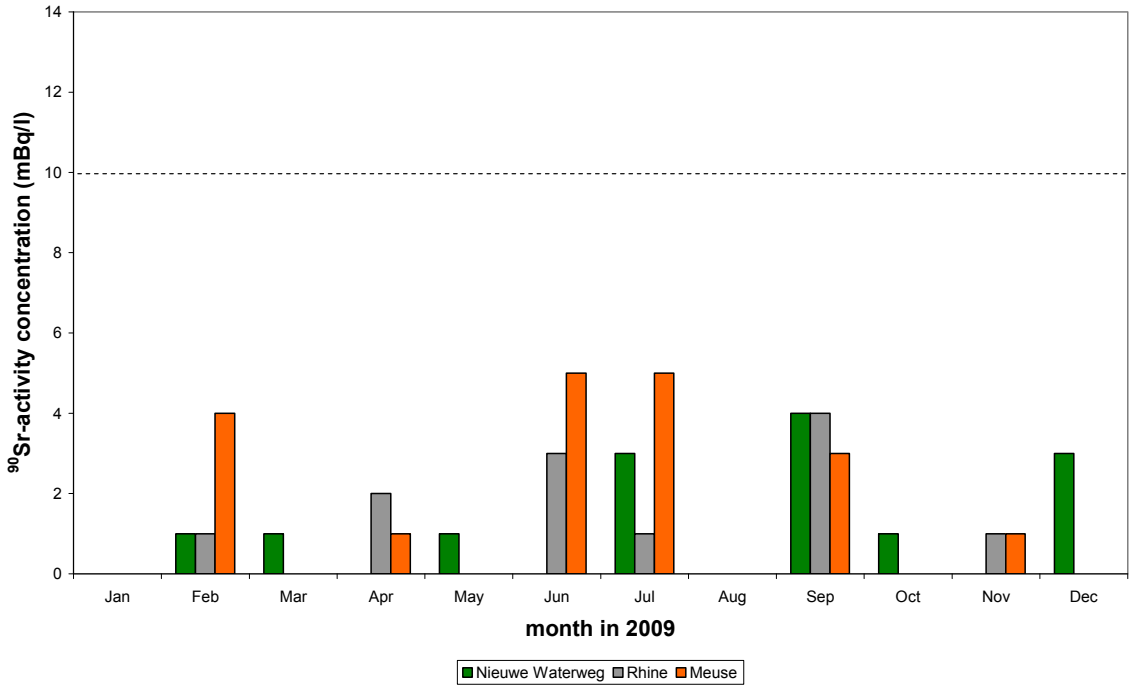



*Figure 5.8: The $^{90}$Sr-activity concentration for the Nieuwe Waterweg, Rhine and Meuse, with yearly averages of 1.8, 1.8 and 3.0 mBq·L$^{-1}$, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 mBq·L$^{-1}$ [40].*

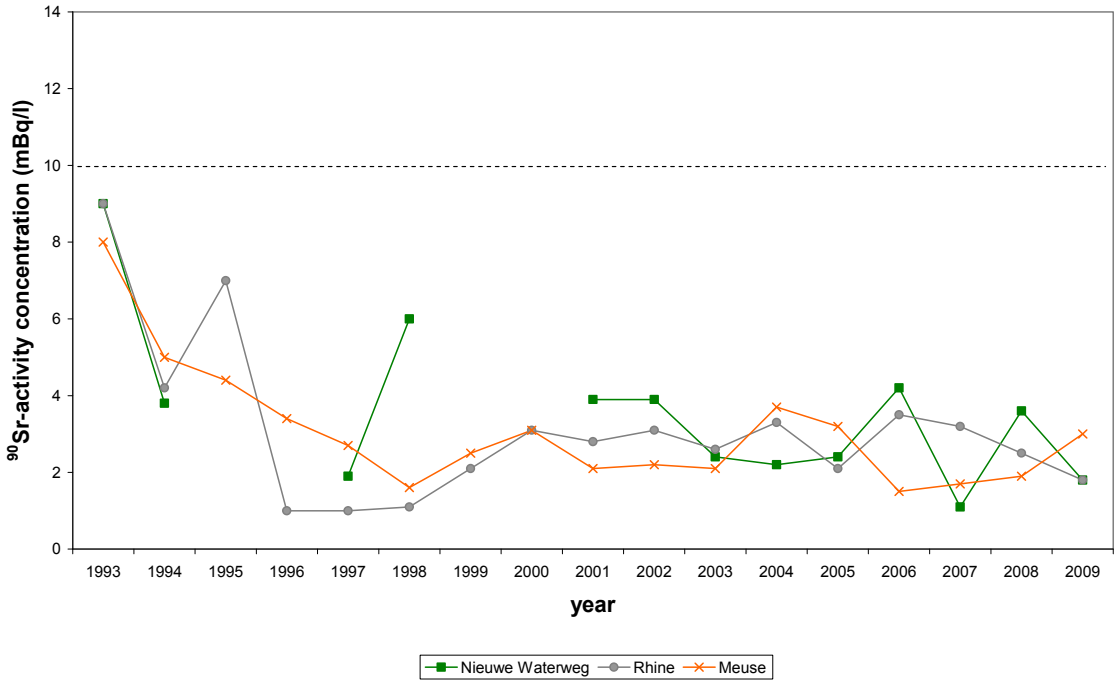



*Figure 5.9: Yearly averaged $^{90}$Sr-activity concentrations. Data are not available for the Nieuwe Waterweg in 1995, 1996, 1999 and 2000.*

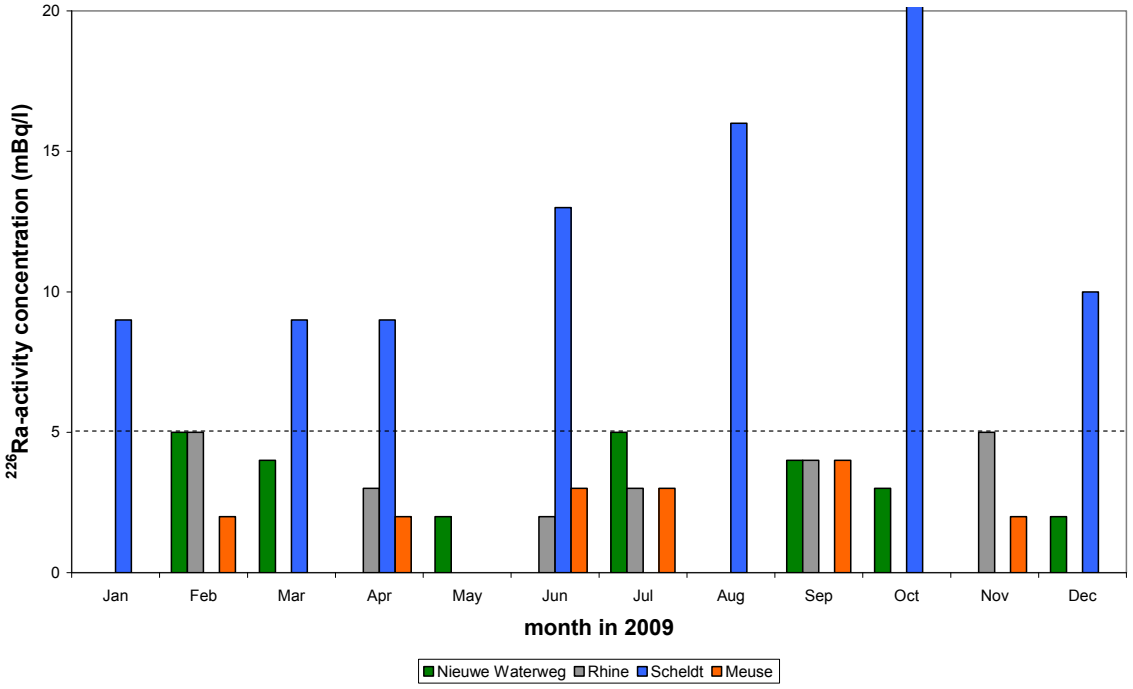



*Figure 5.10: The $^{226}$Ra-activity concentration for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 3.6, 3.7, 12.4 and 2.7 mBq·L$^{-1}$, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 5 mBq·L$^{-1}$ [40].*

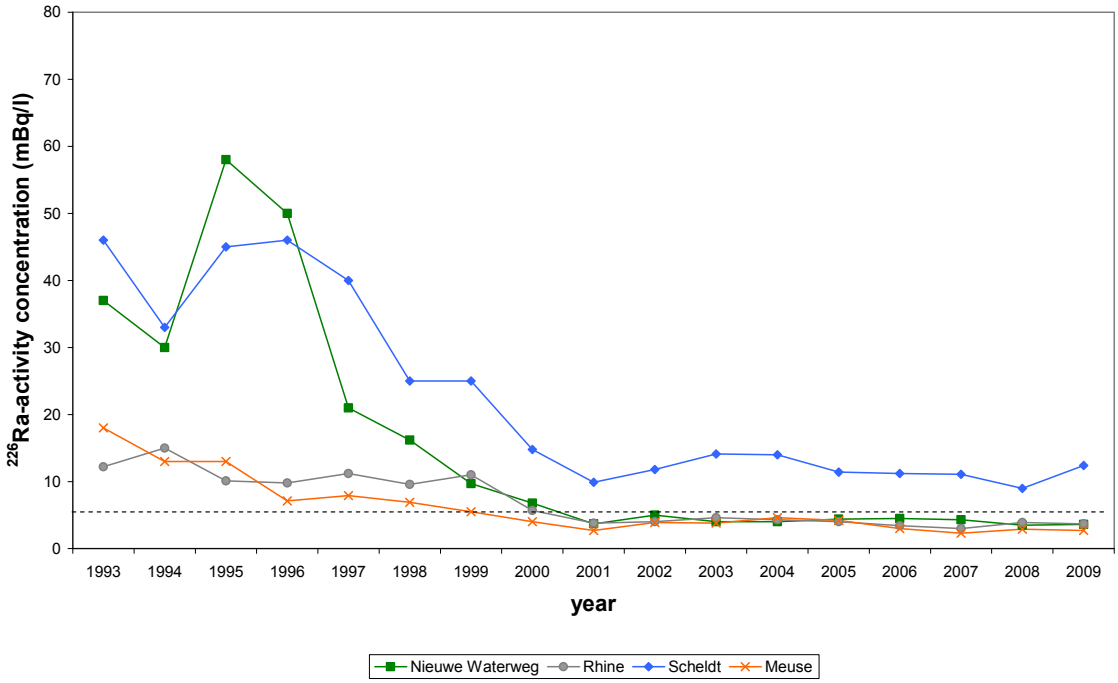



*Figure 5.11: Yearly averaged $^{226}$Ra-activity concentrations.*

The nuclide $^{60}Co$ is a known corrosion product of nuclear power plants. The $^{60}Co$-activity concentration in suspended solids in the Meuse exceeds the target value (10 $Bq \cdot kg^{-1}$) in 6 out of 45 samples taken. In 2009, the yearly averaged $^{60}Co$-activity concentrations are below the target value of 10 $Bq \cdot kg^{-1}$.

The nuclide $^{131}I$ is released into the environment by medical facilities. The $^{131}I$-activity concentration in suspended solids in the Noordzeekanaal and Meuse exceeds the target value (20 $Bq \cdot kg^{-1}$) in 6 out of 6 and 10 out of 45 samples taken, respectively. In 2009, the yearly averaged $^{131}I$-activity concentration in the Noordzeekanaal (29 $Bq \cdot kg^{-1}$) is higher than those in previous years, and exceeds the target value of 20 $Bq \cdot kg^{-1}$.

The yearly averaged concentrations of $^{137}Cs$ in suspended solids in 2009 are within the range of those in previous years. The yearly averaged $^{137}Cs$-concentrations are below the target value of 40 $Bq \cdot kg^{-1}$.

In suspended solids $^{210}Po$ is mostly in equilibrium with $^{210}Pb$. Therefore, the Centre for Water Management only reports $^{210}Pb$. The nuclides $^{210}Po$ and $^{210}Pb$ originate from the uranium decay chain and are released by the phosphate processing industry [36]. The $^{210}Pb$-activity concentration in the Nieuwe Waterweg, Rhine and Meuse exceeds the target value (100 $Bq \cdot kg^{-1}$) in 4 out of 7, 6 out of 6 and 5 out of 6 samples taken, respectively. In 2009 the yearly averaged $^{210}Pb$-activity concentrations in the Nieuwe Waterweg, Rhine and Meuse (112, 120 and 153 $Bq \cdot kg^{-1}$, respectively) are above the target value of 100 $Bq \cdot kg^{-1}$, but within range of those in previous years.

Since 2009, location Ketelmeer is no longer monitored for radioactivity in suspended solids.

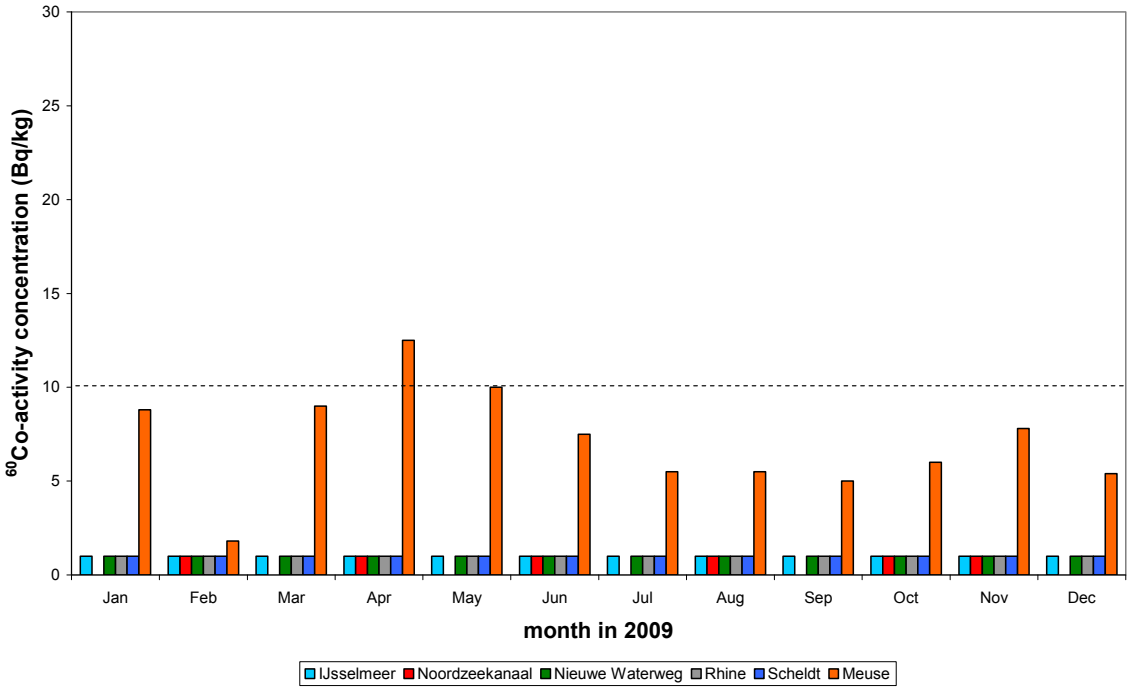



*Figure 5.12: The $^{60}$Co-activity concentration in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse. The yearly averages of all except for the Meuse (6.6 Bq·kg$^{-1}$) are < 1 Bq·kg$^{-1}$. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 10 Bq·kg$^{-1}$ [40].*

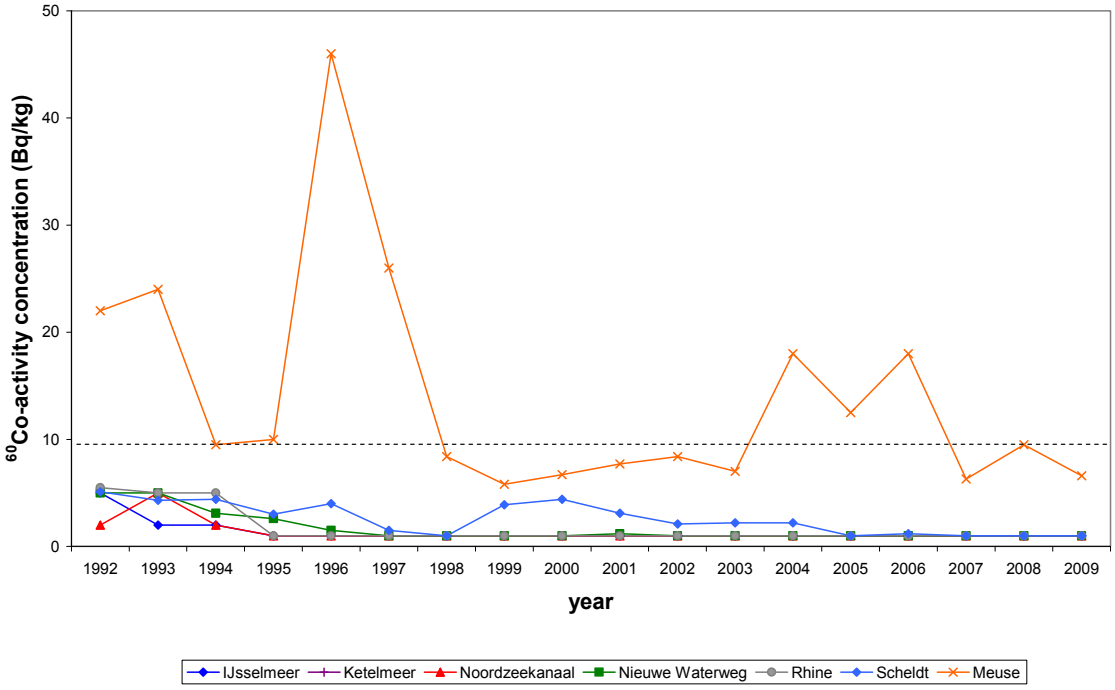



*Figure 5.13: Yearly averaged $^{60}$Co-activity concentrations in suspended solids. Data on Ketelmeer are available from 1995 - 2008.*

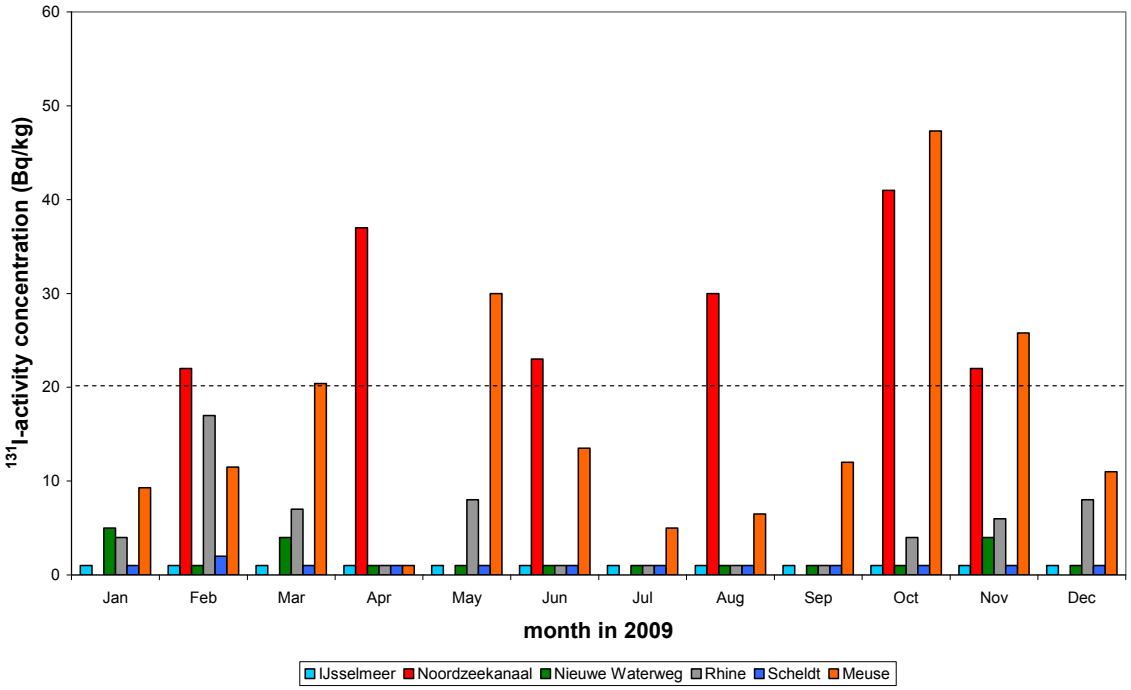



*Figure 5.14: The $^{131}$I-activity concentration in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of < 1, 29, < 1.4, 4.4, < 1, and 16 Bq·kg$^{-1}$, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 20 Bq·kg$^{-1}$ [40].*

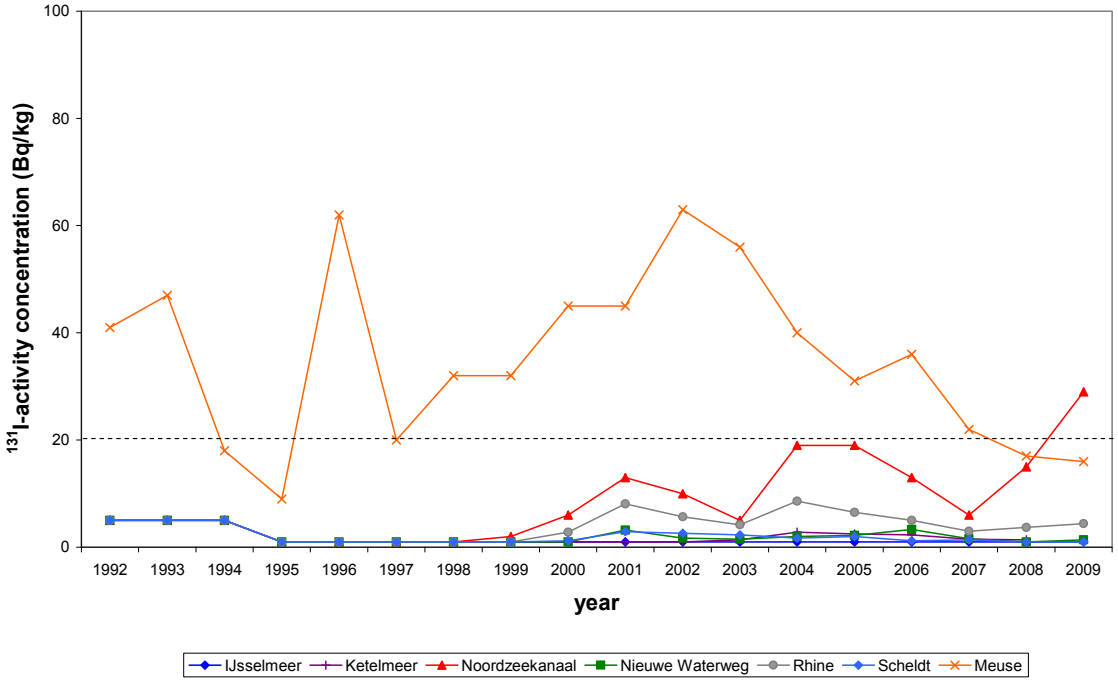



*Figure 5.15: Yearly averaged $^{131}$I-activity concentrations in suspended solids. Data on Ketelmeer are available from 1995 - 2008.*

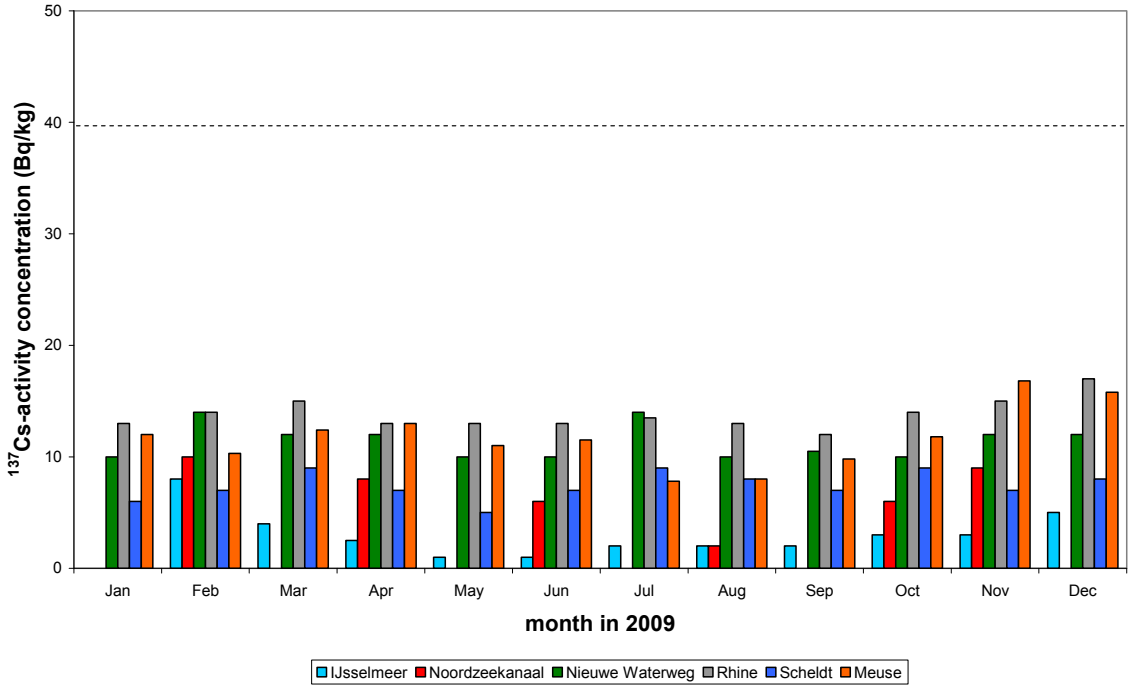



*Figure 5.16: The $^{137}$Cs-activity concentration in suspended solids for the IJsselmeer, Noordzeekanaal, Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 2.9, 6.8, 11.3, 13.8, 7.4, and 11.7 Bq·kg$^{-1}$, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 40 Bq·kg$^{-1}$ [40].*

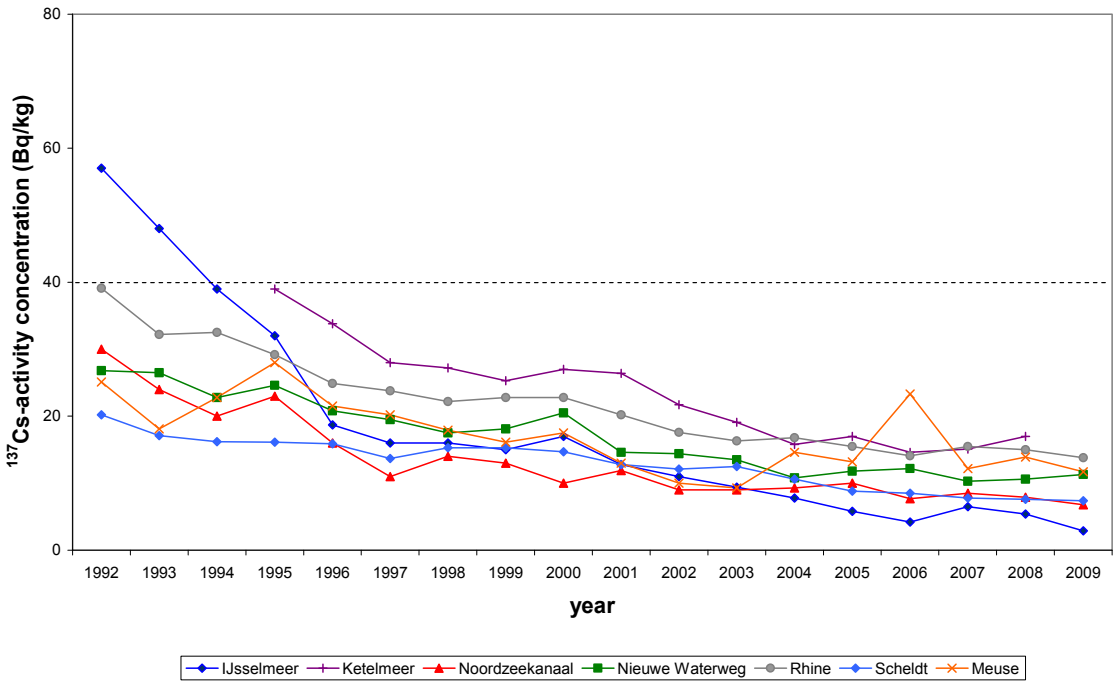



*Figure 5.17: Yearly averaged $^{137}$Cs-activity concentrations in suspended solids. Data on Ketelmeer are available from 1995 - 2008.*

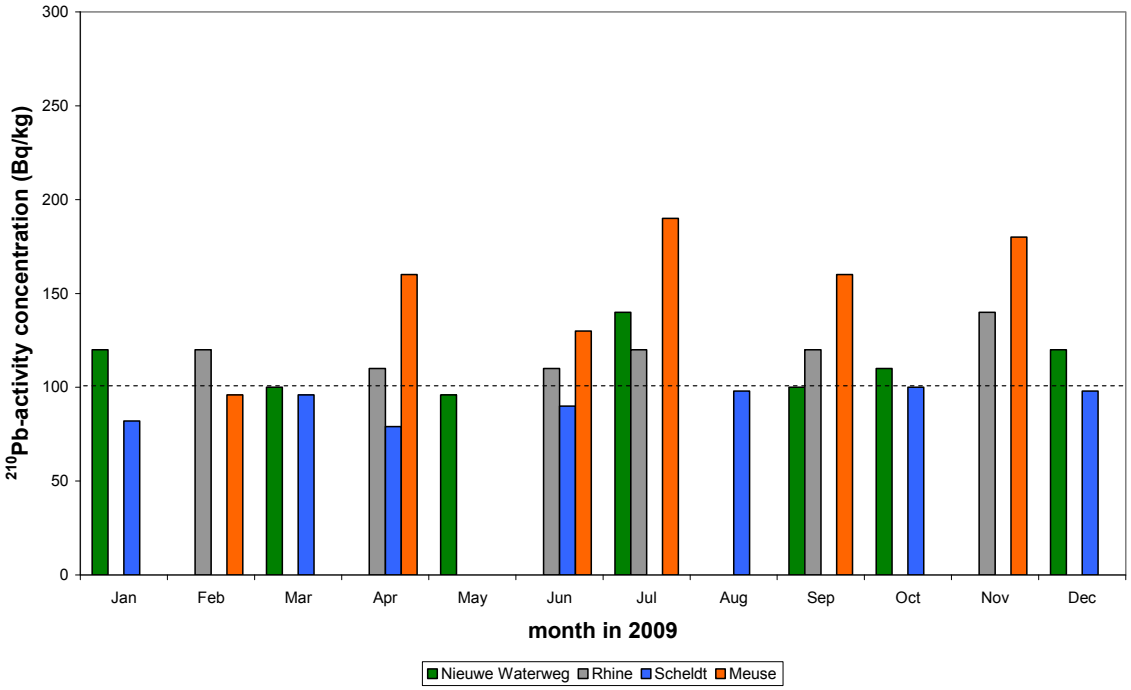



*Figure 5.18: The $^{210}$Pb-activity concentration in suspended solids for the Nieuwe Waterweg, Rhine, Scheldt and Meuse, with yearly averages of 112, 120, 92, and 153 Bq·kg$^{-1}$, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value of 100 Bq·kg$^{-1}$ [40].*

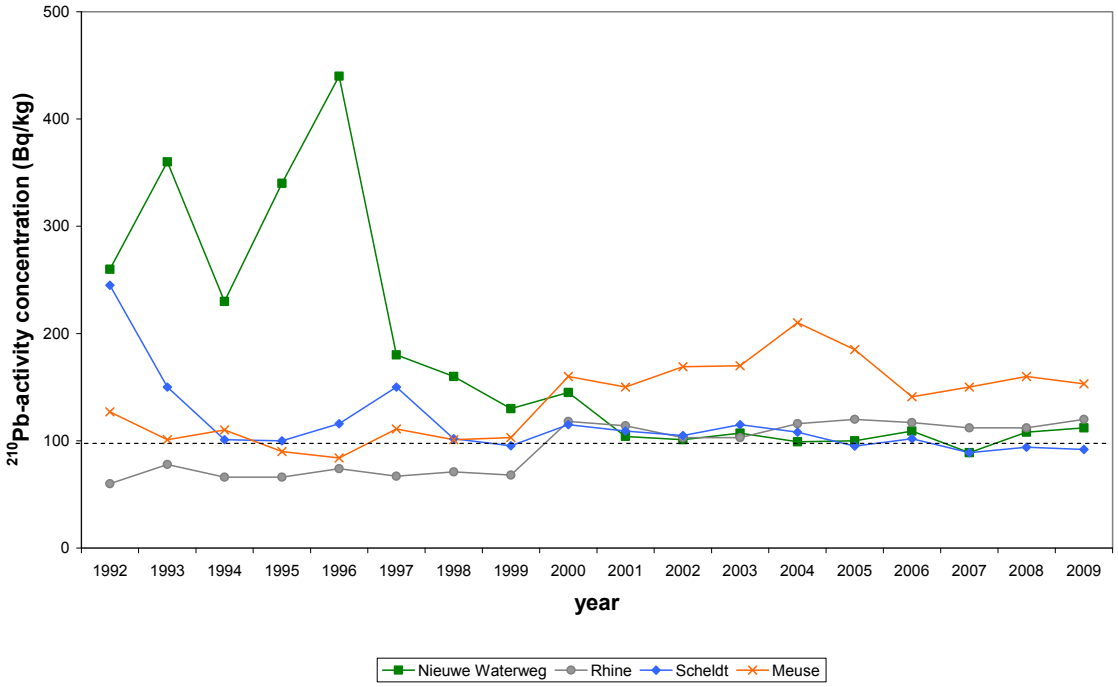



*Figure 5.19: Yearly averaged $^{210}$Pb-activity concentrations in suspended solids.*

## 5.3 The results for seawater

The results for seawater are presented in Tables A13 and A14 and in Figures 5.20 to 5.31.
Gross α and residual β are indicative parameters [36]. In the first half of 2000 the background of the measuring equipment was unstable and higher than usual, which resulted in lower results. Therefore, yearly averaged concentrations of gross α in 2000 are based on data starting from the end of July 2000. Changes in the trend of gross α in the period 1985-1997 are explained elsewhere [36]. In the Southern North Sea, Eems-Dollard and Wadden Sea East the yearly averaged gross α-activity concentrations of 2009 are higher than those in previous years (Figure 5.21).

Residual β shows an apparent change in the trend since 1994 (Figure 5.23). This is caused by a change in measuring technique, which only applies to salt and brackish water [36]. In the Westerscheldt and the Southern North Sea the yearly averaged residual β-activity concentrations of 2009 are higher than 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 by the nuclear power plants at Doel (Belgium) and Borssele (the Netherlands) are monitored in the Westerscheldt (WS). The impact of reprocessing plants at Sellafield (England) and Le Havre (France) is monitored in the Central North Sea (CN) and Southern North Sea (ZN), respectively [36]. The impact of both sources (nuclear power and reprocessing plants) is monitored indirectly in the Delta Coastal Waters (VD).

The yearly averaged $^{3}H$-concentrations in 2009 are within the range of those in previous years (Figure 5.25). The yearly averaged $^{90}Sr$-concentrations in 2009 are within the range of those in previous years (Figure 5.27).

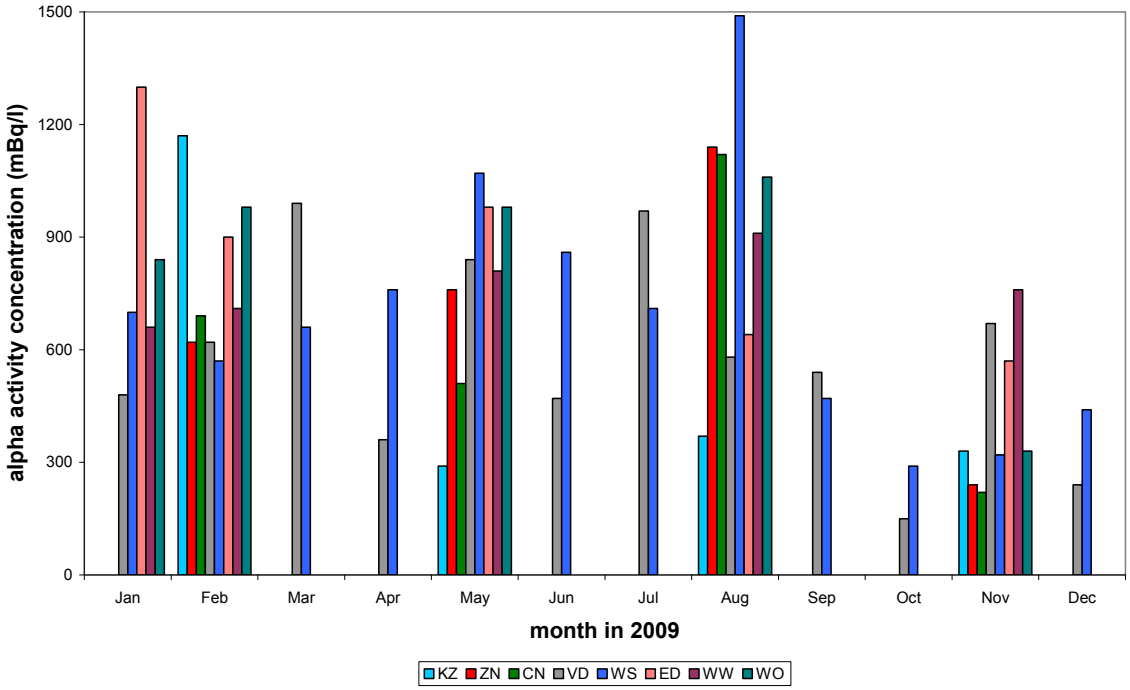



*Figure 5.20: The gross α-activity concentration in seawater. The yearly averages for the Coastal area (KZ), Southern North Sea (ZN), Central North Sea (CN), Delta Coastal Waters (VD), Westerscheldt (WS), Eems-Dollard (ED), Wadden Sea West (WW) and Wadden Sea East (WO) are 500, 690, 640, 580, 690, 880, 770 and 840 mBq·L$^{-1}$, respectively.*

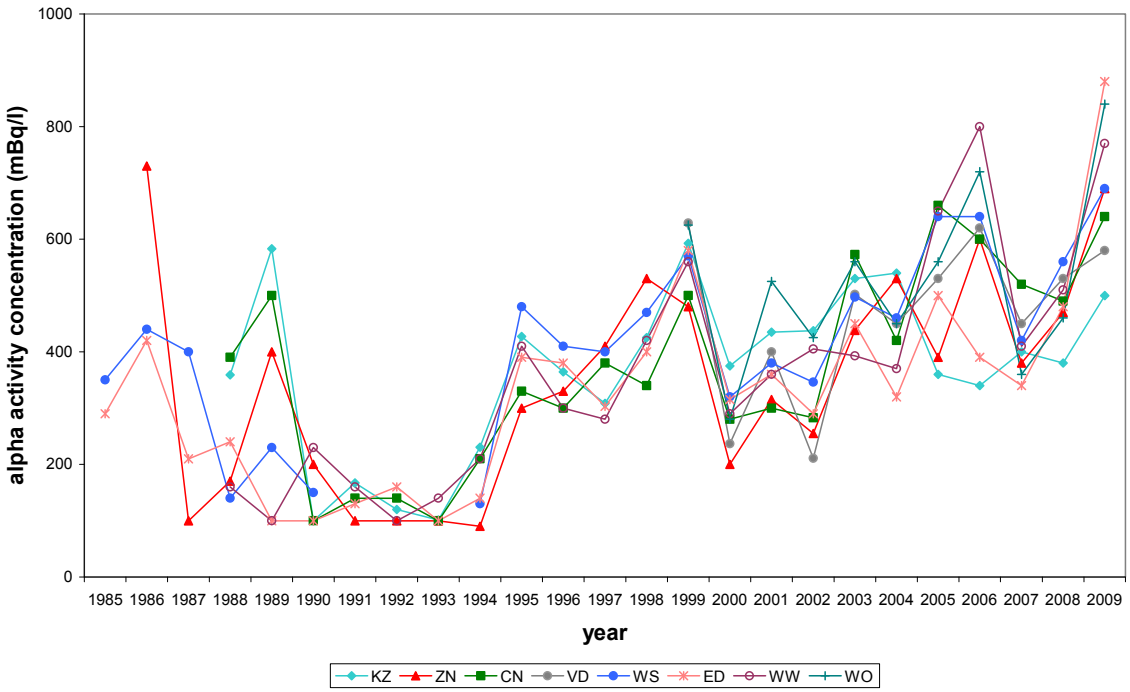



*Figure 5.21: Yearly averaged gross α-activity concentrations.*

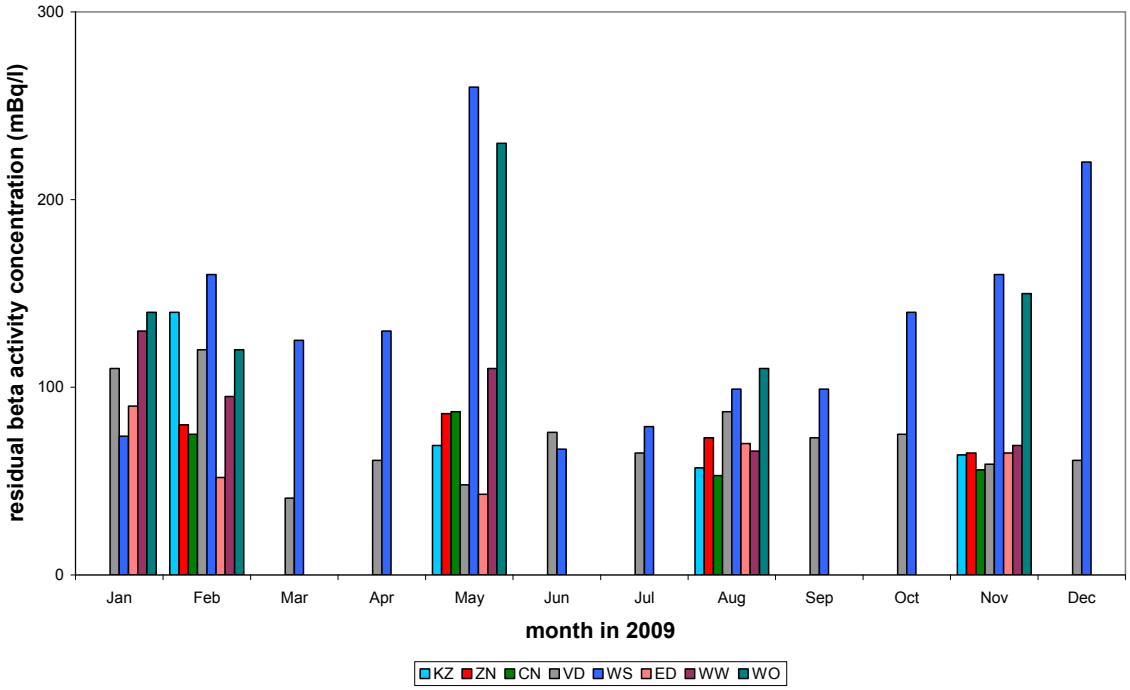



*Figure 5.22: The residual β-activity concentration in seawater. The yearly averages for the Coastal area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East are 82, 76, 68, 73, 134, 64, 94, and 150 mBq·L$^{-1}$, respectively.*

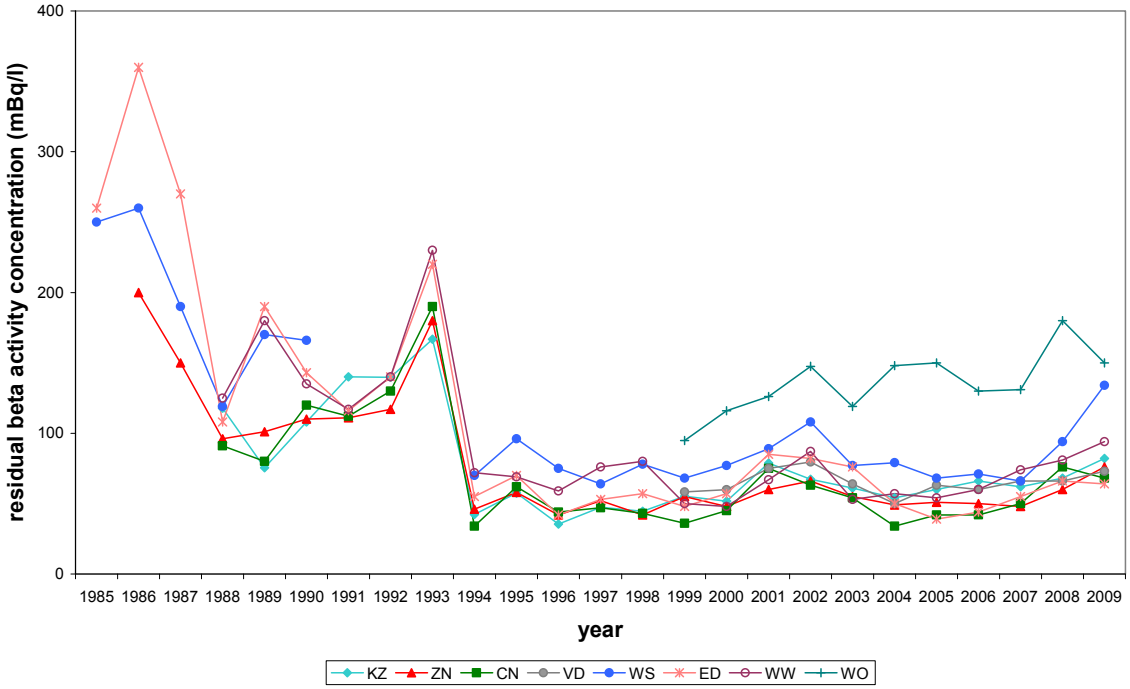



*Figure 5.23: Yearly averaged residual β-activity concentrations.*

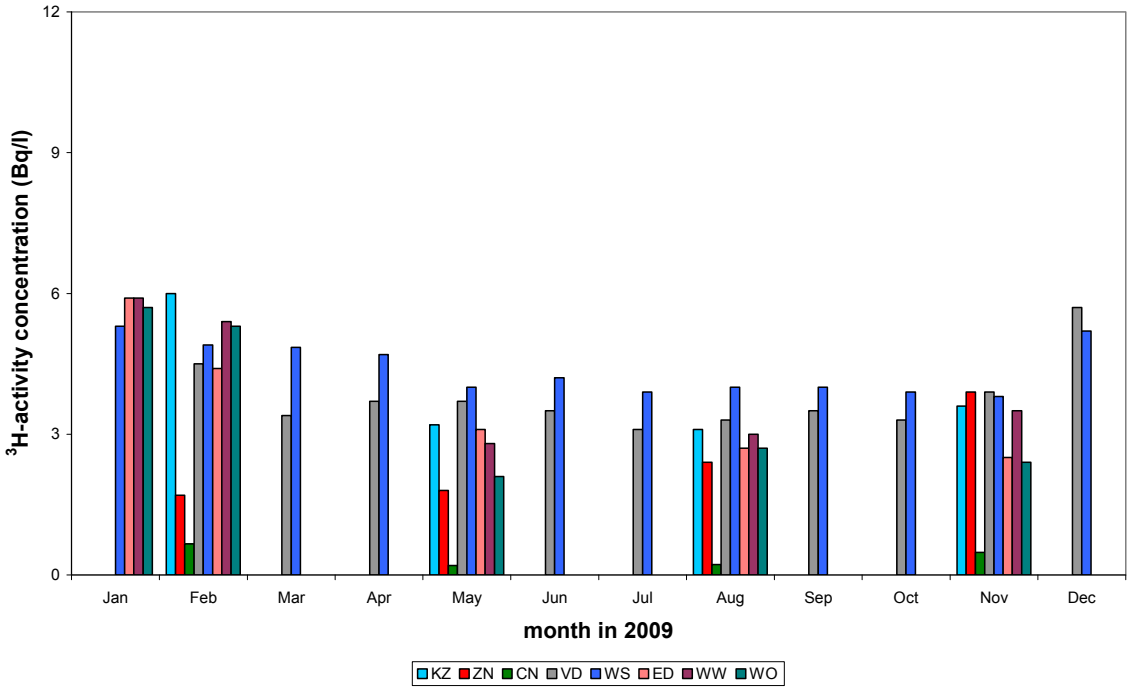



*Figure 5.24: The $^3$H-activity concentration in seawater. The yearly averages for the Coastal area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East are 4.0, 2.4, 0.39, 3.8, 4.4, 3.7, 4.1, and 3.6 Bq·L$^{-1}$, respectively.*

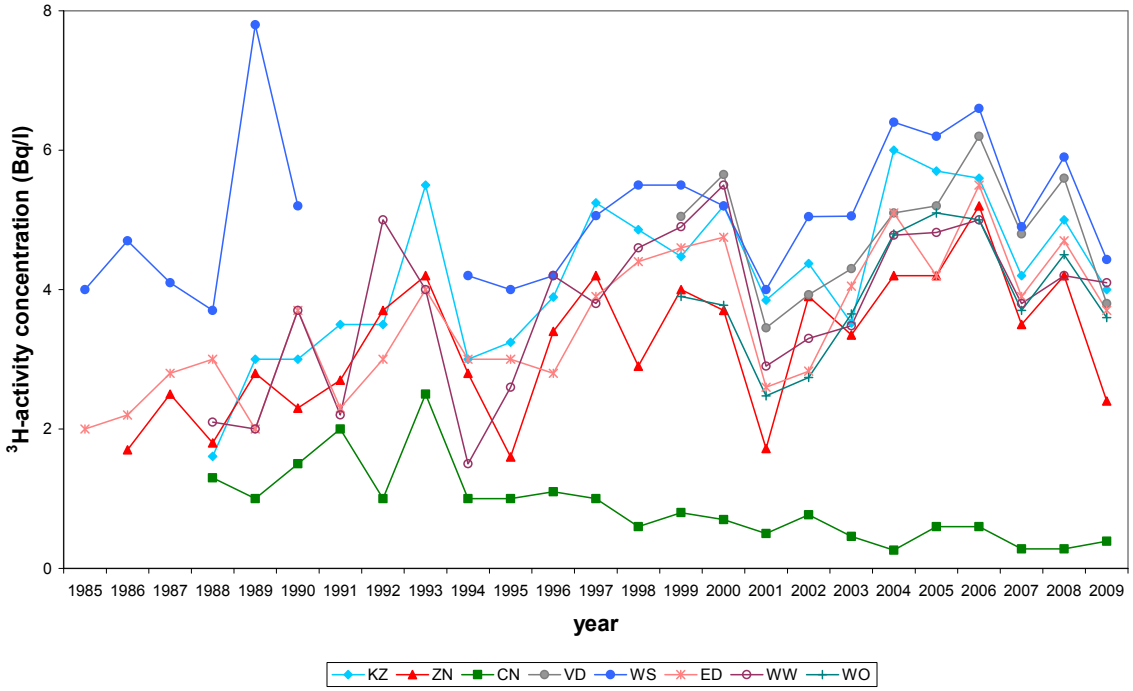



*Figure 5.25: Yearly averaged $^3$H-activity concentrations.*

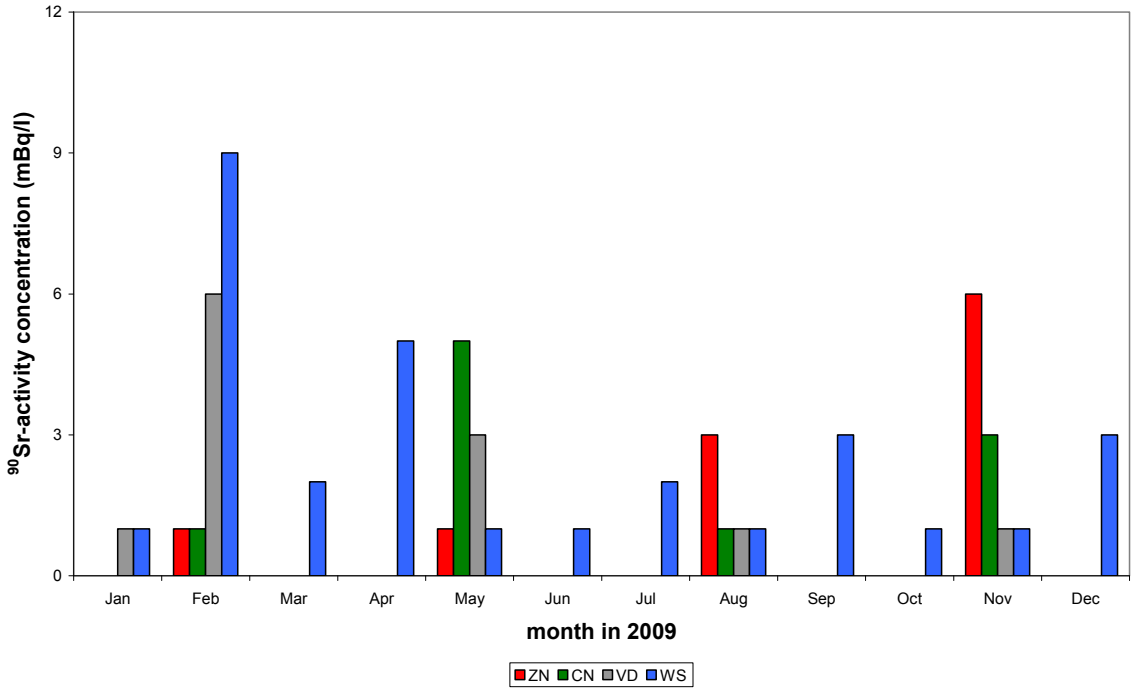



*Figure 5.26: The $^{90}$Sr-activity concentration in seawater. The yearly averages for the Southern North Sea, Central North Sea, Delta Coastal Waters and Westerscheldt are 2.5, 2.2, 2.2, and 2.2 mBq·L$^{-1}$, respectively.*

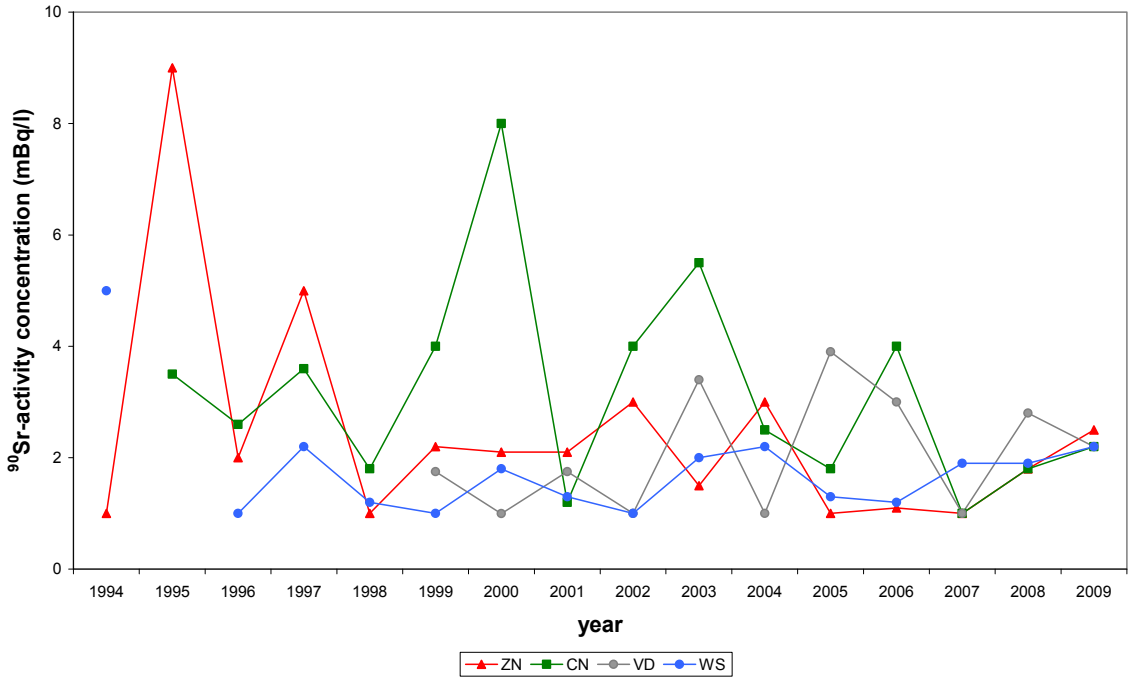



*Figure 5.27: Yearly averaged $^{90}$Sr-activity concentrations.*

Since 2009 $^{137}Cs$ and $^{210}Pb$ are determined at Wadden Sea West again, but they are no longer determined at Wadden Sea East.
The yearly averaged concentrations of $^{137}Cs$ in 2009 are within the range of those in previous years (Figure 5.29).
The yearly averaged concentrations of $^{210}Pb$ in 2009 are within the range of those in previous years (Figure 5.31). In suspended solids $^{210}Po$ is mostly in equilibrium with $^{210}Pb$. Since 2009, the Centre for Water Management only reports $^{210}Pb$, just like for surface water. In case the gross α value is increased, $^{210}Po$ is determined as well.

The nuclides $^{210}Pb$ and $^{210}Po$ originate from the uranium decay chain, and are released, for example, by the phosphate processing industry and production platforms for oil and gas [36]. Discharges via the main rivers are monitored in the Coastal area (KZ). Discharges by ore and phosphate processing industries in Belgium and the Netherlands are monitored in the Westerscheldt (WS). Discharges by Germany, Delfzijl and Eemshaven are monitored in the Eems-Dollard (ED). The impact of these discharges is monitored indirectly in the Wadden Sea (WW and WO) together with activity originating from the North Sea.

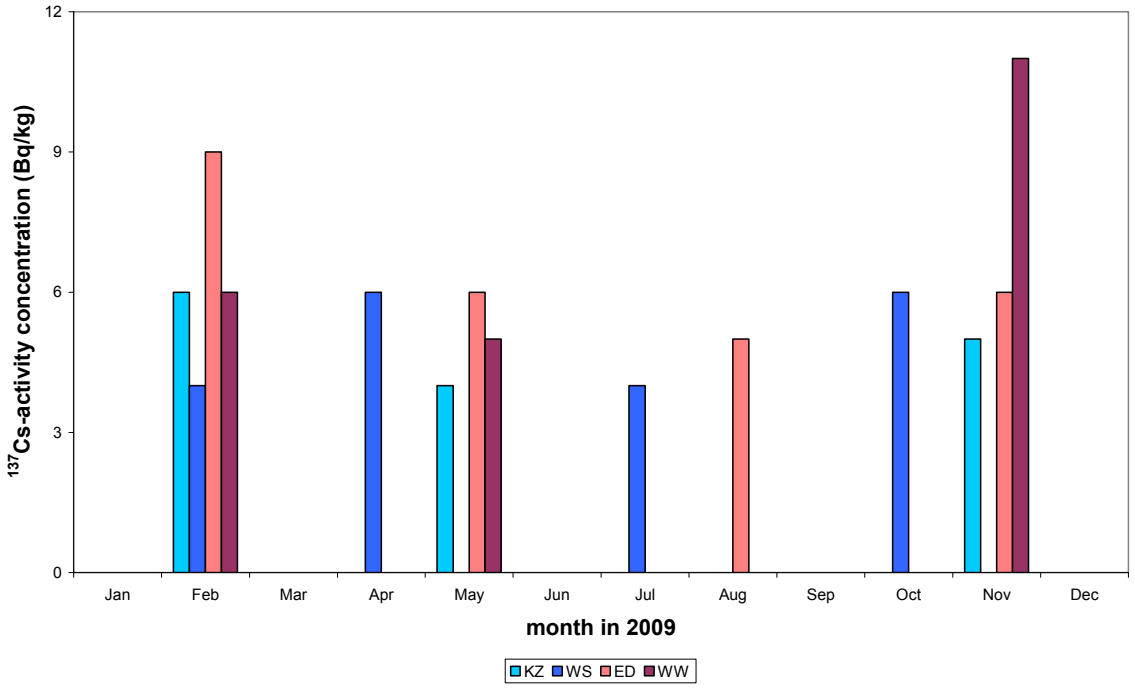



*Figure 5.28: The $^{137}$Cs-activity concentration in suspended solids in seawater. The yearly averages for the Coastal area, Westerscheldt, Eems-Dollard and Wadden Sea West are 5, 5, 6.5 and 5.3 Bq·kg$^{-1}$, respectively.*

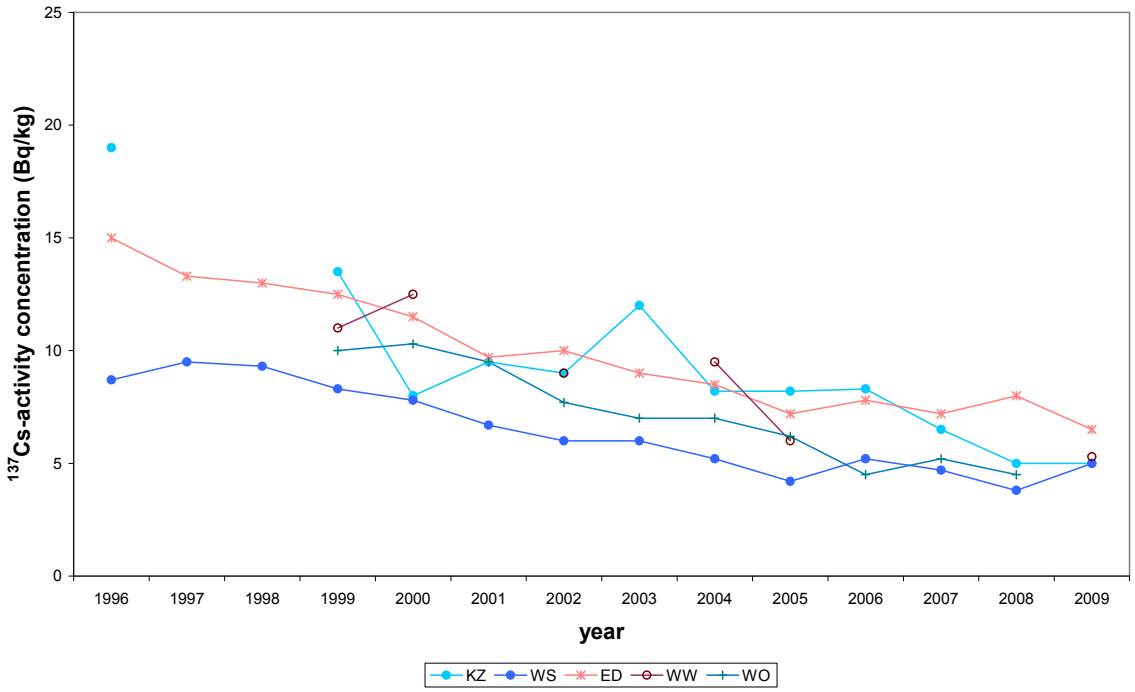



*Figure 5.29: Yearly averaged $^{137}$Cs-activity concentrations in suspended solids. Since 2009 $^{137}$Cs is determined at Wadden Sea West instead of Wadden Sea East.*

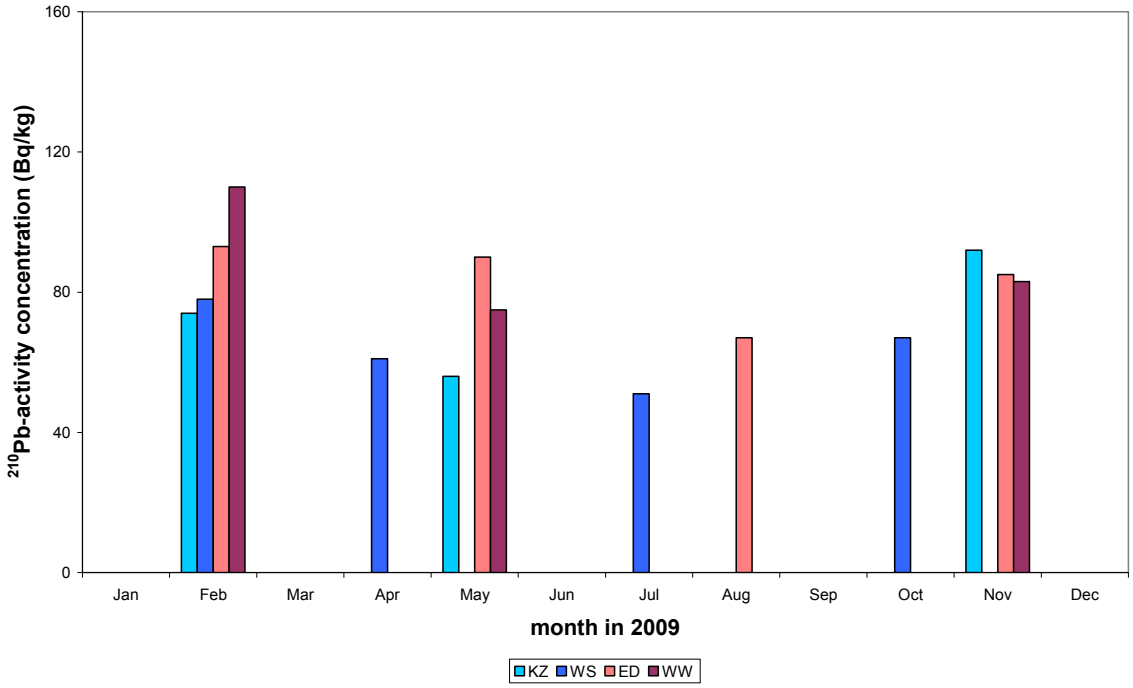



*Figure 5.30: The $^{210}$Pb-activity concentration in suspended solids in seawater. The yearly averages for the Coastal area, Westerscheldt, Eems-Dollard and Wadden Sea West are 74, 64, 84 and 89 Bq·kg$^{-1}$, respectively.*

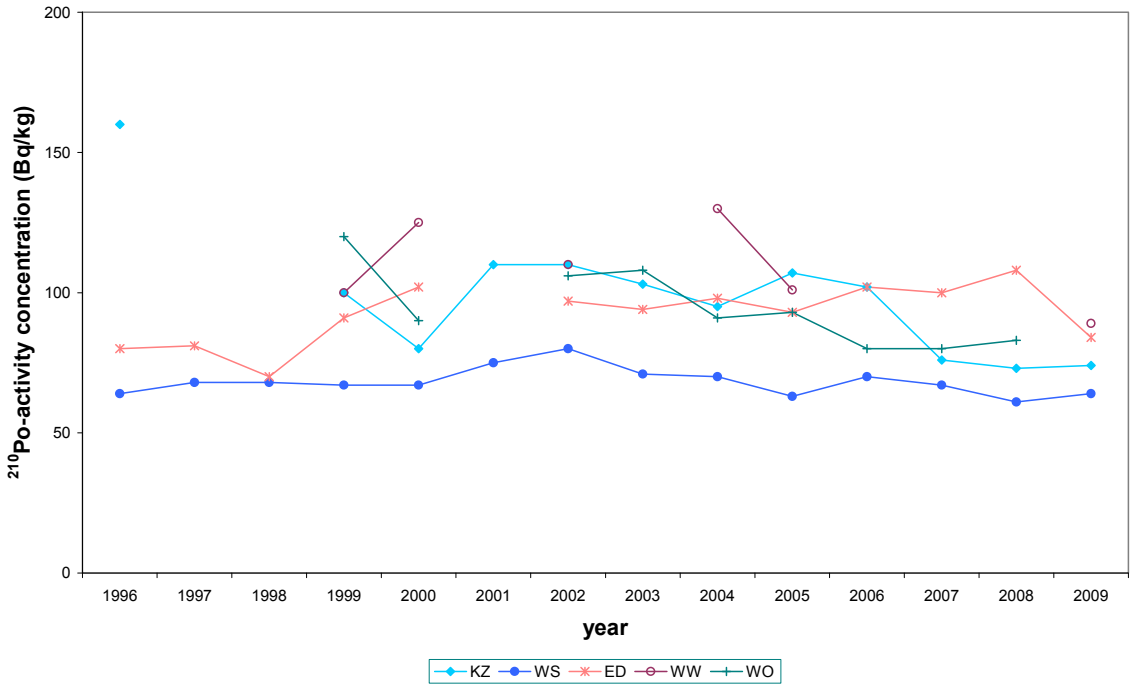



*Figure 5.31: Yearly averaged $^{210}$Pb-activity concentrations in suspended solids. Since 2009 $^{210}$Pb is determined at Wadden Sea West instead of Wadden Sea East.*

# 6 Water for human consumption

In addition to the Recommendation on the Application of Article 36 of the Euratom Treaty [1] regulations for drinking water are given in Council Directive 98/83/EC [41]. According to this directive the parameters tritium and the total indicative dose should be monitored. Screening methods for gross α- and gross β-activity concentrations may be used to monitor the total indicative dose. If the gross α- and gross β-activity concentrations are less than 0.1 and 1.0 $Bq \cdot L^{-1}$, respectively, one can assume that the total indicative dose is less than the set limit of 0.1 $mSv \cdot year^{-1}$ [42, 43].

In the Netherlands, drinking water production stations monitor raw input water for $^{3}H$-, gross α -, gross β- and residual β-activity concentrations. The monitoring frequency per location ranges from once to 39 times per year depending on the volume of water produced. The activity concentrations are averaged per production station.

The results for 2009 are presented in Table 6.1. For gross α, $^{3}H$, gross β and residual β several hundred analyses were performed divided over 174 to 195 production stations.

*Table 6.1: Analyses on drinking water in 2009.*

| Parameter | Gross α | $^{3}H$ | Residual β | Gross β |
|---|---|---|---|---|
| Average value [(1)] | < 0.1 $Bq \cdot L^{-1}$ | < 4.0 $Bq \cdot L^{-1}$ | < 0.3 $Bq \cdot L^{-1}$ | < 0.3 $Bq \cdot L^{-1}$ |
| No. of all production stations | 187 | 191 | 174 | 195 |
| No. of all analyses | 350 | 407 | 392 | 436 |
| Maximum value [(2)] | 0.1 $Bq \cdot L^{-1}$ | 14 $Bq \cdot L^{-1}$ | 0.5 $Bq \cdot L^{-1}$ | 0.8 $Bq \cdot L^{-1}$ |
| No. of production stations [(3)] | 3 | 1 | 1 | 1 |
| No. of analyses [(4)] | 1-2 | 4 | 1 | 1 |

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

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

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

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

In 2009, the gross α-activity concentration averaged per production station did not exceed 0.1 $Bq \cdot L^{-1}$ at any of the 187 production stations.

For $^{3}H$, gross β and residual β the results are within the range of those in previous years [5, 31, 44, 45, 46, 47]. Since there is almost no $^{40}K$ present, there is no difference between average gross β- and residual β-activity concentrations. The gross β-activity concentrations were below 1.0 $Bq \cdot L^{-1}$. The $^{3}H$-activity concentrations were below the set limit of 100 $Bq \cdot L^{-1}$ [41, 43].

The activity of natural nuclides, such as $^{226}Ra$ and $^{222}Rn$, in Dutch drinking water is very low. In 1994, a survey was carried out to determine the radon activity of Dutch water [48]. The average concentration found was 2.2 $Bq \cdot L^{-1}$ for drinking water produced from groundwater. The difference between this value and those mentioned in Table 6.1 is due to the contribution of short-lived and volatile

natural radionuclides (radon daughters), which are not included in the gross α-, gross β- and residual β-activity concentrations.

# 7 Milk

RIKILT - Institute of Food Safety monitors radioactivity in milk on a weekly basis mainly via the National Monitoring Network Radioactivity in Food (Landelijk Meetnet Radioactiviteit in Voedsel, LMRV). The LMRV is a monitoring network that in principal is set up as an emergency network for monitoring relatively high contamination levels. The LMRV consists of 70 NaI-monitors of which 26 are stationed at dairy factories. The weekly samples of all locations are combined into a monthly average for the whole country. The monthly averages for 2009 are presented in Table 7.1. None of the samples exceeded the limit of 370 $Bq \cdot kg^{-1}$ set by the European Union [51].

*Table 7.1: Monthly averaged activity concentrations in milk in 2009*

| **Month** | **Number of samples** | **$^{40}K$ $Bq \cdot L^{-1}$** | **$^{60}Co$ $Bq \cdot L^{-1}$** | **$^{131}I$ $Bq \cdot L^{-1}$** | **$^{134}Cs$ $Bq \cdot L^{-1}$** | **$^{137}Cs$ $Bq \cdot L^{-1}$** |
|---|---|---|---|---|---|---|
| January | 72 | 49.0 ± 6.3 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| February | 72 | 48.8 ± 5.7 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| March | 85 | 48.8 ± 6.8 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| April | 69 | 47.9 ± 6.0 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| May | 96 | 50.9 ± 9.1 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| June | 58 | 51.4 ± 10.6 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| July | 73 | 49.7 ± 12.6 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| August | 56 | 53.3 ± 13.7 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| September | 64 | 49.8 ± 9.3 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| October | 53 | 51 ± 14.5 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| November | 70 | 60.6 ± 12.3 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| December | 59 | 61.8 ± 14.7 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |
| Average | 827 (1) | 51.7 ± 11.1 | < 1.4 | < 0.6 | < 0.6 | < 0.5 |

*(1) Yearly total.*

The Institute for Food Safety analysed 47 milk samples for $^{90}Sr$ in 2009. The samples were collected across the Netherlands. The $^{90}Sr$-activity concentration was below the detection limit (5 $Bq \cdot L^{-1}$) in all samples taken.

# 8 Food

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

The measurements on food performed by the Food and Consumer Product Safety Authority were carried out according to standard procedures [49, 50]. The results for 2009 are presented in Table 8.1, a total of 592 samples were analysed. None of the samples exceed the set limit of 600 $Bq \cdot kg^{-1}$ (for milk and dairy products 370 $Bq \cdot kg^{--1}$) [51].

Since 2005, the Food and Consumer Product Safety Authority yearly monitors activity concentrations in a mixed diet. In 2009, during a period of 4 weeks 592 samples were taken from retail shops, auctions and distribution centres, including 101 samples of honey [52]. However honey is not considered to be part of the mixed diet, samples are taken each year because it is a product that is known to contain possible higher levels of radioactivity.
The separate ingredients were divided in 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.

In 2009, RIKILT - Institute of Food Safety also measured radioactivity in food products as part of a monitoring program for export certification, especially meat and eggs. Samples were taken every 2 weeks and measurements were carried out according to standard procedures. The results for 2009 are presented in Table 8.2, a total of 927 samples were analysed. None of the samples exceed the set limit of 600 $Bq \cdot kg^{-1}$ (for milk and dairy products 370 $Bq \cdot kg^{-1}$). In addition, radioactivity was measured in 484 food products for individual screening purposes via the National Monitoring Network Radioactivity in Food, especially fruit, fruit products and vegetables (data not shown).
RIKILT - Institute of Food Safety analysed 12 mixed diets for $^{90}Sr$ content in 2009. The $^{90}Sr$ concentration was below the detection limit of 10 $Bq \cdot kg^{-1}$ in all meals.

## 8.1 Honey

In total 101 samples of honey were analysed [52]. The activity (sum of $^{134}Cs$ and $^{137}Cs$) was found to be below the set limit of 600 $Bq \cdot kg^{-1}$ [51]. Only 15 samples of honey contained $^{137}Cs$. The activity varied from 11.6 up to 347 $Bq \cdot kg^{-1}$.

## 8.2 Game and poultry

All 30 samples in the product group 'Game and poultry' measured by RIKILT (Table 8.2) that contained $^{137}Cs$ were game. The activity varied from 3.0 up to 266 $Bq \cdot kg^{-1}$. The activity (sum of $^{134}Cs$ and $^{137}Cs$) was below the set limit of 600 $Bq \cdot kg^{-1}$ [51].

*Table 8.1: Results of analysis of food for $^{134}Cs$ and $^{137}Cs$ in 2009 as measured by the 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 | 75 | < 7.6 (0) | < 6.0 (0) |
| Vegetables | 125 | < 7.6 (0) | < 6.0 (0) |
| Fruit and fruit products | 44 | < 7.6 (0) | < 6.0 (0) |
| Milk and dairy products | 57 | < 7.6 (0) | < 6.0 (0) |
| Meat and meat products | 84 | < 7.6 (0) | < 6.0 (0) |
| Game and poultry | 39 | < 7.6 (0) | < 6.0 (0) |
| Salads | 28 | < 7.6 (0) | < 6.0 (0) |
| Oil and butter | 39 | < 7.6 (0) | < 6.0 (0) |
| Honey | 101 | < 7.6 (0) | 11.6 – 347 (15) |

*(1) Number of positive samples between brackets*

*Table 8.2: Results of analysis of food for $^{134}Cs$ and $^{137}Cs$ in 2009 as measured by RIKILT - Institute of Food Safety.*

| **Product** | **Number of samples** | **$^{134}Cs$ (1) Bq·kg$^{-1}$** | **$^{137}Cs$ (1) Bq·kg$^{-1}$** |
|---|---|---|---|
| Vegetables | 54 | < 0.6 (0) | < 0.5 (0) |
| Meat and meat products | 492 | < 0.6 (0) | < 0.5 (0) |
| Game and poultry | 200 | < 0.6 (0) | 3.0-266 (30) |
| Eggs | 118 | < 0.6 (0) | < 0.5 (0) |
| Fish and seafood products | 63 | < 0.6 (0) | < 0.5 (0) |

*(1) Number of positive samples between brackets*

# 9 Nuclear power plant at Borssele

The Nuclear Research & consultancy Group (NRG) is commissioned by Elektriciteits-Productiemaatschappij Zuid-Nederland (N.V. EPZ) to perform monthly measurements on environmental samples taken in the vicinity of the nuclear power plant at Borssele (owned by N.V. EPZ). Samples are taken to monitor the compartments air, water and soil. The monitoring program presented [53] here forms only part of the total monitoring program performed near the nuclear power plant. A more detailed description of the monitoring program, and underlying strategy is reported elsewhere [54, 55]. The 2009 monitoring program is shown in Table 9.1 and Figure 9.1. Radioactive nuclides were determined in air dust, grass, soil, water, suspended solids, seaweed and sediment.

*Table 9.1: Monitoring program for environmental samples in the vicinity of the nuclear power plant at Borssele in 2009. The location numbers correspond with the location numbers given in Figure 9.1.*

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

*(1) γ-spectroscopic analysis of specific γ-emitting nuclides: $^{60}Co$, $^{137}Cs$, natural occurring radionuclides and elemental and organically bound $^{131}I$.*

*(2) Analysis is performed on a combined sample of monthly samples of all four or five locations.*

*(3) γ-spectroscopic analysis of specific γ-emitting nuclides: $^{60}Co$, $^{131}I$ and $^{137}Cs$.*

*(4) The four samples taken near the outlet are not shown in Figure 9.1.*

*(5) γ-spectroscopic analysis of specific γ-emitting nuclides: $^{54}Mn$, $^{60}Co$, $^{134}Cs$ and $^{137}Cs$.*

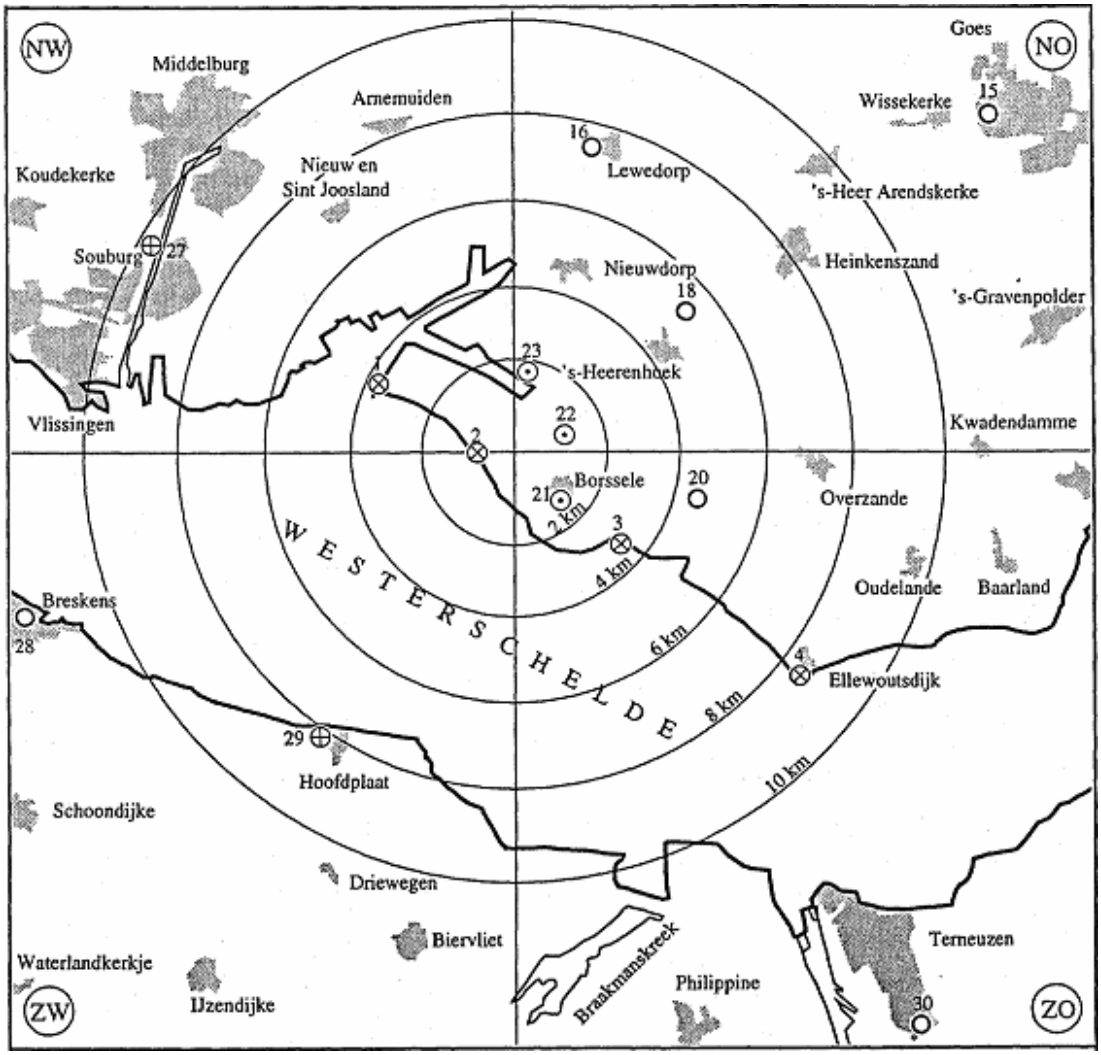



*Figure 9.1: Overview of monitoring locations for the monitoring program in the vicinity of the nuclear power plant at Borssele as conducted by NRG. The numbers given in Table 9.1 correspond with the locations in the map.*

## 9.1 Air

The results of gross α- and β-activity concentrations in air dust are presented in Tables A15 and A16.
Due to large uncertainties caused by variations in dust thickness on the filters, gross α-activity concentrations in air dust should be regarded as indicative values [6].
The period between sampling and analysis is at least five days, which is long compared to the decay time of the short-lived decay products of $^{222}$Rn and $^{220}$Rn. This is to ensure that these naturally occurring decay products do not contribute to the measured α- and β-activity concentrations.

The yearly averages of the gross α- and β-activity concentrations of long-lived nuclides in 2009 are within the range of the results from 2007 and 2008, as is illustrated in Figures 9.2 and 9.3.

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

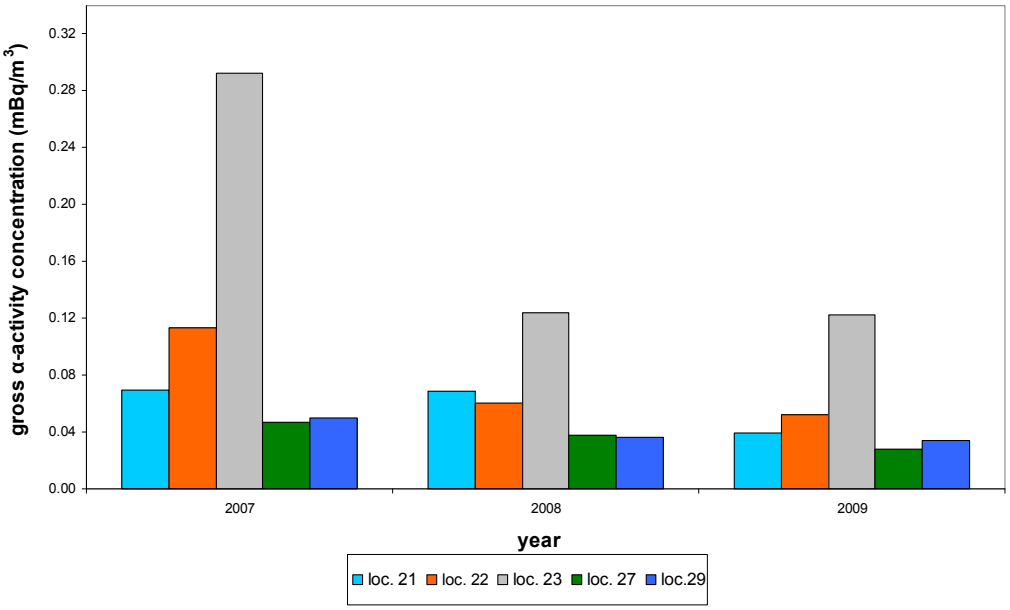



*Figure 9.2: Yearly averaged gross α-activity concentrations in air dust at five locations in the vicinity of Borssele (see Figure 9.1).*

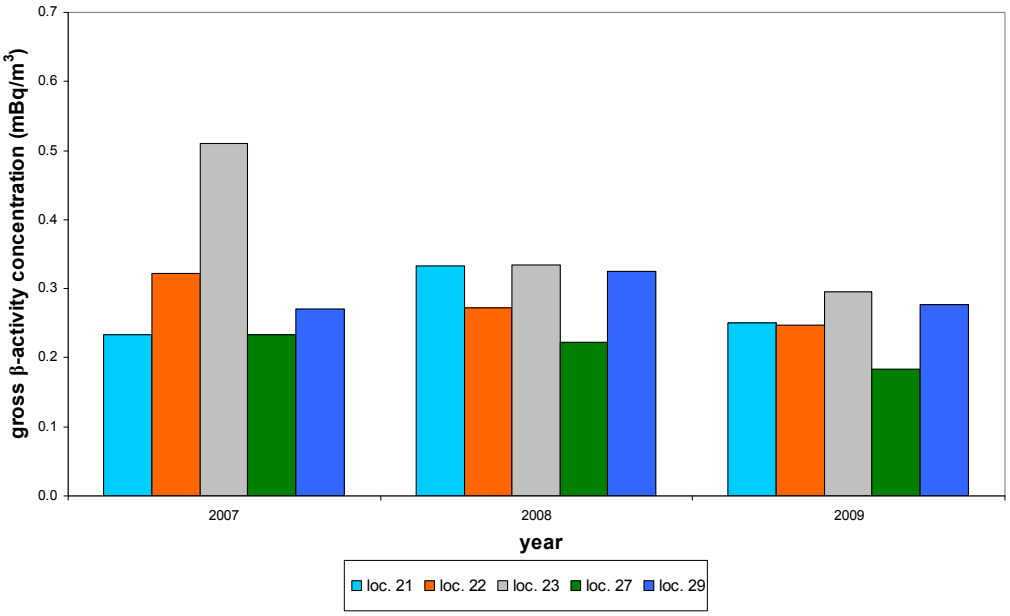



*Figure 9.3: Yearly averaged gross β-activity concentrations in air dust at five locations in the vicinity of Borssele (see Figure 9.1).*

## 9.2 Soil

The results for the nuclides considered in the gammaspectroscopic analysis in grass and soil are given in Tables A18 and A19. The four soil samples are taken near the outlet of the nuclear power plant. The yearly averaged concentrations of $^{54}$Mn, $^{60}$Co, $^{134}$Cs and $^{137}$Cs in soil in 2009 are within the range of those in previous years [55, 56, 57].

## 9.3 Water

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

The yearly averages of the residual β and $^{3}$H-activity concentrations in water in 2009 are within the range of the results from 2007 and 2008, as is illustrated in Figure 9.4 and 9.5.

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

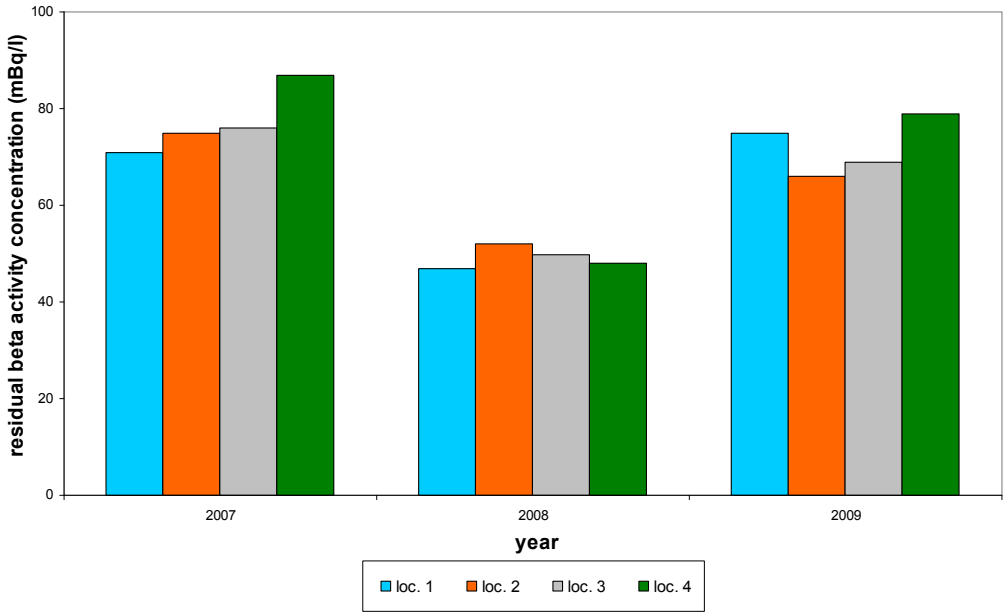



*Figure 9.4: Yearly averaged residual β-activity concentrations in water from the Westerscheldt at four locations in the vicinity of Borssele (see Figure 9.1).*

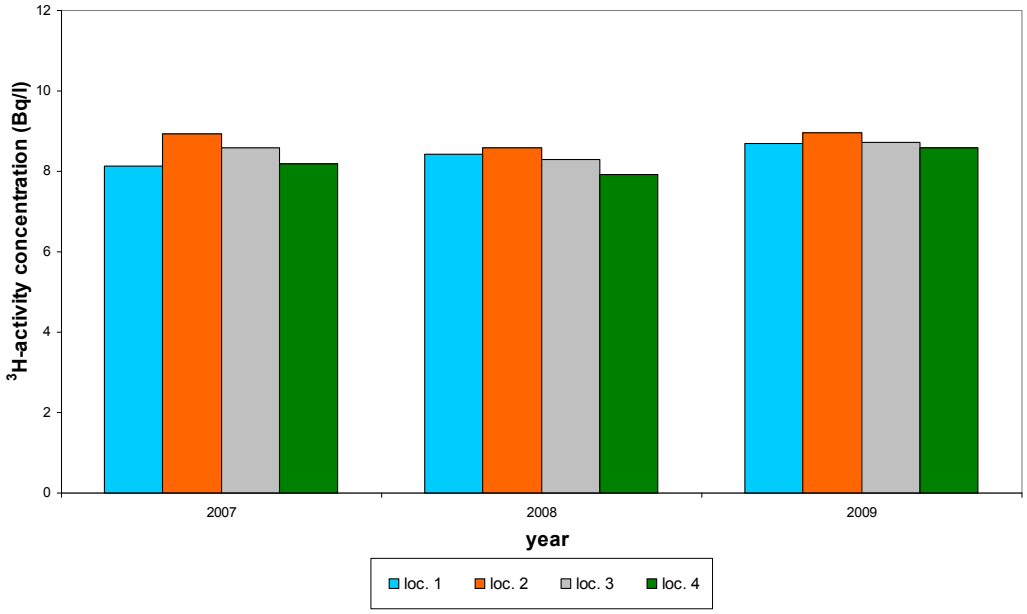



*Figure 9.5: Yearly averaged $^3$H-activity concentrations in water from the Westerscheldt at four locations in the vicinity of Borssele (see Figure 9.1).*

# 10 Conclusions

The yearly total activity in deposition from $^{210}$Po (32.5 Bq·m$^{-2}$) is the highest since 1993, and approximately the same level as in 2008.

In surface waters, the yearly averaged gross α-activity concentration exceeds the target value of 100 mBq·L$^{-1}$ in the Noordzeekanaal (220 mBq·L$^{-1}$; all of 6 samples above target value), Nieuwe Waterweg, (113 mBq·L$^{-1}$; 6 out of 13 samples above target value) and Scheldt (380 mBq·L$^{-1}$; all of 13 samples above target value). The concentrations are within the range of those in previous years.

The yearly averaged $^{3}$H-activity concentration exceeds the target value of 10 Bq·L$^{-1}$ in the Scheldt (11.9 Bq·L$^{-1}$; 4 out of 7 samples above target value) and the Meuse (14.0 Bq·L$^{-1}$; 4 out of 13 samples above target value). The concentrations are within the range of those in previous years.

The yearly averaged $^{226}$Ra-activity concentration exceeds the target value of 5 mBq·L$^{-1}$ in the Scheldt (12.4 mBq·L$^{-1}$; all of 7 samples above target value). The concentration is within the range of those in previous years.

The $^{60}$Co-activity concentration in suspended solids in the Meuse exceeds the target value of 10 Bq·kg$^{-1}$ in 6 out of 45 samples taken, but the yearly averaged concentration in the Meuse is below the target value.

The $^{131}$I-activity concentration in suspended solids in the Meuse exceeds the target value of 20 Bq·kg$^{-1}$ in 10 out of 45 samples taken, but the yearly averaged concentration in the Meuse is below the target value. The yearly averaged $^{131}$I-activity concentration in the Noordzeekanaal exceeds the target value, and is higher than those in previous years (29 Bq·kg$^{-1}$; all of 6 samples above target value).

The yearly averaged $^{210}$Pb-activity concentration in suspended solids exceeds the target value of 100 Bq·kg$^{-1}$ in the Nieuwe Waterweg (112 Bq·kg$^{-1}$; 4 out of 7 samples above target value), Rhine (120 Bq·kg$^{-1}$; all of 6 samples above target value) and Meuse (153 Bq·kg$^{-1}$; 5 out of 6 samples above target value). The concentrations are within the range of those in previous years.

For seawater, the yearly averaged gross α-activity concentrations in the Southern North Sea, Eems-Dollard and Wadden Sea East, are higher than those in previous years.

The yearly averaged residual β-activity concentrations in the Westerscheldt and the Southern North Sea, are higher than those in previous years.

The gross α-activity concentration in drinking water averaged per production station did not exceed the screening value (0.1 Bq·L$^{-1}$) at any of the 187 production stations.

The results of all other radioactivity measurements are within the range of those in previous years.

Since 2009, the determination of Sr-90 in mixed diet is carried out by RIKILT - Institute of Food Safety. The Netherlands now fully comply with the Euratom recommendations.

# Appendix A Result tables

*Table A1: Weekly averaged gross α- and gross β-activity concentrations in air dust sampled with a High Volume Sampler at RIVM in 2009.*

| **Week [1] Number** | **Gross α [2] $mBq.m^{-3}$** | **Gross β $mBq.m^{-3}$** | **Week [1] number** | **Gross α [2] $mBq.m^{-3}$** | **Gross β $mBq.m^{-3}$** |
|---|---|---|---|---|---|
| 1 [3] | 0.038 | 0.39 ± 0.04 | 27 | 0.025 | 0.29 ± 0.03 |
| 2 | 0.042 | 0.81 ± 0.07 | 28 | 0.023 | 0.32 ± 0.03 |
| 3 | 0.021 | 0.32 ± 0.03 | 29 | 0.037 | 0.32 ± 0.03 |
| 4 [3, 4] | 0.025 | 0.23 ± 0.03 | 30 | 0.032 | 0.34 ± 0.04 |
| 5 [3, 4] | 0.036 | 0.67 ± 0.07 | 31 | 0.024 | 0.44 ± 0.05 |
| 6 | 0.015 | 0.24 ± 0.03 | 32 | 0.028 | 0.44 ± 0.05 |
| 7 | 0.036 | 0.27 ± 0.03 | 33 | 0.045 | 0.60 ± 0.07 |
| 8 | 0.031 | 0.30 ± 0.03 | 34 | 0.032 | 0.44 ± 0.05 |
| 9 | 0.029 | 0.26 ± 0.03 | 35 | 0.025 | 0.33 ± 0.04 |
| 10 | 0.034 | 0.18 ± 0.02 | 36 | 0.025 | 0.51 ± 0.05 |
| 11 | 0.026 | 0.30 ± 0.03 | 37 | 0.022 | 0.50 ± 0.05 |
| 12 | 0.020 | 0.31 ± 0.03 | 38 | 0.045 | 0.64 ± 0.07 |
| 13 | 0.019 | 0.26 ± 0.03 | 39 | 0.022 | 0.35 ± 0.04 |
| 14 [3] | 0.028 | 0.49 ± 0.05 | 40 | 0.030 | 0.39 ± 0.04 |
| 15 | 0.08 | 0.88 ± 0.09 | 41 | 0.023 | 0.38 ± 0.04 |
| 16 | 0.035 | 0.59 ± 0.06 | 42 [3, 4] | 0.036 | 0.46 ± 0.05 |
| 17 | 0.021 | 0.48 ± 0.05 | 43 [3] | 0.036 | 0.45 ± 0.05 |
| 18 | 0.029 | 0.39 ± 0.04 | 44 | 0.031 | 0.48 ± 0.05 |
| 19 | 0.023 | 0.45 ± 0.05 | 45 | 0.028 | 0.33 ± 0.04 |
| 20 | 0.027 | 0.43 ± 0.05 | 46 | 0.028 | 0.44 ± 0.05 |
| 21 | 0.021 | 0.30 ± 0.03 | 47 | 0.046 | 0.72 ± 0.08 |
| 22 | 0.018 | 0.41 ± 0.04 | 48 | 0.021 | 0.29 ± 0.03 |
| 23 | 0.025 | 0.36 ± 0.04 | 49 | 0.025 | 0.25 ± 0.03 |
| 24 | 0.026 | 0.40 ± 0.04 | 50 [3] | 0.029 | 0.59 ± 0.06 |
| 25 | 0.019 | 0.35 ± 0.04 | 51 | 0.035 | 0.55 ± 0.06 |
| 26 | 0.039 | 0.76 ± 0.08 | 52 | 0.016 | 0.23 ± 0.03 |
| Average | | | | 0.029 | 0.421 ± 0.007 [5] |
| SD [6] | | | | 0.010 | 0.15 |

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

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

*[3] Sampling occurred with a lower flow (about one third of regular flow) during part of the week (varying from 0.4 to 1.2 days), due to problems with the High Volume Sampler.*

*[4] Sampling did not occur during part of the week (varying from 0.4 to 3.1 days) due to maintenance on the High Volume Sampler.*

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

*[6] SD is the standard deviation of the weekly results.*

Table A2: Detection limits (μBq/$m^3$) in the residue measurement of air dust sampled during a 7 days sampling period with a HVS at RIVM in 2010. Between 2000 and July 2009 the detection limits are higher than before 2000 [58] due to a different detector set up. Measurements were carried out on a coaxial detector with a 10 days delay between sampling and start of measurement and a sample volume of about 50,000 $m^3$. The detector set up was changed in the second half of 2009, including a change in counting time from 100,000 seconds to 178,200 seconds. Therefore detection limits are lower from July onwards.

| **Nuclide** | **Detection limit μBq·$m^{-3}$** | |
|---|---|---|
| | **Januari-June** | **July-December** |
| $^{7}$Be | 12.5 | 3.9 |
| $^{22}$Na | 1.2 | 0.4 |
| $^{60}$Co | 1.5 | 0.4 |
| $^{131}$I | 3.0 (1) | |
| $^{137}$Cs | 1.1 | 0.3 |
| $^{210}$Pb | 22.2 | 7.7 |

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

*Table A3: Weekly averaged $^{7}$Be-, $^{137}$Cs- and $^{210}$Pb-activity concentrations in air dust sampled with a HVS at RIVM in 2009. As from week 27 a new detector set up is used, which results in lower detection limits (see Table A2).*

| Week number | Period | $^{7}$Be µBq·m$^{-3}$ | $^{137}$Cs µBq·m$^{-3}$ | $^{210}$Pb µBq·m$^{-3}$ |
|---|---|---|---|---|
| 1 (1) | 02/01-09/01 | 3600 ± 300 | < 1.5 | 330 ± 40 |
| 2 | 09/01-16/01 | 3300 ± 200 | < 6 | 880 ± 70 |
| 3 | 16/01-23/01 | 3200 ± 300 | < 1.8 | 290 ± 30 |
| 4 (1, 2) | 23/01-29/01 | 2900 ± 300 | < 3 | 220 ± 30 |
| 5 (1, 2) | 29/01-05/02 | 3600 ± 300 | < 2 | 710 ± 70 |
| 6 | 05/02-13/02 | 2400 ± 200 | < 1.6 | 200 ± 20 |
| 7 | 13/02-20/02 | 1850 ± 160 | < 2 | 270 ± 30 |
| 8 | 20/02-27/02 | 4500 ± 400 | < 1.8 | 210 ± 30 |
| 9 | 27/02-06/03 | 2900 ± 300 | < 1.0 | 250 ± 30 |
| 10 | 06/03-13/03 | 2800 ± 200 | < 1.9 | 125 ± 14 |
| 11 | 13/03-20/03 | 4100 ± 400 | < 2 | 240 ± 30 |
| 12 | 20/03-27/03 | 3900 ± 300 | < 8 | 210 ± 20 |
| 13 | 27/03-03/04 | 3100 ± 300 | < 2 | 200 ± 20 |
| 14 (1) | 03/04-10/04 | 3400 ± 300 | < 2 | 460 ± 50 |
| 15 | 10/04-17/04 | 7300 ± 600 | < 2 | 940 ± 90 |
| 16 | 17/04-24/04 | 5700 ± 500 | < 11 | 560 ± 50 |
| 17 | 24/04-01/05 | 5800 ± 500 | < 2 | 420 ± 40 |
| 18 | 01/05-08/05 | 4800 ± 400 | < 2 | 330 ± 30 |
| 19 | 08/05-15/05 | 6900 ± 600 | < 7 | 280 ± 30 |
| 20 | 15/05-22/05 | 5500 ± 500 | < 4 | 270 ± 30 |
| 21 | 22/05-29/05 | 3300 ± 300 | < 1.9 | 220 ± 20 |
| 22 | 29/05-05/06 | 5600 ± 500 | < 4 | 290 ± 30 |
| 23 | 05/06-12/06 | 4900 ± 400 | < 1.6 | 240 ± 30 |
| 24 | 12/06-19/06 | 5500 ± 500 | < 1.8 | 280 ± 30 |
| 25 | 19/06-26/06 | 3800 ± 400 | < 0.9 | 240 ± 20 |
| 26 | 26/06-03/07 | 4900 ± 500 | < 1.3 | 710 ± 70 |

*Continued on the next page.*

Table A3: Continued

| Week number | Period | $^{7}$Be µBq·m$^{-3}$ | $^{137}$Cs µBq·m$^{-3}$ | $^{210}$Pb µBq·m$^{-3}$ |
|---|---|---|---|---|
| 27 | 03/07-10/07 | 3900 ± 400 | < 0.5 | 220 ± 20 |
| 28 | 10/07-17/07 | 4200 ± 400 | < 0.5 | 220 ± 20 |
| 29 | 17/07-24/07 | 3500 ± 300 | < 0.4 | 220 ± 20 |
| 30 | 24/07-31/07 | 4300 ± 400 | < 0.3 | 230 ± 20 |
| 31 | 31/07-07/08 | 5600 ± 500 | < 0.4 | 330 ± 30 |
| 32 | 07/08-14/08 | 5500 ± 500 | < 0.5 | 350 ± 30 |
| 33 | 14/08-21/08 | 5600 ± 600 | < 0.7 | 530 ± 50 |
| 34 | 21/08-28/08 | 5100 ± 500 | < 0.4 | 330 ± 30 |
| 35 | 28/08-04/09 | 3700 ± 400 | < 0.5 | 270 ± 30 |
| 36 | 04/09-11/09 | 4700 ± 500 | < 0.5 | 450 ± 40 |
| 37 | 11/09-18/09 | 4700 ± 500 | < 0.7 | 400 ± 40 |
| 38 | 18/09-25/09 | 4700 ± 500 | < 0.6 | 600 ± 60 |
| 39 | 25/09-02/10 | 2700 ± 300 | < 0.5 | 310 ± 30 |
| 40 | 02/10-09/10 | 3800 ± 400 | < 0.7 | 320 ± 30 |
| 41 | 09/10-16/10 | 4200 ± 400 | < 0.5 | 300 ± 30 |
| 42 (1, 2) | 16/10-23/10 | 3400 ± 300 | < 0.9 | 460 ± 50 |
| 43 (1) | 23/10-30/10 | 2600 ± 300 | < 0.5 | 430 ± 40 |
| 44 | 30/10-06/11 | 2700 ± 300 | < 0.7 | 520 ± 50 |
| 45 | 06/11-13/11 | 2600 ± 300 | < 0.5 | 320 ± 30 |
| 46 | 13/11-20/11 | 4500 ± 400 | < 0.5 | 380 ± 40 |
| 47 | 20/11-27/11 | 5000 ± 500 | < 0.6 | 610 ± 60 |
| 48 | 27/11-04/12 | 2900 ± 300 | < 0.5 | 220 ± 20 |
| 49 | 04/12-11/12 | 3200 ± 300 | < 0.5 | 200 ± 20 |
| 50 (1) | 11/12-18/12 | 2900 ± 300 | 0.56 ± 0.12 | 590 ± 60 |
| 51 | 18/12-24/12 | 3400 ± 300 | 0.93 ± 0.16 | 520 ± 50 |
| 52 | 24/12-31/12 | 2200 ± 200 | < 0.7 | 230 ± 20 |
| Average | | 4060 ± 50 (3) | 0.74 ± 0.10 (3, 4) | 363 ± 5 (3) |
| SD (5) | | 1200 | 0.18 | 180 |

*(1) Sampling occurred with a lower flow (about one third of regular flow) during part of the week (varying from 0.4 to 1.2 days of the week), due to problems with the High Volume Sampler.*

*(2) Sampling did not occur during part of the week (varying from for 0.4 to 3.1 days of the week), due to problems with the High Volume Sampler.*

*(3) The uncertainty in the yearly average is equal to the square root of the sum of the squared weekly uncertainties divided by the number of weeks. Uncertainties are given as 1$\sigma$.*

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

*(5) SD is the standard deviation of the weekly results.*

*Table A4: Precipitation per month and monthly deposited $^{3}H$-, long-lived gross α- and gross β-activity sampled at RIVM in 2009.*

| Month | Precipitation mm | $^{3}H$ (1) Bq·m$^{-2}$ | Gross α Bq·m$^{-2}$ | Gross β Bq·m$^{-2}$ |
|---|---|---|---|---|
| January | 55.8 | < 90 | 1.9 ± 0.3 | 3.7 ± 0.4 |
| February | 56.1 | < 90 | 2.02 ± 0.18 | 5.1 ± 0.4 |
| March | 54.5 | < 90 | 1.7 ± 0.2 | 3.9 ± 0.3 |
| April | 19.1 | < 30 | 9.2 ± 0.8 | 17.3 ± 1.3 |
| May | 61.4 | < 100 | 4.7 ± 0.5 | 12.7 ± 1.0 |
| June | 56.1 | < 90 | 4.2 ± 0.4 | 7.9 ± 0.6 |
| July | 96.9 | < 170 | 3.2 ± 0.4 | 9.7 ± 0.8 |
| August | 58.4 | < 100 | 3.5 ± 0.4 | 9.9 ± 0.8 |
| September | 23.7 | < 40 | 1.4 ± 0.2 | 3.2 ± 0.3 |
| October | 82.6 | < 130 | 1.7 ± 0.3 | 8.5 ± 0.7 |
| November | 138.0 | < 200 | 2.4 ± 0.3 | 9.1 ± 0.7 |
| December | 91.3 | < 150 | 0.95 ± 0.19 | 4.4 ± 0.3 |
| Total | 793.5 | - | 36.9 ± 1.3 (2) | 95 ± 2 (2) |
| Lower limit (3) | - | 0 | - | - |
| Upper limit (3) | - | 1330 | - | - |

*(1) The detection limit (Bq·m$^{-2}$) is mainly dependent on the amount of precipitation since the detection limit of the counting sample itself is more or less constant (1.7 Bq·L$^{-1}$).*

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

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

*Table A5: Yearly totals for long-lived gross α-, gross β- and $^{3}H$-activity in deposition for 1993-2009. Either the yearly total with uncertainty [(1)] or the lower and upper limits [(2)] of the 68% confidence range are given.*

| Year | Precipitation mm | $^{3}H$ Bq·m$^{-2}$ | Gross α Bq·m$^{-2}$ | Gross β Bq·m$^{-2}$ |
|---|---|---|---|---|
| 1993 | 886 | 1310 ± 30 | 54.3 ± 0.7 | 87.8 ± 0.8 |
| 1994 | 1039 | 1210 ± 30 | 52 ± 2 | 91 ± 3 |
| 1995 | 724 | 970 ± 40 | 33.6 - 44.6 | 95 ± 8 |
| 1996 | 626 | 970 ± 50 | 16.4 ± 1.5 | 67 ± 5 |
| 1997 | 760 | 1160 ± 60 | 22.0 - 25.0 | 87 ± 3 |
| 1998 | 1238 | 1090 - 2190 | 31.1 ± 1.3 | 106 ± 3 |
| 1999 | 916 | 1420 - 1900 | 25.5 ± 1.1 | 84 ± 2 |
| 2000 | 935 | 260 - 1440 | 35.2 ± 1.3 | 104 ± 3 |
| 2001 | 1053 | 0 - 2420 | 23.9 ± 1 | 97 ± 3 |
| 2002 | 965 | 300 - 1710 | 20.6 ± 0.9 | 97 ± 2 |
| 2003 | 605 | 260 - 1080 | 13.6 - 16.7 | 70.0 ± 1.8 |
| 2004 | 875 | 0 - 1600 | 14.3 - 17.1 | 73.5 ± 1.8 |
| 2005 | 856 | 0 - 1530 | 17.6 ± 1.0 | 88 ± 2 |
| 2006 | 854 | 280 - 1820 | 25.7 ± 1.5 | 98 ± 3 |
| 2007 | 984 | 335 - 1600 | 24.4 ± 1.2 | 85 ± 2 |
| 2008 | 908 | 102 - 1550 | 39.4 ± 1.5 | 106 ± 3 |
| 2009 | 794 | 0 - 1330 | 36.9 ± 1.3 | 95 ± 2 |

*[(1)] Uncertainties are given as 1σ.*

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

*Table A6: Monthly deposited $^{210}Po$-activity [(1)] sampled at RIVM in 2009.*

| Month | $^{210}Po$ Bq·m$^{-2}$ |
|---|---|
| January | 1.99 ± 0.12 |
| February | 2.57 ± 0.11 |
| March | 1.83 ± 0.08 |
| April | 8.4 ± 0.4 |
| May | 3.6 ± 0.2 |
| June | 3.7 ± 0.3 |
| July | 3.08 ± 0.18 |
| August | 2.23 ± 0.17 |
| September | 1.19 ± 0.07 |
| October | 1.83 ± 0.10 |
| November | 1.40 ± 0.12 |
| December | 0.64 ± 0.08 |
| Total | 32.5 ± 0.7 [(2)] |
| Lower limit [(3)] | - |
| Upper limit [(3)] | - |

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

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

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

*Table A7: Yearly totals for $^{7}$Be, $^{137}$Cs, $^{210}$Pb- and $^{210}$Po-activity in deposition for 1993-2009. 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·m$^{-2}$ | Bq·m$^{-2}$ | Bq·m$^{-2}$ | Bq·m$^{-2}$ | Bq·m$^{-2}$ |
| 1993 | 1090 ± 20 | 0.50 - 0.76 | 105 ± 2 | 78 ± 3 | 7.2 ± 0.5 |
| 1994 | 1320 ± 30 | 0.36 - 0.71 | 118 ± 3 | 82 ± 3 | 12.0 - 14.2 |
| 1995 | 990 ± 20 | 0.37 - 0.63 | 96 ± 2 | n/a [(5)] | n/a [(5)] |
| 1996 | 920 ± 20 | 0.52 - 0.83 | 63 - 67 | 57 ± 3 | 9 ± 2 |
| 1997 | 1090 ± 30 | 0.11 - 0.69 | 65 - 69 | 80 ± 4 | 0 - 10.2 |
| 1998 | 1840 ± 50 | 0.56 - 0.85 | 162 ± 4 | 91 ± 4 | 3.0 - 15.1 |
| 1999 | 1580 ± 30 | 1.16 - 1.99 | 158 ± 4 | - [(6)] | 0.7 - 5.3 |
| 2000 | 1490 ± 30 | 0 - 4.82 | 177 ± 6 | - | 0.6 - 8.0 |
| 2001 | 1480 ± 30 | 0 - 4.50 | 83 - 104 | - | 6.5 - 9.4 |
| 2002 | 1510 ± 30 | 0 - 5.22 | 119 - 142 | - | 6.1 - 8.5 |
| 2003 | 1000 - 1050 | 0 - 4.69 | 88 - 113 | - | 4.3 - 5.6 |
| 2004 | 1330 ± 30 | 0.22 - 5.53 | 64 - 102 | - | 5.4 - 7.7 |
| 2005 | 1320 ± 30 | 0 - 6.09 | 87 - 117 | - | 8.9 - 10.2 |
| 2006 | 1400 ± 30 | 0.06 - 7.47 | 66 - 103 | - | 14.8 - 16.4 [(7)] |
| 2007 | 1760 ± 40 | 0.11 - 7.37 | 72 - 132 | - | 13.4 ± 0.4 [(7)] |
| 2008 | 1990 ± 40 | 0 - 7.63 | 63 - 143 | - | 29.4 ± 0.7 |
| 2009 | 1410 ± 30 | 0 - 4.3 | 82 - 125 | - | 32.5 ± 0.7 |

*[(1)] Uncertainties are given as 1σ.*

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

*[(3)] Data from γ-spectroscopy.*

*[(4)] Data from α-spectroscopy.*

*[(5)] Not available. Result rejected [59].*

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

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

*Table A8: Weekly deposited $^{7}$Be-, $^{137}$Cs- and $^{210}$Pb-activity (1) sampled at RIVM in 2009. As from week 27 a new detector set up is used, which results in lower detection limits.*

| Week Number | Period | Precipitation mm | $^{7}$Be Bq·m$^{-2}$ | $^{137}$Cs Bq·m$^{-2}$ | $^{210}$Pb Bq·m$^{-2}$ |
|---|---|---|---|---|---|
| 1 | 02/01-09/01 | 6.3 | 5.4 ± 1.0 | < 0.15 | < 1.5 |
| 2 | 09/01-16/01 | 7.0 | 17 ± 2 | < 0.12 | < 1.6 |
| 3 | 16/01-23/01 | 34.5 | 20 ± 3 | < 0.16 | < 1.6 |
| 4 | 23/01-30/01 | 8.0 | 9.7 ± 1.3 | < 0.16 | < 1.7 |
| 5 | 30/01-06/02 | 6.9 | 5.2 ± 1.8 | < 0.14 | < 1.4 |
| 6 | 06/02-13/02 | 28.4 | 23 ± 3 | < 0.15 | < 4 |
| 7 | 13/02-20/02 | 16.5 | 33 ± 4 | < 0.15 | < 1.5 |
| 8 | 20/02-27/02 | 4.3 | 19 ± 4 | < 0.3 | < 3 |
| 9 | 27/02-06/03 | 5.6 | 17 ± 2 | < 0.12 | < 1.4 |
| 10 | 06/03-13/03 | 15.6 | 26 ± 3 | < 0.15 | < 1.6 |
| 11 | 13/03-20/03 | 1.6 | 13.5 ± 1.9 | < 0.15 | < 6 |
| 12 | 20/03-27/03 | 22.0 | 40 ± 5 | < 0.2 | < 1.4 |
| 13 | 27/03-03/04 | 9.7 | 18 ± 2 | < 0.08 | < 1.5 |
| 14 | 03/04-10/04 | 2.5 | 12.9 ± 1.6 | < 0.12 | 5.0 ± 0.9 |
| 15 | 10/04-17/04 | 7.3 | 49 ± 6 | < 0.13 | 6.9 ± 1.2 |
| 16 | 17/04-24/04 | 0.3 | 15 ± 2 | < 0.09 | < 4 |
| 17 | 24/04-01/05 | 9.0 | 19 ± 3 | < 0.12 | 2.9 ± 0.7 |
| 18 | 01/05-08/05 | 13.0 | 37 ± 5 | < 0.14 | 2.4 ± 0.5 |
| 19 | 08/05-15/05 | 3.5 | 33 ± 4 | < 0.14 | 3.2 ± 0.8 |
| 20 | 15/05-22/05 | 22.0 | 62 ± 7 | < 0.13 | < 4 |
| 21 | 22/05-29/05 | 22.9 | 75 ± 9 | < 0.13 | 6.9 ± 1.2 |
| 22 | 29/05-05/06 | 0.2 | 18 ± 2 | < 0.12 | 4.3 ± 0.9 |
| 23 | 05/06-12/06 | 40.0 | 63 ± 8 | < 0.14 | 2.8 ± 0.8 |
| 24 | 12/06-19/06 | 10.6 | 36 ± 4 | < 0.15 | 3.6 ± 1.2 |
| 25 | 19/06-26/06 | 0.2 | 6.7 ± 0.9 | < 0.14 | < 1.5 |
| 26 | 26/06-03/07 | 5.1 | 10.8 ± 1.5 | < 0.19 | 2.1 ± 0.7 |

*Continued on the next page.*

*Table A8: Continued.*

| Week Number | Period | Precipitation mm | $^{7}$Be Bq·m$^{-2}$ | $^{137}$Cs Bq·m$^{-2}$ | $^{210}$Pb Bq·m$^{-2}$ |
|---|---|---|---|---|---|
| 27 | 03/07-10/07 | 20.8 | 24 ± 3 | < 0.02 | 3.1 ± 0.4 |
| 28 | 10/07-17/07 | 18.0 | 45 ± 6 | < 0.02 | 1.6 ± 0.2 |
| 29 | 17/07-24/07 | 35.0 | 57 ± 8 | < 0.02 | 2.2 ± 0.3 |
| 30 | 24/07-31/07 | 23.1 | 71 ± 9 | < 0.02 | 2.4 ± 0.3 |
| 31 | 31/07-07/08 | 7.2 | 19 ± 3 | < 0.02 | 2.4 ± 0.3 |
| 32 | 07/08-14/08 | 11.5 | 18 ± 2 | < 0.02 | 1.5 ± 0.2 |
| 33 | 14/08-21/08 | 1.4 | 15 ± 2 | < 0.02 | 2.9 ± 0.4 |
| 34 | 21/08-28/08 | 2.4 | 19 ± 3 | < 0.02 | 2.9 ± 0.4 |
| 35 | 28/08-04/09 | 36.0 | 47 ± 6 | < 0.02 | 1.9 ± 0.3 |
| 36 | 04/09-11/09 | 16.3 | 20 ± 3 | < 0.03 | 0.72 ± 0.11 |
| 37 | 11/09-18/09 | 4.4 | 12.0 ± 1.6 | < 0.02 | 1.9 ± 0.2 |
| 38 | 18/09-25/09 | 0.0 | 3.7 ± 0.5 | < 0.02 | 1.6 ± 0.2 |
| 39 | 25/09-02/10 | 3.0 | 4.4 ± 0.6 | < 0.02 | 0.84 ± 0.12 |
| 40 | 02/10-09/10 | 39.5 | 31 ± 4 | < 0.02 | 1.42 ± 0.19 |
| 41 | 09/10-16/10 | 29.0 | 44 ± 6 | < 0.02 | 1.7 ± 0.2 |
| 42 | 16/10-23/10 | 3.2 | 18 ± 2 | < 0.02 | 1.17 ± 0.16 |
| 43 | 23/10-30/10 | 10.9 | 7.8 ± 1.0 | < 0.02 | 0.79 ± 0.12 |
| 44 | 30/10-06/11 | 40.3 | 39 ± 5 | < 0.02 | 2.9 ± 0.4 |
| 45 | 06/11-13/11 | 13.3 | 25 ± 3 | < 0.03 | 0.96 ± 0.14 |
| 46 | 13/11-20/11 | 9.4 | 11.5 ± 1.5 | < 0.02 | 0.87 ± 0.13 |
| 47 | 20/11-27/11 | 48.0 | 59 ± 8 | < 0.02 | 2.1 ± 0.3 |
| 48 | 27/11-04/12 | 27.0 | 20 ± 3 | < 0.02 | 0.89 ± 0.13 |
| 49 | 04/12-11/12 | 35.6 | 47 ± 6 | < 0.02 | 1.31 ± 0.18 |
| 50 | 11/12-18/12 | 4.2 | 8.2 ± 1.1 | < 0.02 | 2.1 ± 0.3 |
| 51 | 18/12-24/12 | 20.0 | 33 ± 4 | < 0.02 | 1.9 ± 0.3 |
| 52 | 24/12-31/12 | 31.5 | 32 ± 4 | < 0.02 | 0.97 ± 0.14 |
| Total [2] | | 793.5 | 1410 ± 30 | - | - |
| Lower limit [3] | | - | - | 0 | 82 |
| Upper limit [3] | | - | - | 4.3 | 125 |

*[1] Measurements are carried out using γ-spectroscopy.*

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

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

*Table A9: Yearly averaged α-activity concentration in air and ambient dose equivalent rate in 2009 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 | 68 |
| Kollumerwaard | 972 | 3.0 | 71 |
| Valthermond (3) | 974 | 3.0 | 60 |
| Vlaardingen | 976 | 3.6 | 71 |
| Braakman | 978 | 3.5 | 67 |
| Huijbergen | 980 | 3.2 | 58 |
| Houtakker | 982 | 2.7 | 65 |
| Wijnandsrade | 984 | 5.2 | 72 |
| Eibergen | 986 | 3.4 | 62 |
| De Zilk | 988 | 1.7 | 66 |
| Wieringerwerf | 990 | 2.8 | 71 |
| Vredepeel | 992 | 4.1 | 68 |
| Biddinghuizen | 994 | 3.0 | 75 |
| Bilthoven | 998 | 3.2 | 63 |

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

*(2) The station Wageningen has been replaced by the station Arnhem since December 2006.*

*(3) This station was formerly known as Witteveen.*

*Table A10: The yearly averaged ambient dose equivalent rate for the NMR stations in 2009.*

| Station | No. | Ambient dose equivalent rate nSv.h$^{-1}$ | Station | No. | Ambient dose equivalent rate nSv.h$^{-1}$ |
|---|---|---|---|---|---|
| Den Burg | 1001 | 71 | Lelystad | 1103 | 77 |
| Den Oever | 1003 | 70 | Urk | 1105 | 77 |
| Julianadorp | 1004 | 65 | Eemshaven | 1106 | 84 |
| Petten | 1006 | 62 | Uithuizen | 1107 | 83 |
| Kolhorn | 1007 | 78 | Wagenborgen | 1109 | 76 |
| Egmond Aan Zee | 1009 | 67 | Winschoten | 1110 | 73 |
| Heerhugowaard | 1011 | 73 | Ter Apel | 1111 | 73 |
| Haarlem-Noord | 1014 | 74 | Stadskanaal | 1112 | 63 |
| Nederhorst Den Berg | 1015 | 61 | Nieuweschans | 1113 | 72 |
| Enkhuizen | 1018 | 81 | Bellingwolde | 1114 | 61 |
| Oosthuizen | 1019 | 78 | Groningen | 1116 | 76 |
| Zaandam | 1021 | 69 | Leens | 1117 | 88 |
| Gouda | 1024 | 73 | Grijpskerk | 1118 | 73 |
| Dordrecht | 1027 | 63 | Meppel | 1125 | 68 |
| Zuid Beijerland | 1028 | 74 | Hoogeveen | 1126 | 61 |
| Pijnacker [1] | 1032 | - | Steenwijksmoer | 1129 | 65 |
| Rotterdam-Crooswijk | 1033 | 74 | Nieuw Amsterdam | 1130 | 79 |
| Rotterdam-Waalhaven | 1034 | 69 | Nieuw Schoonebeek/ | 1131 | 62 |
| Maasvlakte | 1035 | 85 | Weiteveen | | |
| Maassluis | 1037 | 83 | Emmen | 1132 | 81 |
| Hellevoetsluis | 1038 | 92 | Hengelo (Ov) | 1135 | 70 |
| Ouddorp | 1039 | 74 | Hengelo (Gld) [1] | 1136 | - |
| Wekerom | 1041 | 74 | Enschede [1] | 1139 | - |
| Wageningen | 1043 | 69 | Losser | 1140 | 63 |
| Amersfoort | 1046 | 71 | Oldenzaal | 1141 | 77 |
| Harderwijk | 1050 | 66 | Westerhaar | 1142 | 64 |
| Wijk Bij Duurstede | 1056 | 83 | Rijssen | 1143 | 67 |
| Nieuwegein | 1062 | 81 | 's Heerenberg | 1144 | 62 |
| Zegveld [2] | 1063 | 66 | Dinxperlo | 1145 | 79 |
| Lopik (Cabauw) [3] | 1064 | 85 | Varsseveld | 1146 | 72 |
| Apeldoorn | 1066 | 70 | Groenlo | 1147 | 84 |
| Heerenveen | 1071 | 72 | Deventer | 1148 | 78 |
| Oosterwolde | 1072 | 81 | Etten-Leur | 1154 | 70 |
| Bergum | 1074 | 68 | Den Bosch | 1157 | 69 |
| Witmarsum | 1076 | 88 | Raamsdonkveer | 1159 | 92 |
| Sneek | 1077 | 71 | Ulvenhout | 1160 | 74 |
| St Jacobiparochie | 1081 | 79 | Baarle-Nassau [1] | 1161 | - |
| Holwerd | 1082 | 89 | Uden [1] | 1162 | - |
| Leeuwarden | 1085 | 70 | Mill | 1163 | 65 |
| Zwolle-Zuid | 1087 | 74 | Oss | 1167 | 65 |
| Ommen | 1093 | 65 | Nuenen | 1172 | 71 |
| Hardenberg | 1095 | 65 | Bergeijk | 1174 | 88 |
| Assen | 1097 | 60 | Waalre | 1175 | 69 |
| Rutten | 1099 | 75 | Someren (Dorp) | 1176 | 70 |

*Continued on the next page.*

*Table A10: Continued.*

| Station | No. | Ambient dose equivalent rate nSv.h$^{-1}$ | Station | No. | Ambient dose equivalent rate nSv.h$^{-1}$ |
|---|---|---|---|---|---|
| Oisterwijk | 1178 | 74 | Hoensbroek | 1225 | 84 |
| Riel | 1179 | 72 | Gennep [1] | 1228 | - |
| Oostelbeers | 1180 | 83 | Elst (Gld) | 1229 | 82 |
| Hilvarenbeek | 1181 | 66 | Zevenaar | 1230 | 73 |
| Venray | 1183 | 62 | Nijmegen | 1231 | 75 |
| Nieuw-Bergen | 1184 | 63 | Amstelveen | 1233 | 74 |
| Sevenum | 1185 | 70 | Amsterdam Oost [1] | 1234 | - |
| Reuver | 1188 | 66 | Aalsmeer | 1236 | 72 |
| Nederweert | 1189 | 72 | Nispen | 1237 | 62 |
| Heythuysen | 1190 | 74 | Groesbeek | 1240 | 80 |
| Mariahoop | 1191 | 70 | Tubbergen | 1243 | 67 |
| Stramproy | 1192 | 65 | Haaksbergen | 1244 | 67 |
| Eerbeek | 1193 | 73 | Scheveningen | 1247 | 77 |
| Leiden | 1196 | 74 | Zaltbommel | 1251 | 71 |
| Hulst | 1197 | 76 | IJzendijke | 1252 | 77 |
| Terneuzen | 1199 | 71 | Ritthem | 1253 | 99 |
| Sluis | 1201 | 75 | Vlissingen Haven | 1254 | 72 |
| Vlissingen | 1202 | 78 | Nieuwdorp | 1255 | 75 |
| Halsteren | 1204 | 66 | 's Heerenhoek | 1256 | 125 |
| Oud Gastel | 1206 | 66 | Driewegen | 1257 | 83 |
| Goes | 1207 | 84 | Arnemuiden | 1258 | 72 |
| Bruinisse | 1209 | 75 | Heinkenszand | 1259 | 83 |
| Burgh-Haamstede | 1211 | 63 | Baarland | 1260 | 87 |
| Vrouwenpolder | 1212 | 64 | Biervliet | 1261 | 76 |
| Wemeldinge | 1214 | 77 | Nummer Een | 1262 | 76 |
| Middelburg | 1215 | 78 | Rilland | 1263 | 76 |
| Westkapelle | 1216 | 68 | Putte | 1264 | 57 |
| Stein | 1219 | 84 | Nieuw Namen | 1265 | 80 |
| Maastricht | 1220 | 90 | Beneden Leeuwen | 1272 | 86 |
| Ravensbos (Arensgehout) | 1221 | 84 | Denekamp | 1278 | 65 |
| | | | Winterswijk (Kotten) | 1279 | 69 |
| Vaals | 1222 | 82 | Bilthoven | 1280 | 62 |
| Gulpen | 1223 | 81 | Gastel (Maarheze) | 1281 | 75 |
| Kerkrade | 1224 | 87 | | | |

*[1] Station was not operational in 2009.*

*[2] The station Noordwijk-Binnen has been relocated to Zegsveld since July 2009.*

*[3] The station Rhenen has been relocated to Lopik (Cabouw) since July 2009.*

*Table A11: Gross α-, residual β-, $^{3}H$-, $^{90}Sr$- and $^{226}Ra$-activity concentrations ($mBq \cdot L^{-1}$) in surface water in 2009 as measured by RWS WD Centre for Water Management.*

| Date | Gross α $mBq \cdot L^{-1}$ | Residual β $mBq \cdot L^{-1}$ | $^{3}H$ $mBq \cdot L^{-1}$ | $^{90}Sr$ $mBq \cdot L^{-1}$ | $^{226}Ra$ $mBq \cdot L^{-1}$ |
|---|---|---|---|---|---|
| **Location** | **IJsselmeer** | | | | |
| 22/01/09 | 51 | 45 | | | |
| 03/02/09 | 49 | 41 | 3400 | | |
| 03/03/09 | 54 | 31 | | | |
| 01/04/09 | 5 | 19 | 3300 | | |
| 27/04/09 | 59 | 50 | | | |
| 25/05/09 | 37 | 46 | 3300 | | |
| 23/06/09 | 30 | 36 | | | |
| 22/07/09 | 53 | 55 | 3600 | | |
| 19/08/09 | 47 | 40 | | | |
| 14/09/09 | 35 | 16 | 3000 | | |
| 13/10/09 | 24 | 22 | | | |
| 10/11/09 | 34 | 30 | 2900 | | |
| 08/12/09 | 39 | 31 | | | |
| Average | 40 | 36 | 3250 | | |
| **Location** | **Nieuwe Waterweg** | | | | |
| 21/01/09 | 84 | 20 | | | |
| 18/02/09 | 78 | 57 | 4100 | 1 | 5 |
| 18/03/09 | 110 | 68 | 7200 | < 1 | 4 |
| 15/04/09 | 120 | 2 | | | |
| 13/05/09 | 180 | 60 | 8400 | < 1 | 2 |
| 10/06/09 | 92 | 76 | | | |
| 08/07/09 | 210 | 43 | 4000 | 3 | 5 |
| 05/08/09 | 170 | 49 | | | |
| 02/09/09 | 190 | 37 | 2900 | 4 | 4 |
| 30/09/09 | 53 | 34 | | | |
| 28/10/09 | 77 | 26 | 5200 | < 1 | 3 |
| 25/11/09 | 31 | 44 | | | |
| 22/12/09 | 70 | 68 | 4900 | 3 | 2 |
| Average | 113 | 45 | 5200 | 1.8 | 3.6 |
| **Location** | **Noordzeekanaal** | | | | |
| 16/02/09 | 310 | 55 | 3300 | | |
| 14/04/09 | 180 | 10 | 4900 | | |
| 08/06/09 | 360 | 35 | 3300 | | |
| 03/08/09 | 260 | 47 | 2800 | | |
| 08/10/09 | 110 | 80 | 2400 | | |
| 23/11/09 | 130 | 26 | 2800 | | |
| Average | 220 | 42 | 3200 | | |

*Continued on the next page.*

*Table A11: Continued.*

| Date | Gross α mBq·L$^{-1}$ | Residual β mBq·L$^{-1}$ | $^{3}$H mBq·L$^{-1}$ | $^{90}$Sr mBq·L$^{-1}$ | $^{226}$Ra mBq·L$^{-1}$ |
|---|---|---|---|---|---|
| **Location** | **Rhine** | | | | |
| 14/01/09 | 40 | 33 | 3400 | | |
| 11/02/09 | 60 | 63 | 4300 | 1 | 5 |
| 11/03/09 | 66 | 72 | 6400 | | |
| 08/04/09 | 57 | 41 | 2300 | 2 | 3 |
| 06/05/09 | 44 | 44 | 5300 | | |
| 03/06/09 | 57 | 55 | 3300 | 3 | 2 |
| 01/07/09 | 65 | 53 | 2900 | | |
| 29/07/09 | 47 | 63 | 3100 | 1 | 3 |
| 26/08/09 | 82 | 53 | 2600 | | |
| 23/09/09 | 88 | 55 | 6700 | 4 | 4 |
| 21/10/09 | 53 | 41 | 8800 | | |
| 18/11/09 | 60 | 36 | 5700 | 1 | 5 |
| 16/12/09 | 75 | 37 | 2500 | | |
| Average | 61 | 50 | 4400 | 1.8 | 3.7 |
| **Location** | **Scheldt** | | | | |
| 05/01/09 | | | 6600 | | 9 |
| 19/01/09 | 450 | 120 | | | |
| 02/02/09 | 260 | 150 | | | |
| 02/03/09 | 270 | 150 | 10000 | | 9 |
| 01/04/09 | 280 | 95 | | | |
| 29/04/09 | 220 | 49 | 13000 | | 9 |
| 25/05/09 | 280 | 100 | | | |
| 24/06/09 | 490 | 97 | 15000 | | 13 |
| 22/07/09 | 360 | 160 | | | |
| 18/08/09 | 700 | 100 | 12000 | | 16 |
| 14/09/09 | 610 | 100 | | | |
| 12/10/09 | 250 | 180 | 19000 | | 21 |
| 09/11/09 | 190 | 94 | | | |
| 07/12/09 | 530 | 170 | 7900 | | 10 |
| Average | 380 | 120 | 11900 | | 12.4 |
| **Location** | **Meuse** | | | | |
| 13/01/09 | 25 | 37 | 1200 | | |
| 10/02/09 | 46 | 52 | 8500 | 4 | 2 |
| 10/03/09 | 18 | 22 | 1600 | | |
| 07/04/09 | 33 | 27 | 6700 | < 1 | 2 |
| 06/05/09 | 40 | 32 | 2400 | | |
| 02/06/09 | 43 | 25 | 1100 | 5 | 3 |
| 30/06/09 | 29 | 13 | 49000 | | |
| 28/07/09 | 41 | 39 | 1400 | 5 | 3 |
| 25/08/09 | 28 | 27 | 40000 | | |
| 22/09/09 | 72 | 28 | 40000 | 3 | 4 |
| 20/10/09 | 30 | 10 | 26000 | | |
| 17/11/09 | 24 | 13 | 2300 | < 1 | 2 |
| 15/12/09 | 45 | 21 | 1200 | | |
| Average | 36 | 27 | 14000 | 3 | 2.7 |

*Table A12: $^{60}$Co-, $^{131}$I-, $^{137}$Cs- and $^{210}$Pb-activity concentrations in suspended solids (Bq·kg$^{-1}$) in surface water in 2009 as measured by RWS WD Centre for Water Management.*

| **Date** | **$^{60}$Co** | **$^{131}$I** | **$^{137}$Cs** | **$^{210}$Pb** |
|---|---|---|---|---|
| | **Bq·kg$^{-1}$** | **Bq·kg$^{-1}$** | **Bq·kg$^{-1}$** | **Bq·kg$^{-1}$** |
| **Location** | **IJsselmeer** | | | |
| 03/02/09 | < 1 | < 1 | 8 | |
| 03/03/09 | < 1 | < 1 | 4 | |
| 01/04/09 | < 1 | < 1 | 3 | |
| 27/04/09 | < 1 | < 1 | 2 | |
| 25/05/09 | < 1 | < 1 | < 1 | |
| 23/06/09 | < 1 | < 1 | < 1 | |
| 22/07/09 | < 1 | < 1 | 2 | |
| 19/08/09 | < 1 | < 1 | 2 | |
| 14/09/09 | < 1 | < 1 | 2 | |
| 13/10/09 | < 1 | < 1 | 3 | |
| 10/11/09 | < 1 | < 1 | 3 | |
| 08/12/09 | < 1 | < 1 | 5 | |
| Average | < 1 | < 1 | 2.9 | |
| **Location** | **Nieuwe Waterweg** | | | |
| 21/01/09 | < 1 | 5 | 10 | 120 |
| 18/02/09 | < 1 | < 1 | 14 | |
| 18/03/09 | < 1 | 4 | 12 | 100 |
| 15/04/09 | < 1 | < 1 | 12 | |
| 13/05/09 | < 1 | < 1 | 10 | 96 |
| 10/06/09 | < 1 | < 1 | 10 | |
| 08/07/09 | < 1 | < 1 | 14 | 140 |
| 05/08/09 | < 1 | < 1 | 10 | |
| 02/09/09 | < 1 | < 1 | 10 | 100 |
| 30/09/09 | < 1 | < 1 | 11 | |
| 28/10/09 | < 1 | < 1 | 10 | 110 |
| 25/11/09 | < 1 | 4 | 12 | |
| 22/12/09 | < 1 | < 1 | 12 | 120 |
| Average | < 1 | < 1.4 | 11.3 | 112 |
| **Location** | **Noordzeekanaal** | | | |
| 16/02/09 | < 1 | 22 | 10 | |
| 14/04/09 | < 1 | 37 | 8 | |
| 08/06/09 | < 1 | 23 | 6 | |
| 03/08/09 | < 1 | 30 | 2 | |
| 09/10/09 | < 1 | 41 | 6 | |
| 23/11/09 | < 1 | 22 | 9 | |
| Average | < 1 | 29 | 6.8 | |

*Continued on the next page.*

*Table A12: Continued.*

| Date | $^{60}$Co Bq·kg$^{-1}$ | $^{131}$I Bq·kg$^{-1}$ | $^{137}$Cs Bq·kg$^{-1}$ | $^{210}$Pb Bq·kg$^{-1}$ |
|---|---|---|---|---|
| **Location** | **Rhine** | | | |
| 15/01/09 | < 1 | 4 | 13 | |
| 12/02/09 | < 1 | 17 | 14 | 120 |
| 11/03/09 | < 1 | 7 | 15 | |
| 09/04/09 | < 1 | < 1 | 13 | 110 |
| 06/05/09 | < 1 | 8 | 13 | |
| 03/06/09 | < 1 | < 1 | 13 | 110 |
| 01/07/09 | < 1 | < 1 | 14 | |
| 29/07/09 | < 1 | < 1 | 13 | 120 |
| 26/08/09 | < 1 | < 1 | 13 | |
| 23/09/09 | < 1 | < 1 | 12 | 120 |
| 20/10/09 | < 1 | 4 | 14 | |
| 18/11/09 | < 1 | 6 | 15 | 140 |
| 16/12/09 | < 1 | 8 | 17 | |
| Average | < 1 | 4.4 | 13.8 | 120 |
| **Location** | **Scheldt** | | | |
| 05/01/09 | < 1 | < 1 | 6 | 82 |
| 02/02/09 | < 1 | 2 | 7 | |
| 02/03/09 | 1 | < 1 | 9 | 96 |
| 01/04/09 | 1 | < 1 | 8 | |
| 28/04/09 | < 1 | < 1 | 6 | 79 |
| 25/05/09 | < 1 | < 1 | 5 | |
| 24/06/09 | < 1 | < 1 | 7 | 90 |
| 22/07/09 | 1 | < 1 | 9 | |
| 18/08/09 | < 1 | < 1 | 8 | 98 |
| 14/09/09 | < 1 | < 1 | 7 | |
| 12/10/09 | < 1 | < 1 | 9 | 100 |
| 09/11/09 | < 1 | < 1 | 7 | |
| 07/12/09 | < 1 | < 1 | 8 | 98 |
| Average | < 1 | < 1 | 7.4 | 92 |
| **Location** | **Meuse** | | | |
| 06/01/09 | 17 | < 1 | 15 | |
| 13/01/09 | 6 | 17 | 11 | |
| 20/01/09 | 8 | 18 | 12 | |
| 27/01/09 | 4 | <1 | 10 | |
| 03/02/09 | 2 | 10 | 10 | |
| 10/02/09 | < 1 | 15 | 9 | 96 |
| 17/02/09 | < 1 | < 1 | 7 | |
| 24/02/09 | 3 | 20 | 15 | |
| 03/03/09 | 6 | 14 | 12 | |

*Continued on the next page.*

*Table A12: Continued.*

| Date | $^{60}$Co Bq·kg$^{-1}$ | $^{131}$I Bq·kg$^{-1}$ | $^{137}$Cs Bq·kg$^{-1}$ | $^{210}$Pb Bq·kg$^{-1}$ |
|---|---|---|---|---|
| **Location** | **Meuse** | | | |
| 10/03/09 | 11 | 28 | 13 | |
| 17/03/09 | 11 | 19 | 14 | |
| 24/03/09 | 10 | 40 | 12 | |
| 31/03/09 | 7 | < 1 | 11 | |
| 07/04/09 | 10 | < 1 | 15 | 160 |
| 23/04/09 | 15 | < 1 | 11 | |
| 07/05/09 | 11 | 59 | 11 | |
| 20/05/09 | 9 | < 1 | 11 | |
| 04/06/09 | 8 | 16 | 13 | 130 |
| 18/06/09 | 7 | 11 | 10 | |
| 02/07/09 | 4 | < 1 | 3 | |
| 17/07/09 | < 1 | 17 | 7 | |
| 21/07/09 | 9 | < 1 | 11 | |
| 28/07/09 | 8 | < 1 | 10 | 190 |
| 04/08/09 | 6 | < 1 | 10 | |
| 11/08/09 | 5 | < 1 | 8 | |
| 18/08/09 | 5 | 12 | 6 | |
| 25/08/09 | 6 | 12 | 8 | |
| 01/09/09 | 6 | 16 | 10 | |
| 08/09/09 | 7 | 17 | 10 | |
| 15/09/09 | 6 | 15 | 11 | |
| 22/09/09 | < 1 | < 1 | 9 | 160 |
| 29/09/09 | 5 | 11 | 9 | |
| 06/10/09 | 4 | 48 | 12 | |
| 13/10/09 | 6 | 55 | 12 | |
| 20/10/09 | 7 | 47 | 11 | |
| 26/10/09 | 7 | 39 | 12 | |
| 03/11/09 | 6 | 44 | 19 | |
| 10/11/09 | 11 | 16 | 14 | |
| 17/11/09 | 7 | 21 | 18 | 180 |
| 24/11/09 | 7 | 22 | 16 | |
| 01/12/09 | 5 | 7 | 14 | |
| 08/12/09 | 6 | 10 | 19 | |
| 15/12/09 | 4 | 17 | 18 | |
| 23/12/09 | 8 | 17 | 15 | |
| 29/12/09 | 4 | 4 | 13 | |
| Average | 6.6 | 16 | 11.7 | 153 |

*Table A13: Gross α-, residual β-, $^{3}H$- and $^{90}Sr$-activity concentrations ($mBq \cdot L^{-1}$) in seawater in 2009 as measured by RWS WD Centre for Water Management.*

| **Date** | **Gross α $mBq \cdot L^{-1}$** | **Residual β $mBq \cdot L^{-1}$** | **$^{3}H$ $mBq \cdot L^{-1}$** | **$^{90}Sr$ $mBq \cdot L^{-1}$** |
|---|---|---|---|---|
| **Location** | **Coastal area** | | | |
| 12/02/09 | 1170 | 140 | 6000 | |
| 14/05/09 | 290 | 69 | 3200 | |
| 14/08/09 | 370 | 57 | 3100 | |
| 09/11/09 | 330 | 64 | 3600 | |
| Average | 500 | 82 | 4000 | |
| **Location** | **Southern North Sea** | | | |
| 12/02/09 | 620 | 80 | 1700 | < 1 |
| 14/05/09 | 760 | 86 | 1800 | < 1 |
| 13/08/09 | 1140 | 73 | 2400 | 3 |
| 11/11/09 | 240 | 65 | 3900 | 6 |
| Average | 690 | 76 | 2400 | 2.5 |
| **Location** | **Central North Sea** | | | |
| 10/02/09 | 690 | 75 | 660 | < 1 |
| 12/05/09 | 510 | 87 | 200 | 5 |
| 12/08/09 | 1120 | 53 | 220 | < 1 |
| 10/11/09 | 220 | 56 | 480 | 3 |
| Average | 640 | 68 | 390 | 2.2 |
| **Location** | **Delta Coastal Waters** | | | |
| 08/01/09 | 480 | 110 | | 1 |
| 16/02/09 | 620 | 120 | 4500 | 6 |
| 18/03/09 | 990 | 41 | 3400 | |
| 23/04/09 | 360 | 61 | 3700 | |
| 19/05/09 | 840 | 48 | 3700 | 3 |
| 25/06/09 | 470 | 76 | 3500 | |
| 16/07/09 | 970 | 65 | 3100 | |
| 18/08/09 | 580 | 87 | 3300 | < 1 |
| 16/09/09 | 540 | 73 | 3500 | |
| 14/10/09 | 150 | 75 | 3300 | |
| 12/11/09 | 670 | 59 | 3900 | < 1 |
| 09/12/09 | 240 | 61 | 5700 | |
| Average | 580 | 73 | 3800 | 2.2 |

*Continued on the next page.*

*Table A13: Continued.*

| Date | Gross α mBq·L$^{-1}$ | Residual β mBq·L$^{-1}$ | $^{3}$H mBq·L$^{-1}$ | $^{90}$Sr mBq·L$^{-1}$ |
|---|---|---|---|---|
| **Location** | **Westerscheldt** | | | |
| 06/01/09 | 700 | 74 | 5300 | 1 |
| 04/02/09 | 570 | 160 | 4900 | 9 |
| 02/03/09 | 830 | 90 | 5300 | < 1 |
| 30/03/09 | 490 | 160 | 4400 | 3 |
| 27/04/09 | 760 | 130 | 4700 | 5 |
| 26/05/09 | 1070 | 260 | 4000 | < 1 |
| 23/06/09 | 860 | 67 | 4200 | < 1 |
| 20/07/09 | 710 | 79 | 3900 | 2 |
| 17/08/09 | 1490 | 99 | 4000 | < 1 |
| 15/09/09 | 470 | 99 | 4000 | 3 |
| 14/10/09 | 290 | 140 | 3900 | < 1 |
| 10/11/09 | 320 | 160 | 3800 | < 1 |
| 07/12/09 | 440 | 220 | 5200 | 3 |
| Average | 690 | 134 | 4430 | 2.2 |
| **Location** | **Eems-Dollard** | | | |
| 21/01/09 | 1300 | 90 | 5900 | |
| 20/02/09 | 900 | 52 | 4400 | |
| 19/05/09 | 980 | 43 | 3100 | |
| 18/08/09 | 640 | 70 | 2700 | |
| 11/11/09 | 570 | 65 | 2500 | |
| Average | 880 | 64 | 3700 | |
| **Location** | **Wadden Sea West** | | | |
| 13/01/09 | 660 | 130 | 5900 | |
| 11/02/09 | 710 | 95 | 5400 | |
| 11/05/09 | 810 | 110 | 2800 | |
| 10/08/09 | 910 | 66 | 3000 | |
| 21/11/09 | 760 | 69 | 3500 | |
| Average | 770 | 94 | 4100 | |
| **Location** | **Wadden Sea East** | | | |
| 15/01/09 | 840 | 140 | 5700 | |
| 16/02/09 | 980 | 120 | 5300 | |
| 14/05/09 | 980 | 230 | 2100 | |
| 13/08/09 | 1060 | 110 | 2700 | |
| 16/11/09 | 330 | 150 | 2400 | |
| Average | 840 | 150 | 3600 | |

*Table A14: $^{137}Cs$- and $^{210}Pb$-activity concentrations in suspended solids ($Bq \cdot kg^{-1}$) in seawater in 2009 as measured by RWS WD Centre for Water Management. Since 2009, $^{210}Pb$ is reported instead of $^{210}Po$. Since 2009 $^{137}Cs$ and $^{210}Pb$ are not determined at Wadden Sea East, but at Wadden Sea West.*

| **Date** | **$^{137}Cs$ $Bq \cdot kg^{-1}$** | **$^{210}Pb$ $Bq \cdot kg^{-1}$** |
|---|---|---|
| **Location** | **Coastal area** | |
| 12/02/09 | 6 | 74 |
| 25/05/09 | 4 | 56 |
| 09/11/09 | 5 | 92 |
| Average | 5 | 74 |
| **Location** | **Westerscheldt** | |
| 03/02/09 | 4 | 78 |
| 28/04/09 | 6 | 61 |
| 21/07/09 | 4 | 51 |
| 13/10/09 | 6 | 67 |
| Average | 5 | 64 |
| **Location** | **Eems-Dollard** | |
| 19/02/09 | 9 | 93 |
| 20/05/09 | 6 | 90 |
| 19/08/09 | 5 | 67 |
| 10/11/09 | 6 | 85 |
| Average | 6.5 | 84 |
| **Location** | **Wadden Sea West** | |
| 12/02/09 | 6 | 110 |
| 12/05/09 | 5 | 75 |
| 30/11/09 | 5 | 83 |
| Average | 5.3 | 89 |

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

| **Date** [1] | | | **Gross α** [2] **mBq·m$^{-3}$** | | |
|---|---|---|---|---|---|
| **Location** | **21** | **22** | **23** | **27** | **29** |
| 06/02/09 | 0.033 | 0.024 | 0.069 | 0.027 | 0.033 |
| 05/03/09 | 0.046 | 0.089 | 0.10 | 0.018 | 0.013 |
| 02/04/09 | 0.082 | 0.117 | 0.211 | 0.022 | 0.024 |
| 06/05/09 | 0.054 | 0.094 | 0.23 | 0.013 | 0.026 |
| 04/06/09 | 0.031 | 0.015 | 0.014 | 0.028 | 0.021 |
| 08/07/09 | 0.063 | 0.049 | 0.094 | 0.028 | 0.045 |
| 06/08/09 | 0.026 | 0.054 | 0.071 | 0.029 | 0.041 |
| 07/09/09 | 0.025 | 0.038 | 0.30 | 0.041 | 0.045 |
| 08/10/09 | 0.032 | 0.038 | 0.112 | 0.020 | 0.057 |
| 05/11/09 | 0.022 | 0.036 | 0.096 | 0.072 | 0.035 |
| 03/12/09 | 0.027 | 0.027 | 0.040 | 0.016 | 0.023 |
| 07/01/10 | 0.027 | 0.043 | 0.131 | 0.021 | 0.045 |

*[1] End date of monthly sampling period.*

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

*Table A16: Monthly averaged gross β-activity concentrations in air dust in the vicinity of the nuclear power plant at Borssele.*

| **Date** [1] | | | **Gross β mBq·m$^{-3}$** | | |
|---|---|---|---|---|---|
| **Location** | **21** | **22** | **23** | **27** | **29** |
| 06/02/09 | 0.46 ± 0.03 | 0.409 ± 0.019 | 0.40 ± 0.03 | 0.21 ± 0.03 | 0.418 ± 0.015 |
| 05/03/09 | 0.10 ± 0.03 | 0.213 ± 0.017 | 0.18 ± 0.05 | 0.14 ± 0.03 | 0.109 ± 0.011 |
| 02/04/09 | 0.18 ± 0.03 | 0.187 ± 0.017 | 0.29 ± 0.03 | 0.11 ± 0.03 | 0.160 ± 0.013 |
| 06/05/09 | 0.16 ± 0.02 | 0.155 ± 0.014 | 0.31 ± 0.03 | 0.14 ± 0.02 | 0.175 ± 0.016 |
| 04/06/09 | 0.25 ± 0.03 | 0.251 ± 0.017 | 0.18 ± 0.03 | 0.14 ± 0.02 | 0.257 ± 0.020 |
| 08/07/09 | 0.23 ± 0.02 | 0.222 ± 0.014 | 0.28 ± 0.03 | 0.19 ± 0.02 | 0.13 ± 0.04 |
| 06/08/09 | 0.19 ± 0.03 | 0.223 ± 0.017 | 0.20 ± 0.02 | 0.16 ± 0.02 | 0.253 ± 0.016 |
| 07/09/09 | 0.23 ± 0.02 | 0.209 ± 0.015 | 0.56 ± 0.03 | 0.25 ± 0.02 | 0.44 ± 0.02 |
| 08/10/09 | 0.32 ± 0.03 | 0.286 ± 0.016 | 0.34 ± 0.02 | 0.14 ± 0.02 | 0.386 ± 0.015 |
| 05/11/09 | 0.27 ± 0.03 | 0.30 ± 0.02 | 0.25 ± 0.02 | 0.30 ± 0.02 | 0.304 ± 0.013 |
| 03/12/09 | 0.30 ± 0.03 | 0.251 ± 0.018 | 0.25 ± 0.02 | 0.14 ± 0.02 | 0.324 ± 0.012 |
| 07/01/10 | 0.31 ± 0.02 | 0.262 ± 0.015 | 0.31 ± 0.02 | 0.28 ± 0.02 | 0.37 ± 0.02 |

*[1] End date of monthly sampling period.*

*Table A17: Monthly averaged activity concentrations of γ-emitters in air dust in the vicinity of the nuclear power plant at Borssele. Analysis is performed on a combined sample of the monthly samples of all five locations (21, 22, 23, 27 and 29).*

| Date (1) | $^{60}$Co | $^{131}I_{el}$ (2) | $^{131}I_{or}$ (2) | $^{137}$Cs | Nat. (3) |
|---|---|---|---|---|---|
| | mBq·m$^{-3}$ | mBq·m$^{-3}$ | mBq·m$^{-3}$ | mBq·m$^{-3}$ | mBq·m$^{-3}$ |
| 06/02/09 | < 0.04 | < 0.1 | < 0.3 | < 0.04 | 1.52 ± 0.05 |
| 05/03/09 | < 0.08 | < 0.1 | < 0.3 | < 0.06 | 1.57 ± 0.06 |
| 02/04/09 | < 0.07 | < 0.1 | < 0.2 | < 0.06 | 1.69 ± 0.02 |
| 06/05/09 | < 0.06 | < 0.1 | < 0.2 | < 0.05 | 2.3 ± 0.2 |
| 04/06/09 | < 0.10 | < 0.2 | < 0.4 | < 0.06 | 1.65 ± 0.07 |
| 08/07/09 | < 0.07 | < 0.2 | < 0.3 | < 0.06 | 1.86 ± 0.06 |
| 06/08/09 | < 0.06 | < 0.2 | < 0.4 | < 0.05 | < 0.9 |
| 07/09/09 | < 0.08 | < 0.2 | < 0.3 | < 0.06 | 1.71 ± 0.08 |
| 08/10/09 | < 0.06 | < 0.1 | < 0.2 | < 0.05 | 1.57 ± 0.05 |
| 05/11/09 | < 0.06 | < 0.2 | < 0.3 | < 0.06 | 1.75 ± 0.13 |
| 03/12/09 | < 0.06 | < 0.1 | < 0.3 | < 0.05 | 2.6 ± 0.3 |
| 07/01/10 | < 0.06 | < 0.1 | < 0.3 | < 0.05 | 2.31 ± 0.19 |

*(1) End date of monthly sampling period.*

*(2) Elemental respectively organically bound $^{131}$I.*

*(3) Natural occurring γ-emitters.*

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

| Date | Mass | $^{60}$Co | $^{131}$I | $^{137}$Cs |
|---|---|---|---|---|
| | kg·m$^{-2}$ | Bq·kg$^{-1}$ (1) | Bq·kg$^{-1}$ (1) | Bq·kg$^{-1}$ (1) |
| 06/02/09 | 0.223 | < 3 | < 3 | < 3 |
| 05/03/09 | 0.220 | < 3 | < 2 | < 2 |
| 02/04/09 | 0.098 | < 6 | < 6 | < 4 |
| 06/05/09 | 0.213 | < 3 | < 3 | < 2 |
| 04/06/09 | 0.256 | < 3 | < 2 | < 2 |
| 08/07/09 | 0.196 | < 3 | < 2 | < 2 |
| 06/08/09 | 0.212 | < 3 | < 2 | < 2 |
| 07/09/09 | 0.293 | < 2 | < 1 | < 2 |
| 08/10/09 | 0.299 | < 2 | < 2 | < 2 |
| 05/11/09 | 0.177 | < 3 | < 3 | < 3 |
| 03/12/09 | 0.402 | < 1 | < 1 | < 1 |
| 07/01/10 | 0.333 | < 2 | < 2 | 0.3 ± 0.2 |

*(1) Dry weight.*

*Table A19: Activity concentrations of γ-emitters in soil in the vicinity of the nuclear power plant at Borssele. Analysis is performed on four samples taken near the outlet of the plant on the 14$^{th}$ of May 2009.*

| 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 | < 0.3 | < 0.3 | < 0.3 | 1.88 ± 0.09 |
| O2 | 68.8 | < 0.2 | < 0.3 | < 0.3 | 1.18 ± 0.08 |
| O3 | 74.4 | < 0.4 | < 0.4 | < 0.4 | 1.70 ± 0.12 |
| O4 | 74.8 | < 0.3 | < 0.4 | < 0.3 | 1.56 ± 0.09 |

*(1) Dry weight.*

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

| **Date** | | **Residual β** **Bq·L$^{-1}$** | | |
|---|---|---|---|---|
| **Location** | **1** | **2** | **3** | **4** |
| 06/02/09 | 0.080 ± 0.008 | 0.062 ± 0.006 | 0.073 ± 0.006 | 0.058 ± 0.005 |
| 05/03/09 | 0.052 ± 0.006 | 0.079 ± 0.008 | 0.055 ± 0.005 | 0.046 ± 0.005 |
| 02/04/09 | 0.040 ± 0.013 | 0.031 ± 0.005 | 0.055 ± 0.006 | 0.036 ± 0.004 |
| 06/05/09 | 0.083 ± 0.014 | 0.073 ± 0.006 | 0.047 ± 0.008 | 0.057 ± 0.005 |
| 04/06/09 | 0.084 ± 0.008 | 0.064 ± 0.006 | 0.054 ± 0.006 | 0.057 ± 0.006 |
| 08/07/09 | 0.077 ± 0.005 | 0.071 ± 0.006 | 0.046 ± 0.005 | 0.041 ± 0.008 |
| 06/08/09 | 0.067 ± 0.007 | 0.075 ± 0.011 | 0.073 ± 0.006 | 0.115 ± 0.006 |
| 07/09/09 | 0.134 ± 0.008 | 0.078 ± 0.007 | 0.077 ± 0.007 | 0.178 ± 0.008 |
| 08/10/09 | 0.090 ± 0.009 | 0.085 ± 0.012 | 0.102 ± 0.008 | 0.092 ± 0.007 |
| 05/11/09 | 0.056 ± 0.012 | 0.061 ± 0.007 | 0.110 ± 0.007 | 0.086 ± 0.007 |
| 03/12/09 | 0.086 ± 0.007 | 0.061 ± 0.007 | 0.087 ± 0.009 | 0.065 ± 0.005 |
| 07/01/10 | 0.051 ± 0.007 | 0.056 ± 0.006 | 0.046 ± 0.005 | 0.116 ± 0.006 |

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

| **Date** | | **$^{3}$H** **Bq·L$^{-1}$** | | |
|---|---|---|---|---|
| **Location** | **1** | **2** | **3** | **4** |
| 06/02/09 | 8.2 ± 1.3 | 8.7 ± 1.3 | 9.3 ± 1.4 | 8.4 ± 1.4 |
| 05/03/09 | 9.2 ± 1.4 | 8.6 ± 1.4 | 7.8 ± 1.3 | 9.3 ± 1.4 |
| 02/04/09 | 9.5 ± 1.4 | 9.6 ± 1.4 | 8.5 ± 1.4 | 8.9 ± 1.4 |
| 06/05/09 | 8.4 ± 1.4 | 8.0 ± 1.4 | 7.6 ± 1.3 | 9.2 ± 1.4 |
| 04/06/09 | 7.3 ± 1.4 | 9.1 ± 1.5 | 8.7 ± 1.4 | 7.2 ± 1.4 |
| 08/07/09 | 9.3 ± 1.4 | 8.0 ± 1.4 | 9.1 ± 1.4 | 8.9 ± 1.4 |
| 06/08/09 | 7.2 ± 1.4 | 9.3 ± 1.4 | 8.8 ± 1.4 | 9.4 ± 1.4 |
| 07/09/09 | 8.7 ± 1.3 | 9.0 ± 1.3 | 8.6 ± 1.4 | 7.6 ± 1.4 |
| 08/10/09 | 8.4 ± 1.4 | 9.4 ± 1.4 | 8.8 ± 1.4 | 7.6 ± 1.3 |
| 05/11/09 | 8.7 ± 1.4 | 9.3 ± 1.4 | 8.8 ± 1.4 | 9.1 ± 1.4 |
| 03/12/09 | 9.1 ± 1.3 | 9.4 ± 1.3 | 8.9 ± 1.3 | 7.8 ± 1.3 |
| 07/01/10 | 10.4 ± 1.4 | 9.0 ± 1.4 | 9.8 ± 1.4 | 9.6 ± 1.4 |

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

| **Date** | | **Gross β kBq·kg$^{-1}$** | | |
|---|---|---|---|---|
| **Location** | **1** | **2** | **3** | **4** |
| 06/02/09 | 0.94 ± 0.06 | 0.75 ± 0.04 | 0.58 ± 0.02 | 0.291 ± 0.018 |
| 05/03/09 | 0.44 ± 0.03 | 0.49 ± 0.03 | 0.61 ± 0.03 | 0.42 ± 0.03 |
| 02/04/09 | 0.61 ± 0.05 | 0.61 ± 0.07 | 0.66 ± 0.04 | 1.33 ± 0.13 |
| 06/05/09 | 0.31 ± 0.05 | 0.63 ± 0.07 | 0.96 ± 0.06 | 0.66 ± 0.05 |
| 04/06/09 | 0.89 ± 0.19 | 0.75 ± 0.15 | 0.91 ± 0.04 | 0.92 ± 0.05 |
| 08/07/09 | 0.94 ± 0.08 | 0.96 ± 0.08 | 0.64 ± 0.06 | 0.72 ± 0.03 |
| 06/08/09 | 0.41 ± 0.07 | 0.66 ± 0.02 | 0.66 ± 0.02 | 0.617 ± 0.019 |
| 07/09/09 | 0.22 ± 0.03 | 0.20 ± 0.03 | 0.95 ± 0.05 | 0.89 ± 0.06 |
| 08/10/09 | 0.69 ± 0.03 | 0.79 ± 0.05 | 0.70 ± 0.04 | 0.77 ± 0.04 |
| 05/11/09 | 0.83 ± 0.05 | 1.15 ± 0.12 | 0.78 ± 0.05 | 0.73 ± 0.11 |
| 03/12/09 | 1.02 ± 0.07 | 1.00 ± 0.04 | 0.84 ± 0.04 | 1.20 ± 0.07 |
| 07/01/10 | 0.79 ± 0.03 | 0.76 ± 0.03 | 0.55 ± 0.02 | 0.60 ± 0.03 |

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

| **Date** | **Mass kg** | **$^{60}$Co Bq·kg$^{-1}$ (1)** | **$^{131}$I Bq·kg$^{-1}$ (1)** | **$^{137}$Cs Bq·kg$^{-1}$ (1)** |
|---|---|---|---|---|
| 06/02/09 | 0.16 | < 3 | < 0.8 | < 2 |
| 05/03/09 | 0.15 | < 3 | < 2 | < 2 |
| 02/04/09 | 0.077 | < 5 | < 5 | < 4 |
| 06/05/09 | 0.069 | < 6 | < 4 | 1.6 ± 0.8 |
| 04/06/09 | 0.105 | < 4 | < 3 | < 3 |
| 08/07/09 | 0.116 | < 4 | < 2 | < 3 |
| 06/08/09 | 0.122 | < 4 | < 3 | 1.2 ± 0.6 |
| 07/09/09 | 0.091 | < 4 | < 3 | < 3 |
| 08/10/09 | 0.106 | < 4 | < 2 | < 2 |
| 05/11/09 | 0.201 | < 2 | < 2 | < 2 |
| 03/12/09 | 0.046 | < 4 | < 3 | < 4 |
| 07/01/10 | 0.095 | < 4 | < 3 | < 3 |

(1) *Dry weight.*

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

| Location | Mass | $^{60}$Co | $^{131}$I | $^{137}$Cs |
|---|---|---|---|---|
| | kg·m$^{-2}$ | Bq·kg$^{-1}$ (1) | Bq·kg$^{-1}$ (1) | Bq·kg$^{-1}$ (1) |
| 06/02/09 | 35.7 | < 0.3 | < 0.3 | < 0.5 |
| 05/03/09 | 34.5 | < 0.4 | < 0.3 | < 0.3 |
| 02/04/09 | 30.4 | < 0.4 | < 0.5 | < 0.3 |
| 06/05/09 | 26.7 | < 0.4 | < 0.3 | 1.04 ± 0.08 |
| 04/06/09 | 29.1 | < 0.3 | < 0.2 | 1.19 ± 0.08 |
| 08/07/09 | 23.8 | < 0.3 | < 0.3 | 1.11 ± 0.08 |
| 06/08/09 | 29.5 | < 0.3 | < 0.2 | 1.13 ± 0.08 |
| 07/09/09 | 35.1 | < 0.3 | < 0.2 | 0.84 ± 0.07 |
| 08/10/09 | 56.3 | < 0.3 | < 0.2 | 0.95 ± 0.08 |
| 05/11/09 | 60.8 | < 0.3 | < 0.3 | 1.31 ± 0.11 |
| 03/12/09 | 66.7 | < 0.3 | < 0.2 | 1.33 ± 0.07 |
| 07/01/10 | 62.0 | < 0.3 | < 0.3 | 1.24 ± 0.08 |

(1) *Dry weight.*

# Appendix B The presentation of data

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

## B.1 Correction for radioactive decay

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

## B.2 Calculation of sums and averages

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

The lower and upper limits are calculated as follows:

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

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

where

| | |
|---|---|
| $x_i$ | Weekly or monthly result which is not a detection limit |
| $\sqrt{\sum s_i^2}$ | The uncertainty in the sum |
| $s_i$ | Uncertainty in the weekly or monthly result (1σ) |
| $MDA_i$ | Weekly or monthly result which is a detection limit |

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

## B.3 Calculation of uncertainties

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

# Appendix C Glossary

| | |
|---|---|
| Ambient dose equivalent | An operational quantity used when monitoring radiation in the environment. The unit of ambient dose equivalent is the Sievert (Sv). |
| Becquerel (Bq) | One radioactive transformation per second. |
| Decay product | A decay product (also known as a daughter product, daughter isotope or daughter nuclide) is a nuclide resulting from the radioactive decay of a parent isotope or precursor nuclide. The daughter product may be stable or it may decay to form a daughter product of its own. |
| Dose rate | The radiation dose delivered per unit of time. |
| Effective dose | The sum of the equivalent doses from internal and external radiation in all tissue and organs of the body, having been weighted by their tissue weighting factors. The unit of effective dose is the Sievert (Sv). |
| Gross alpha activity | Gross α (or total α) activity is the total activity of nuclides emitting α radiation. |
| Gross beta activity | Gross β (or total β) activity is the total activity of nuclides emitting β-radiation. Depending on the measurement methodology it might exclude tritium and/or radon daughters. |
| Radioactivity | The emission of α-particles, β-particles, neutrons and γ- or X-radiation from the disintegration of an atomic nucleus. The unit of radioactivity is the Becquerel (Bq). |
| Radionuclide | An unstable form of an element that undergoes radioactive decay. |
| Residual beta activity | The residual β activity is the total β activity (gross β-activity) minus the β-activity of naturally occurring $^{40}K$. For brackish and salt water the Centre for Water Management uses a direct method to determine the residual β-activity [37]. |

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