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Monitoring of radiation in the environment in the Netherlands
Results in 2004

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Rapport in het kort

Monitoring van straling in het milieu in Nederland
Resultaten in 2004

Radioactiviteitsmetingen aan milieu- en voedselmonsters lieten voor 2004 hetzelfde beeld zien als in voorgaande jaren. Het Euratom Verdrag uit 1957 verplicht Nederland om de radioactiviteit in het milieu te meten. In 2000 is deze meetverplichting in een nieuwe Europese aanbeveling aangescherpt. Er dient nu gemeten te worden aan luchtstof, neerslag, oppervlaktewater, zeewater, drinkwater en voedsel. In vergelijking met de aanbevelingen uit 2000 schiet het Nederlandse meetprogramma op een aantal punten tekort. Er worden geen metingen verricht aan melk en aan een representatief voedselpakket.

Trefwoorden: radioactiviteit, milieu, luchtstof, water, voedsel

Abstract

Monitoring of radiation in the environment in the Netherlands
Results in 2004

Radioactivity measurements on environmental and food samples in 2004 gave a similar overall picture as in previous years. The Euratom Treaty of 1957 obliges the Dutch government to measure radioactivity in the environment. This obligation was accentuated in a new European recommendation in 2000. Measurements should be carried out on airborne particles, deposition, surface water, seawater, drinking water and food. The Dutch monitoring program does not fully comply with this recommendation. Measurements are not carried out on milk and on a representative mixed diet.

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

Preface

The following institutes have contributed to the report:

The National Institute for Public Health and the Environment (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/IMD).

The Institute for Inland Water Management and Waste Water Treatment (RIZA)
Data on surface water from the main inland waters.
drs. J.M. van Steenwijk, mw. M. Holierhoek, C. Engeler, ing. M van der Weijden.

The National Institute for Coastal and Marine Management (RIKZ)
Data on seawater.
drs. V.T. Langenberg, ing. R.W. Bovelander.

The Food and Consumer Product Safety Authority -
The Inspectorate for Health Protection and Veterinary Public Health (VWA/KvW)
Data on foodstuff.
ing. J.A.M. Geertsen.

Contents

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 radioactiviteits-metingen in het Nederlandse milieu in 2004. De metingen zijn verricht door RIVM, RIZA, RIKZ en de Voedsel en Waren Autoriteit.

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*.

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 3,4 Bq·m^{-3}. Het jaargemiddelde voor de berekende kunstmatige β-activiteitsconcentratie in luchtstof week niet significant af van nul. Met het NMR werd daarnaast het omgevingsdosisequivalenttempo bepaald, de jaargemiddelde meetwaarde was 73,1 nSv·h^{-1}. Gebaseerd op eerder onderzoek wordt aangenomen dat deze waarde een overschatting is met 5 tot 10 nSv·h^{-1}.

In oppervlaktewater werd de jaargemiddelde activiteitsconcentratie bepaald van ^{3}H en rest-β (totaal-β minus het van nature aanwezige ^{40}K) en de jaargemiddelde activiteitsconcentratie van ^{137}Cs in zwevend stof. In zeewater werd de jaargemiddelde activiteitsconcentratie bepaald van totaal-α, rest-β, ^{3}H en ^{90}Sr. In zwevend stof in zeewater werd de jaargemiddelde activiteitsconcentratie bepaald van ^{137}Cs en ^{210}Po. De resultaten zijn weergegeven in *Tabel S1*. De ^{3}H-activiteitsconcentratie overschreed in de Maas in acht van de dertien genomen monsters de streefwaarde van 10 Bq·L^{-1}. Het jaargemiddelde (11,8 Bq·L^{-1}) ligt binnen het bereik van dat in voorgaande jaren. De ^{3}H-activiteitsconcentratie in de Schelde overschreed in alle zes genomen monsters de streefwaarde. Het jaargemiddelde (14,8 Bq·L^{-1}) ligt binnen het bereik van dat in voorgaande jaren.

Gangbare waarden die in ruw water voor de drinkwaterproductie gevonden worden, zijn weergegeven in *Tabel S1*. In dit water is weinig kalium, en dus ^{40}K, aanwezig.
In 2004 zijn radioactiviteitsmetingen verricht aan een aantal voedingsproducten. De resultaten zijn weergegeven in *Tabel S1*. Er zijn geen radioactiviteitsmetingen verricht aan melk.

Vergeleken met de aanbevelingen van de Europese Unie blijkt dat het Nederlandse meetprogramma op een aantal punten tekortschiet, met name voor wat betreft controle van melk en overige voedingsmiddelen.

Summary

The Dutch government is obligated to measure radioactivity in air, water and soil under the terms of the Euratom Treaty of 1957. In 2000 the European Union specified this treaty by means of recommendations, in which is described the matrices to be measured (air dust, ambient dose equivalent rate, 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 2004. The measurements were carried out by RIVM, RIZA, RIKZ and the Food and Consumer Product Safety Authority.

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 respectively gross β is the total activity of nuclides emitting α- respectively β-radiation. The results are presented in *Table S1*.

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 3.4 Bq·m^{-3}. The yearly average of the calculated artificial β-activity concentration did not deviate significantly from zero. The NMR was also used to determine the ambient dose equivalent rate, the yearly averaged measured value was 73.1 nSv·h^{-1}. Based upon earlier research it is assumed that this value is an overestimate of 5 to 10 nSv·h^{-1}.

The yearly averaged activity concentrations of ^{3}H and residual β (gross β minus naturally occurring ^{40}K) were determined in surface water. The yearly averaged activity concentration of ^{137}Cs was determined in suspended solids in surface water. In seawater the yearly averaged activity concentration was determined for gross α, residual β, ^{3}H and ^{90}Sr. The yearly averaged activity concentrations of ^{137}Cs and ^{210}Po were determined in suspended solids in seawater. The results are presented in *Table S1*. The ^{3}H-activity concentration in the Meuse exceeded the target value (10 Bq·L^{-1}) in eight out of thirteen samples taken. However the yearly average (11.8 Bq·L^{-1}) is within range of previous years. The ^{3}H-activity concentration in the Scheldt exceeded the target value in all of the six samples taken. The yearly average (14.8 Bq·L^{-1}) is within range of 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 2004 radioactivity measurements were performed on food products. The results are presented in *Table S1*. No radioactivity measurements were performed on milk.

The Dutch monitoring program does not fully comply with the recommendations of the European Union, mainly concerning the measurement of milk and food.

Tabel S1: Overzicht van de resultaten in 2004.
Table S1: Summary of the results in 2004.

Matrix	Parameter	Location	Values	Frequency (per year)
Air dust [1]	Gross α	1	0.04 $mBq \cdot m^{-3}$	52
	Gross β	1	0.367 $mBq \cdot m^{-3}$	52
	^{7}Be	1	3.280 $mBq \cdot m^{-3}$	52
	^{137}Cs	1	<0.002 $mBq \cdot m^{-3}$ [2]	52
	^{210}Pb	1	0.370 $mBq \cdot m^{-3}$	52
Deposition [3]	Gross α	1	16.2 $Bq \cdot m^{-2}$	11 [4]
	Gross β	1	73.5 $Bq \cdot m^{-2}$	11 [4]
	^{3}H	1	<1600 $Bq \cdot m^{-2}$ [5]	12
	^{7}Be	1	1330 $Bq \cdot m^{-2}$	52
	^{137}Cs	1	0.31 $Bq \cdot m^{-2}$	52
	^{210}Pb	1	68 $Bq \cdot m^{-2}$	52
	^{210}Po	1	7.4 $Bq \cdot m^{-2}$	12
Surface water [1]	Residual β	3	0.027 - 0.090 $Bq \cdot L^{-1}$	13
	^{3}H	3	4.4 - 14.8 $Bq \cdot L^{-1}$	6 or 13 [6]
	^{137}Cs	4	11 - 17 $Bq \cdot kg^{-1}$	6, 13 or 52 [6]
Seawater [1]	Gross α	8	320 - 540 $mBq \cdot L^{-1}$	4, 12 or 13 [6]
	Residual β	8	34 - 148 $mBq \cdot L^{-1}$	4, 12 or 13 [6]
	^{3}H	8	260 - 6400 $mBq \cdot L^{-1}$	4, 12 or 13 [6]
	^{90}Sr	4	<1 - 3 $mBq \cdot L^{-1}$	4 or 13 [6]
	^{137}Cs	5	5 - 10 $Bq \cdot kg^{-1}$	2 or 4 [6]
	^{210}Po	5	70 - 130 $Bq \cdot kg^{-1}$	2 or 4 [6]
Drinking water [2]	Gross β	13	<0.2 $Bq \cdot L^{-1}$	91
	Residual β	144	<0.3 $Bq \cdot L^{-1}$	410
	^{3}H	209	<5 $Bq \cdot L^{-1}$	619
Food [7, 8]				
Various kinds of honey	^{137}Cs	-	4 - 233 $Bq \cdot kg^{-1}$	182 (8) [9]
Game and poultry	^{137}Cs	-	5 and 12 $Bq \cdot kg^{-1}$	59 (2) [9]
Dried mushrooms	^{137}Cs	-	n.d.	6 (0) [9]
Fruit	^{137}Cs	-	n.d.	1 (0) [9]
Flavourings	^{137}Cs	-	n.d.	5 (0) [9]
Tea	^{137}Cs	-	n.d.	12 (0) [9]
Cattle feed	^{137}Cs	-	n.d.	32 (0) [9]

[1] = Yearly average is shown.
[2] = Detection limit of individual measurement is shown.
[3] = Yearly total is shown.
[4] = No results available for October due to a very hygroscopic sample.
[5] = Yearly total based on twelve detection limits.
[6] = Frequency is depending on location.
[7] = Given range represents values of individual samples.
[8] = Samples were analysed for ^{134}Cs as well, but it was not detectable.
[9] = Total number of samples taken. Number of positive samples between brackets.
n.d. = not detected

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. It is advisable to monitor radiation in the environment to provide knowledge of levels of radiation under normal circumstances and to look out for any abnormalities. 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 2004. Secondly, it is aimed at determining compliance of monitoring programs in the Netherlands with the EU recommendation and at reporting omissions. Thirdly, it is the Dutch national report on radioactivity in the environment to the EU and to other Member States.

The definition used in this report for the residual β-activity is the total β-activity (gross β-activity) minus the β-activity of ^{40}K.
In the Chapters the results will, in general, 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. In Chapter 9 general conclusions are presented.

2. Airborne particles

The 2004 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].

Table 2.1: Monitoring program in 2004 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 gross α- and β-activity

The weekly results of gross α- and β-activity concentrations in air dust are given in *Figure 2.1* and *Table A1* (see Appendix A). Due to large uncertainties caused by variations in dust thickness on the filters, gross α-activity concentrations in air dust should be regarded as indicative values [5]. The period between sampling and analysis is 5 to 10 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. Usually there is a good correlation between high activity concentrations of gross β and high activity concentrations of ^{210}Pb (*Figure 2.7*) as is the case in week 50 of 2004.

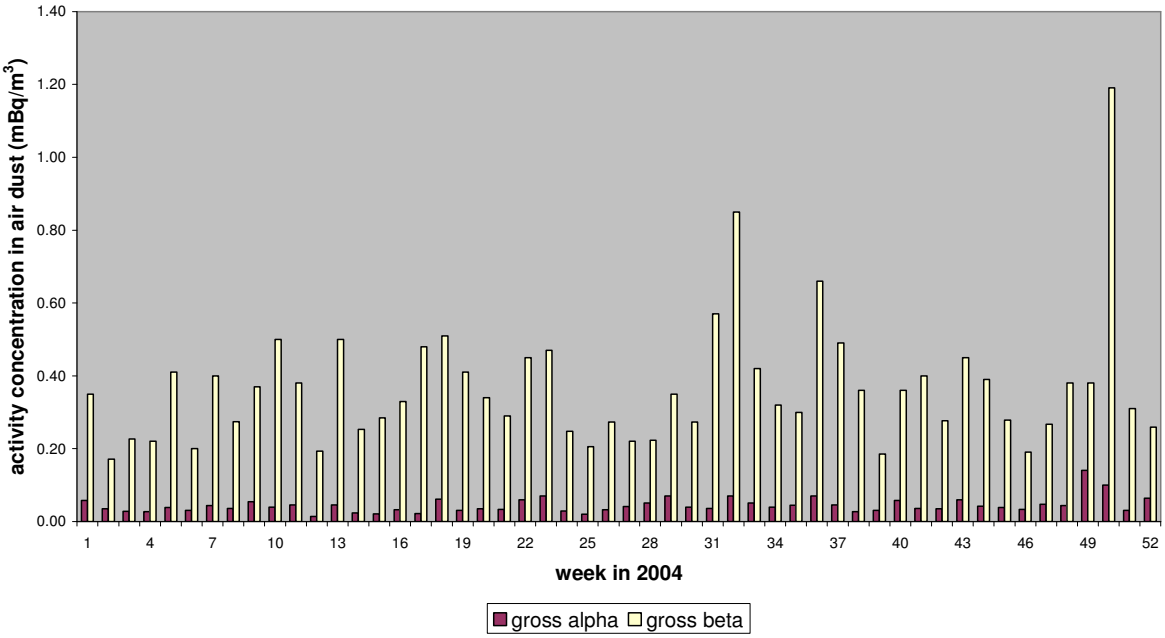


Figure 2.1: Weekly results of gross α- and β-activity concentrations of long-lived nuclides in air dust sampled at RIVM in 2004.

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.

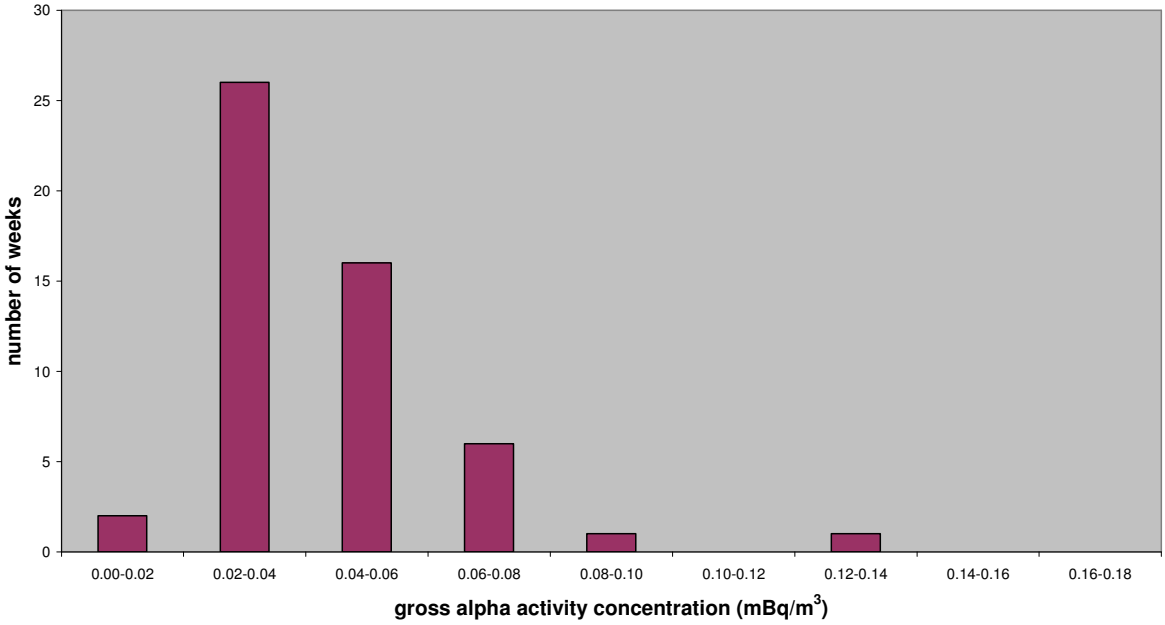


Figure 2.2: Frequency distribution of gross α-activity concentration of long-lived nuclides in air dust collected weekly at RIVM in 2004. The yearly average is 0.04 (SD=0.02) mBq·m^{-3}. SD is the standard deviation and illustrates the variation in weekly averages during the year.

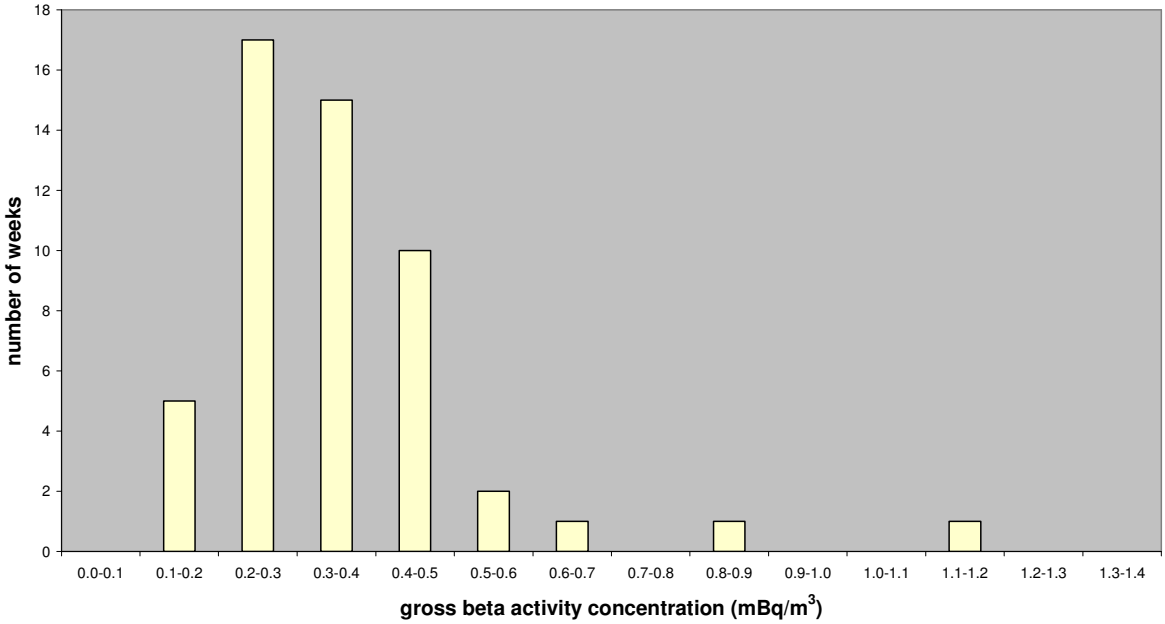


Figure 2.3: Frequency distribution of gross β-activity concentration of long-lived nuclides in air dust collected weekly at RIVM in 2004.
The yearly average is 0.367 ± 0.004 (SD=0.17) mBq·m^{-3}.

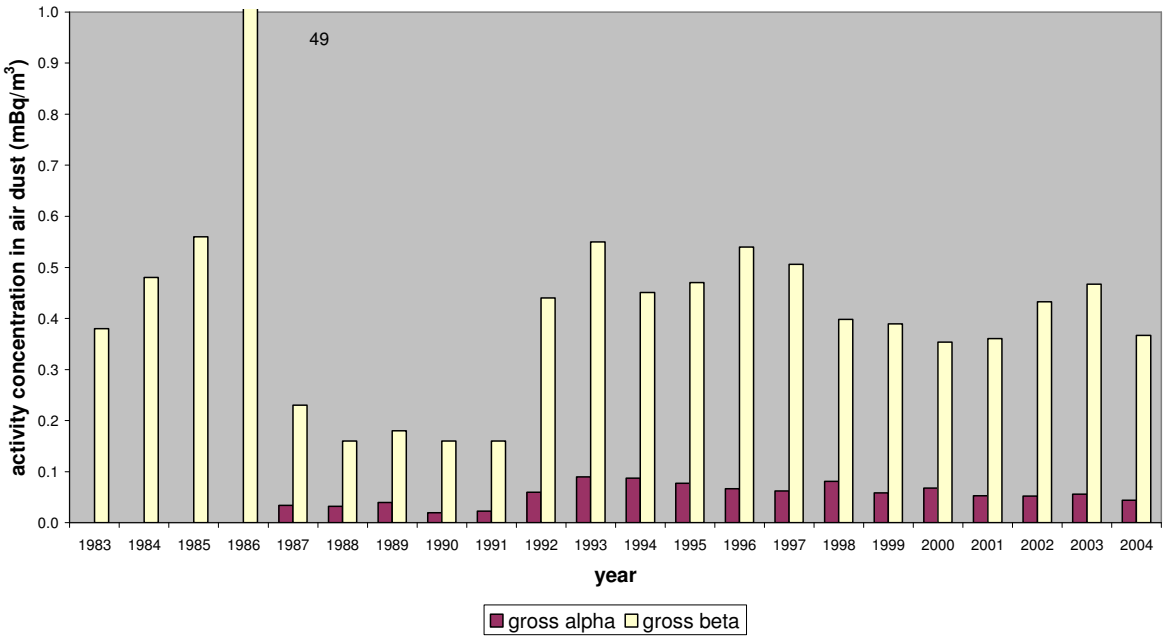


Figure 2.4: Yearly averages of gross α- and gross β-activity concentration of long-lived nuclides in air dust from the outset of the respective monitoring campaigns. The high level in 1986 was caused by the accident at the Chernobyl nuclear power plant.

The yearly averages of the gross α- and β-activity concentrations of long-lived nuclides in 2004 are within the range of the results from the period 1992-2003 [6].
Figure 2.4 shows an apparent change in the activity concentrations in 1987. This is caused by an alteration in the measuring technique since mid 1986 [7]. Due to this alteration in measuring technique gross α data came available. The year 1992 was the start of yet a different sampling procedure (sampling of air dust with a High Volume Sampler) and sample treatment which resulted in another change in the measurement results [8]. The results between mid 1986 and 1992 are underestimates due to the different sampling procedure and sample treatment.

2.2 γ-Emitting nuclides

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

The behaviour of ^{7}Be in the atmosphere has been studied world-wide [9, 10, 11, 12, 13, 14, 15]. Natural ^{7}Be (half-life 53.3 days) is formed by spallation reactions of cosmogenic radiation with atmospheric nuclei, such as carbon, nitrogen and oxygen resulting in the formation of BeO or $Be(OH)_2$ molecules. Approximately 70% of ^{7}Be is produced in the stratosphere, with the remaining 30% being produced in the troposphere. A residence time is estimated at about one year in the stratosphere and about six weeks in the troposphere. Most of the ^{7}Be produced in the stratosphere does not reach the troposphere except during spring when seasonal thinning of the tropopause takes place at midlatitudes, resulting in air exchange between stratosphere and troposphere. In the troposphere ^{7}Be rapidly associates

mainly with submicron-sized aerosol particles. Gravitational settling and precipitation processes accomplish transfer to 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 [16]. Geomagnetic storms, a result of solar activities, are affected by the 11-year solar cycle. 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 [17]. The absence of a 1991 summer peak in the ^{7}Be-activity concentration can be explained by the decrease in cosmogenic radiation.

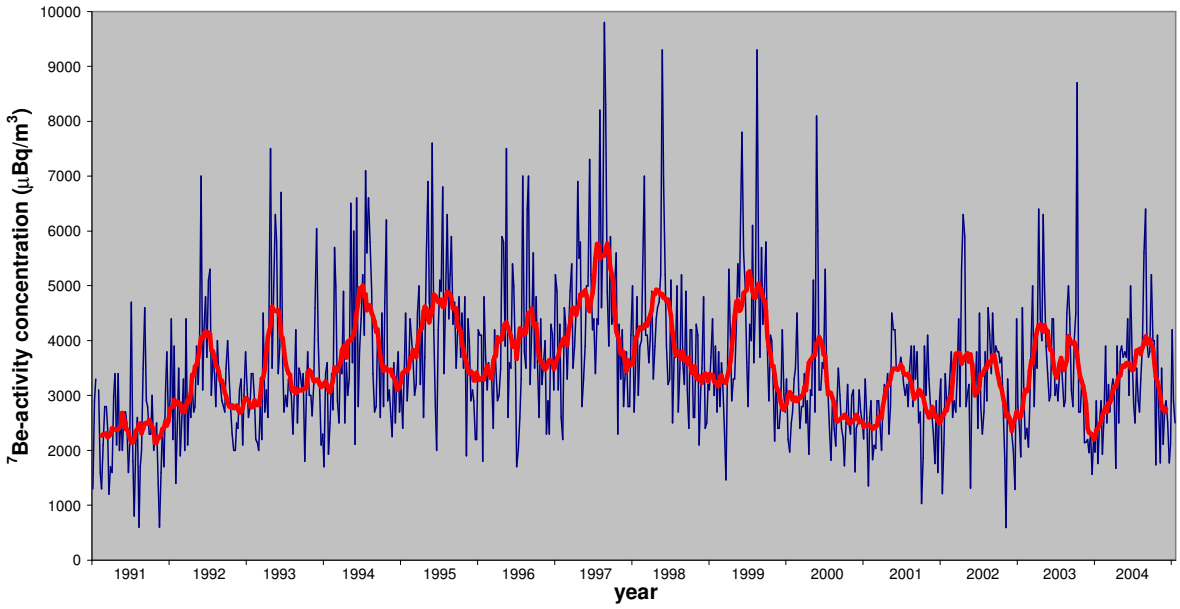


Figure 2.5: Weekly averaged activity concentrations (blue) of ^{7}Be in air dust at RIVM in 1991-2004. The red line represents a moving average of 13 weeks. Yearly average for 2004 is 3280 ±40 (SD=1000) µBq·m^{-3}.

The concentrations found for ^{7}Be in 2004 fit in the pattern described above.

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 [18]. 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 [19]. On the 29th of May 1998 an incident occurred at Algeciras (Spain), an iron foundry melted a ^{137}Cs-source concealed in scrap metal [20]. As a result elevated levels of airborne ^{137}Cs-activity were measured in France, Germany, Italy and Switzerland during late May and early June. *Figure 2.6* shows a slightly elevated level of ^{137}Cs-activity (second peak) around the same period (29th of May until 5th of June 1998). Such slightly elevated levels are not uncommon as can be seen in *Figure 2.6*. These elevations may be related to resuspension of already deposited dust especially during a strong wind from the continent [20].

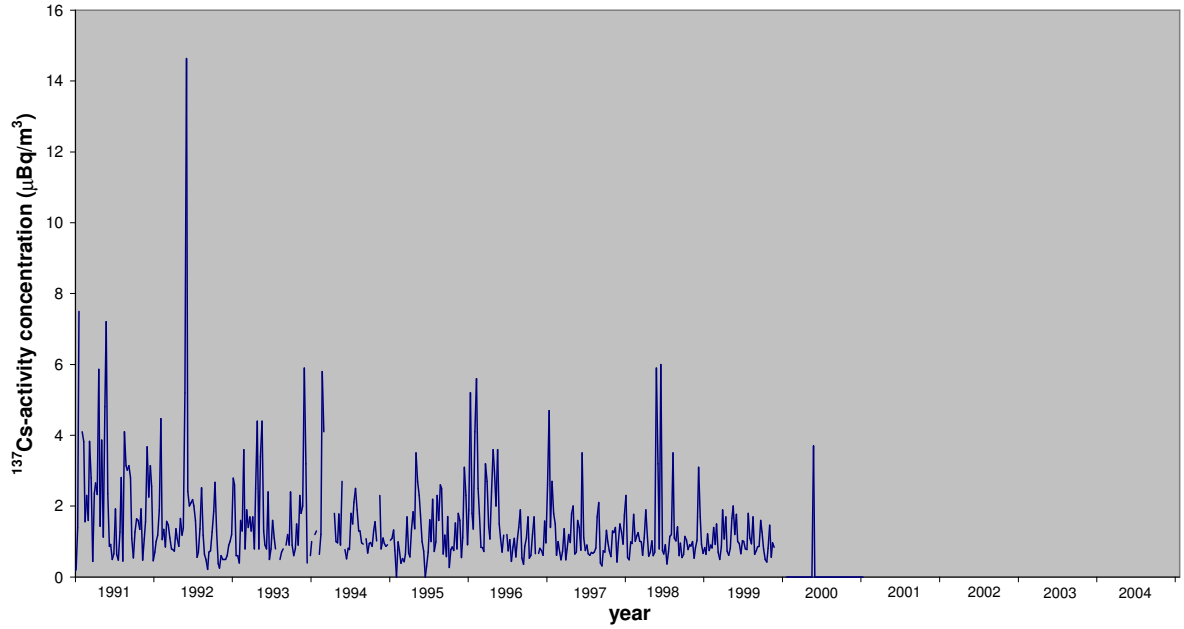


Figure 2.6: Weekly averaged activity concentrations of ^{137}Cs in air dust at RIVM in 1991-2004. In 2004 all measurements were below the detection limit. The detection limit was higher than during 1991-1999, due to a different detector set-up.

The primary source of atmospheric ^{210}Pb (half-life 22.3 years) is the decay of ^{222}Rn exhaled from continental surfaces. Therefore the atmospheric concentration of ^{210}Pb over the continental areas is in general higher than that over the oceanic ones (^{222}Rn exhalation from the ocean is 1000 times less than that from the continents). The reported reference value of ^{210}Pb in air dust is 500 µBq·m^{-3} [21]. In the atmosphere this radionuclide is predominantly associated with submicron-sized aerosols [22, 23]. The mean aerosol (carrying ^{210}Pb) residence time in the troposphere is approximately 5 days [24].

Other sources of ^{210}Pb in air dust are volcanic activity and industrial emissions [25, 26, 27, 28, 29]. Examples of industrial emissions are discharges of power plants using fossil fuels, fertiliser and phosphorus industries, and exhaust gasses 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 [27]. Volcanic eruptions bring U-decay products in the atmosphere like ^{226}Ra, ^{222}Rn, ^{210}Pb and ^{210}Po. Beks et al. [27] 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.

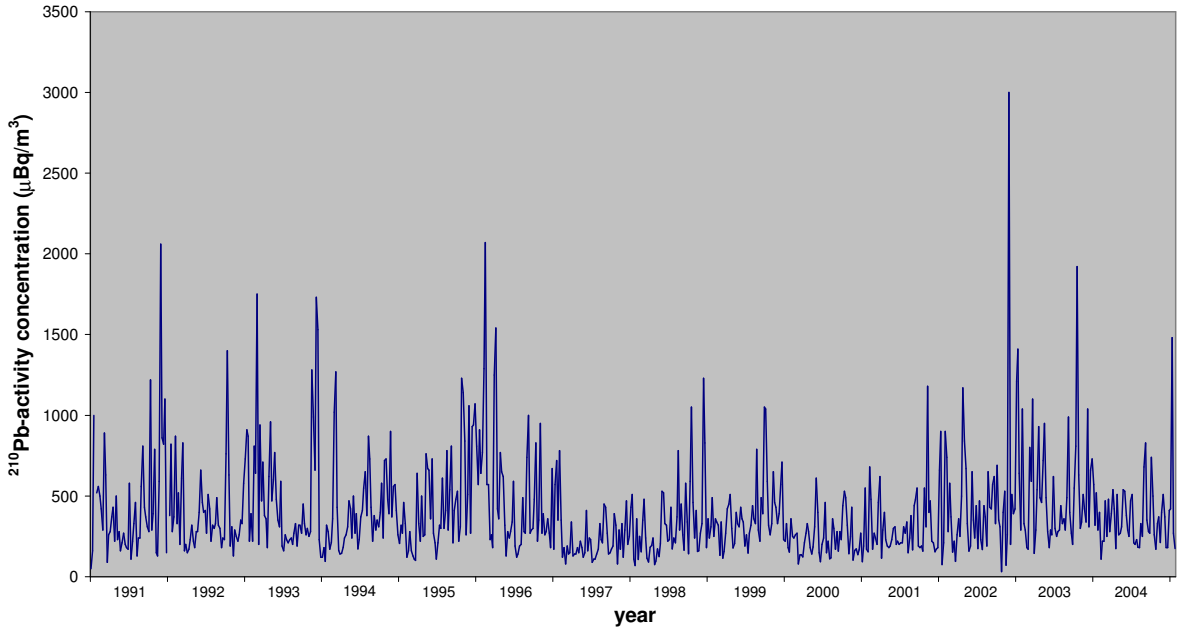


Figure 2.7: Weekly averaged activity concentrations of ^{210}Pb in air dust at RIVM in 1991-2004. Yearly average for 2004 is 370 ± 6 (SD=200) µBq·m^{-3}.

Unusual values might be explained by natural phenomena like an explosive volcanic eruption, Saharan dust [30, 31, 32] 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 [33]. Except for this sample there is a good correlation between high activity concentrations of ^{210}Pb and high activity concentrations of gross β, as is the case in week 50 of 2004 (1480 ± 130 µBq·m^{-3}). During that week the weather conditions were extremely stable with no interaction between different layers in the atmosphere [34]. Hence it is plausible that expelled ^{210}Pb was trapped at lower altitude which resulted in a high activity concentration.

The weekly averaged activity concentrations of ^{210}Pb in 2004 are within range of those found in previous years.

3. Deposition

The 2004 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.

Table 3.1: The 2004 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 gross α- and β-activity

The monthly deposited gross α- and gross β-activities of long-lived nuclides are given in *Figure 3.1* and *Table A4*. The yearly total deposition of gross α and gross β was 16.2 ± 0.9 and 73.5 ± 1.8 Bq·m^{-2}, respectively. These values do not differ significantly from those measured since 1983, as illustrated in *Figure 3.2* and *Table A5*. For gross α one out of twelve measurements was below the detection limit. For gross α and gross β one out of twelve results was not available due to a very hygroscopic sample. The measuring technique for gross α and gross β was changed around mid 1986 [35], which makes it difficult to compare data before 1986 with data after 1986 [36].

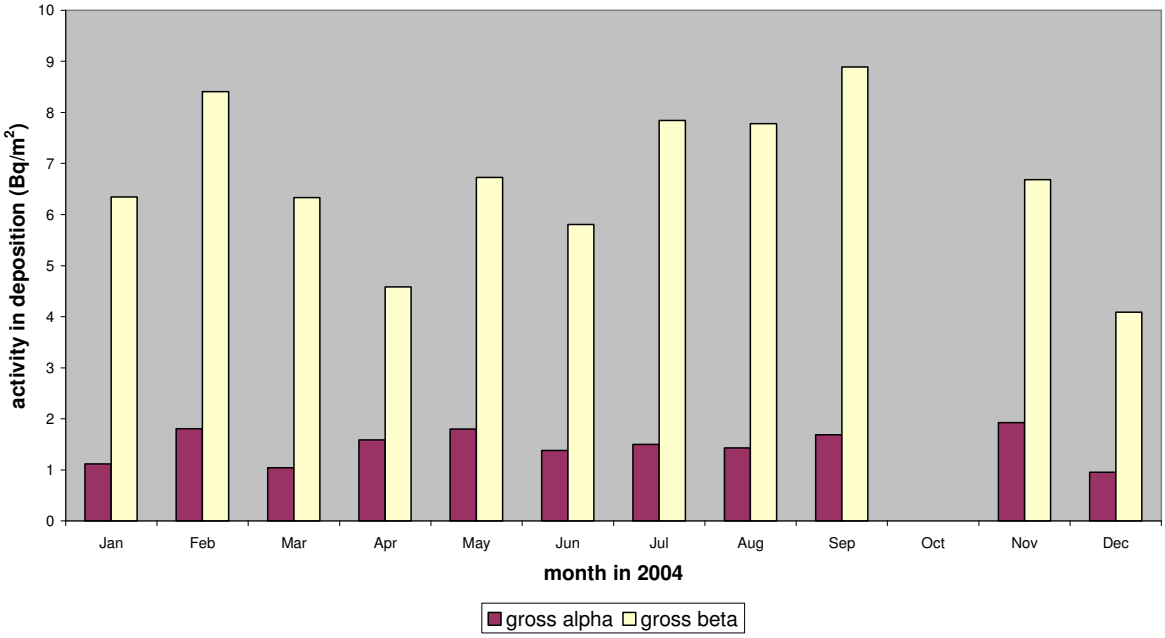


Figure 3.1: Monthly deposited gross α- and gross β-activity of long-lived nuclides at RIVM in 2004. The results for October were not available due to a very hygroscopic sample.

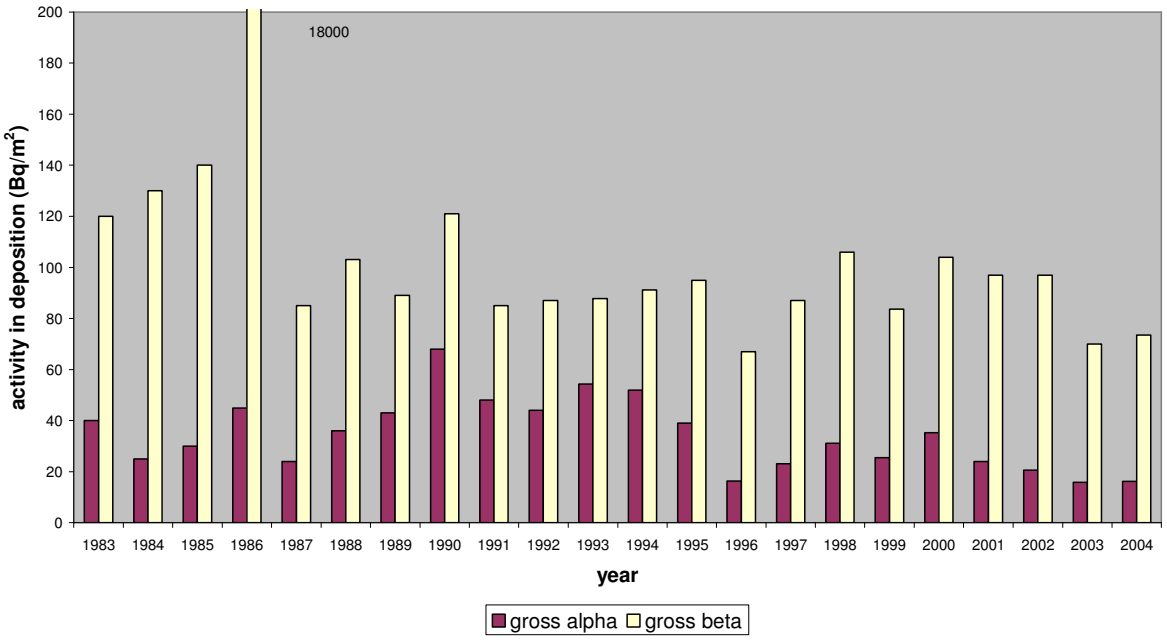


Figure 3.2: Yearly gross α- and gross β-activity of long-lived nuclides deposited at RIVM from 1983 to 2004 (see Table A5). The 1986 level resulted from the accident at the Chernobyl nuclear power plant.

The monthly deposition of ^{3}H is given in *Table A4*. In 2004 less than 1600 $Bq \cdot m^{-2}$ of ^{3}H was deposited. All measurements were below the detection limit. Therefore detection limits were used for the calculation of the yearly total. From 2001 onward single analyses are carried out instead of duplicate. Together with a less stable background this resulted in a higher detection limit for ^{3}H in 2001 than in previous years. From 2002 onward measurements are carried out on a new Liquid Scintillation Counter, which has a more stable background. *Figure 3.3* shows the decay of ^{3}H after the end of the atmospheric nuclear weapons tests in the seventies.

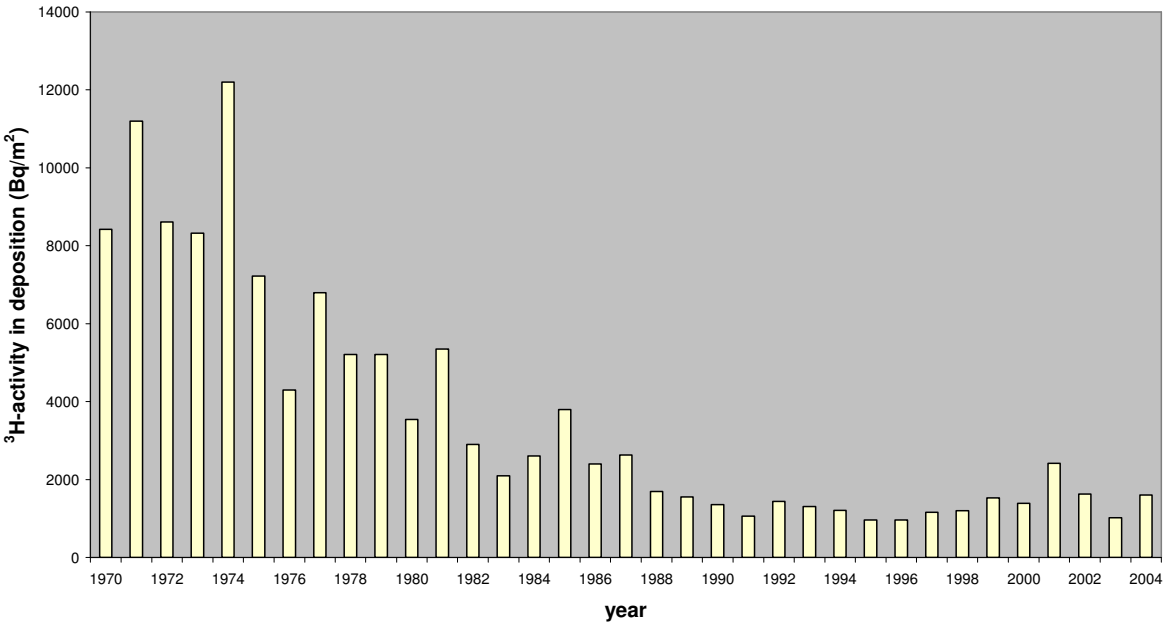


Figure 3.3: Yearly deposition of ^{3}H at RIVM in the period 1970-2004.

The monthly α-spectroscopy results for ^{210}Po are given in *Table A6*. The results for previous years are given in *Table A7*. In 2004 7.4 ± 0.3 Bq·m^{-2} of ^{210}Po was deposited. ^{210}Po was not detected in the samples from February, April, May and June. Therefore detection limits were used for their contribution to the yearly total.

3.2 γ-Emitting nuclides

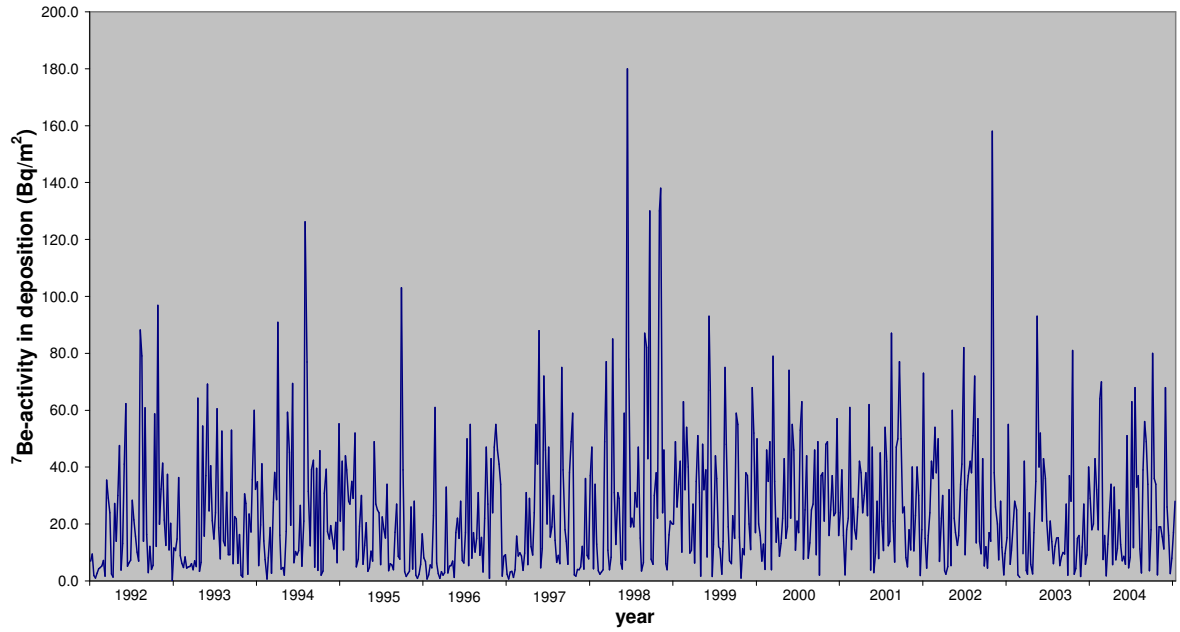


Figure 3.4: Weekly deposited ^{7}Be-activity at RIVM in 1992-2004. Yearly total deposition for 2004 is 1330 ± 30 Bq·m^{-2}.

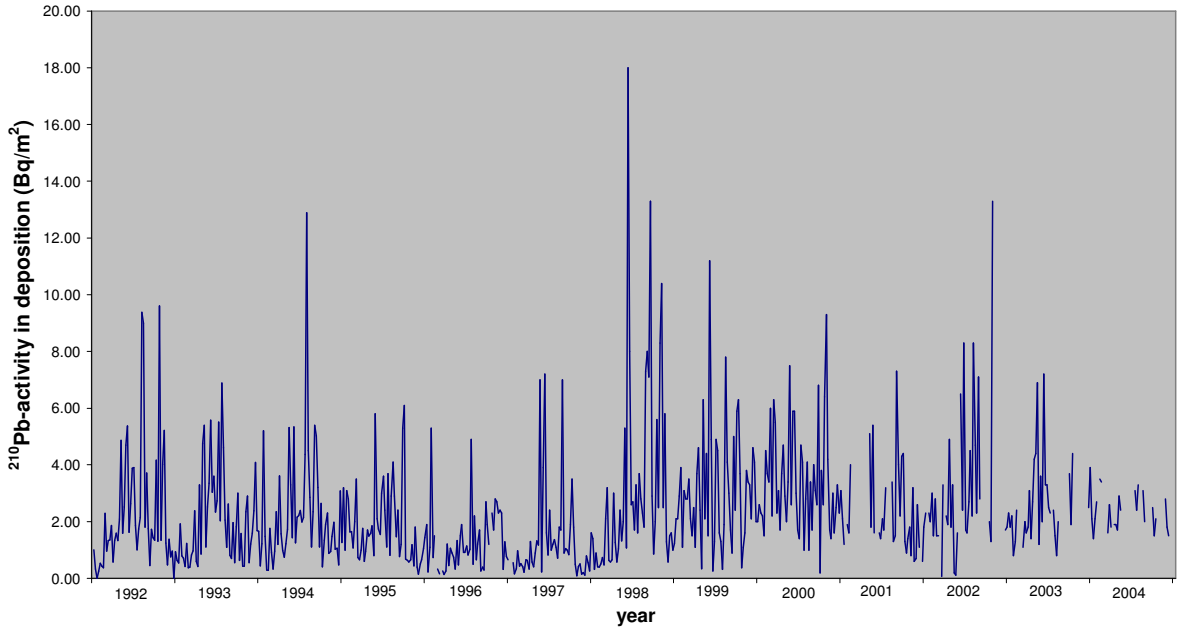


Figure 3.5: Weekly deposited ^{210}Pb-activity at RIVM in 1992-2004. Yearly total deposition for 2004 is 68 ± 4 Bq·m^{-2}.

Detectable quantities of the naturally occurring nuclides ^{7}Be and ^{210}Pb were found in 52 respectively 29 out of 52 samples. The yearly total depositions of ^{7}Be and ^{210}Pb are 1330 ± 30 and 68 ± 4 Bq·m^{-2}, respectively. The nuclide ^{137}Cs was not found (detection limit is 0.1 Bq·m^{-2}) in 50 out of 52 samples. The yearly total deposition of ^{137}Cs is 0.31 ± 0.09 Bq·m^{-2}. Detection limits are excluded from the yearly totals. The weekly results for deposition of ^{7}Be, ^{137}Cs and ^{210}Pb are given in *Table A8*. The results for previous years are given in *Table A7, Figure 3.4* and *3.5*.

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). The data on gross α and artificial β differ in sample size, sampling frequency and analytical procedures from those given in the previous chapter. The difference between the NMR data and those mentioned in the previous chapter is due to the contribution of short-lived natural radionuclides (radon daughters).

The NMR consists of 14 aerosol monitors for determining gross α- and artificial β-activity concentrations and 153 ambient dose equivalent rate monitors [37]. The 14 sites with an aerosol monitor are also equipped with a dose equivalent rate monitor. These 14 dose equivalent rate monitors are differently placed from the 153 dose equivalent rate monitors with regard to height (3.5 meter versus 1 meter above ground level) and surface covering. Therefore, results can differ between the two types of monitors [38]. 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 [39]. 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 error because of an overestimation of the cosmogenic dose rate and an underestimation of the terrestrial dose rate. Based upon earlier research [38, 40] it is assumed that the ambient dose equivalent rate is overestimated by 5 to 10 $nSv.h^{-1}$. However, NMR data are not corrected for these response errors.

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 2004, while *Figure 4.4* presents the yearly averages of ambient dose equivalent rate from 1996 to 2004. In 2004 the yearly averaged gross α-activity concentration in air dust was 3.4 $Bq \cdot m^{-3}$ (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 2.8 $Bq \cdot m^{-3}$. This value is within the range of those in

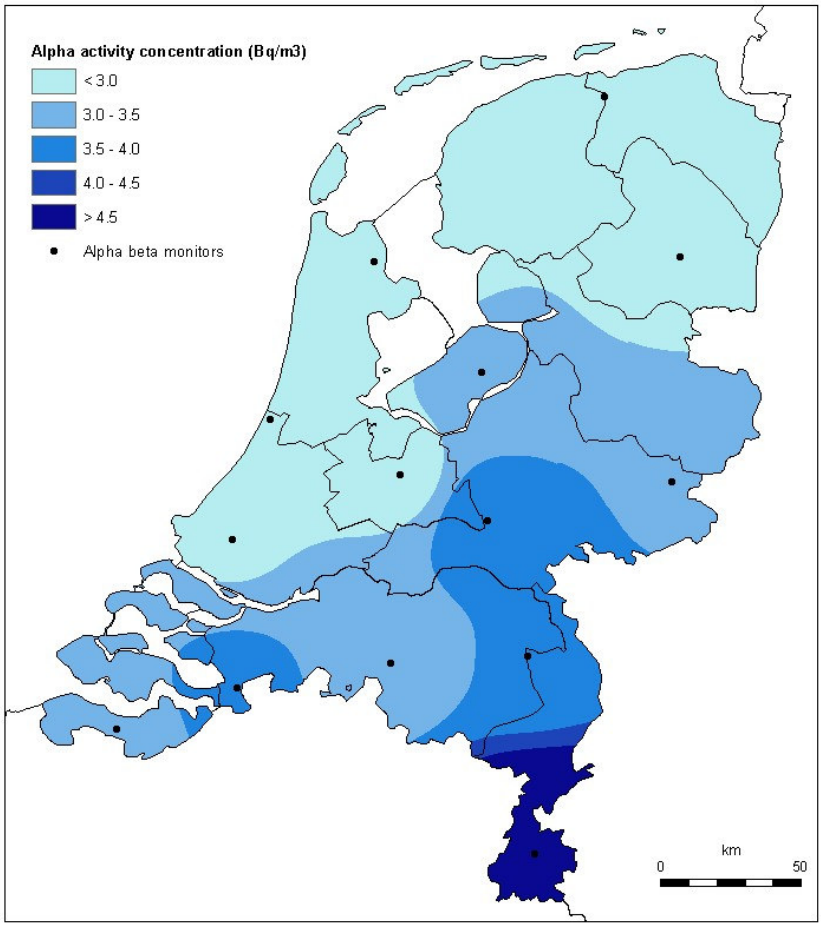


Figure 4.1: Spatial variation in the average gross α-activity concentration of (mainly) short-lived nuclides in air dust in 2004. The dots represent the locations of the aerosol monitors.

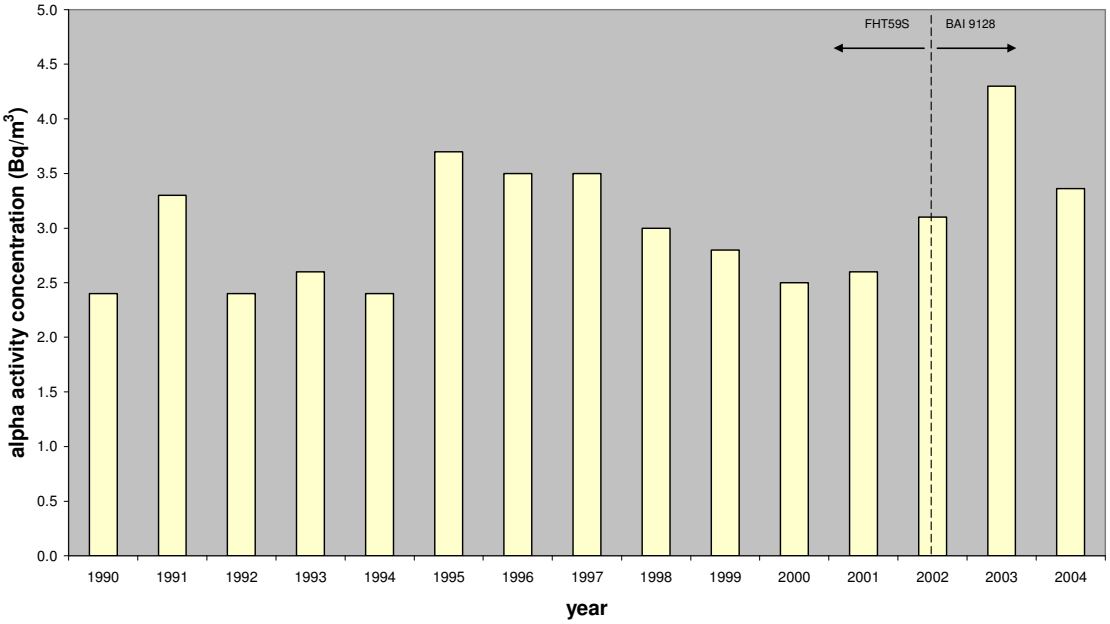


Figure 4.2: Yearly averages for gross α-activity concentration of (mainly) short-lived nuclides in air dust. During the second half of 2002 the FAG FHT59S monitors were gradually replaced by the Berthold BAI 9128 monitors. The Berthold monitor reports about 20% higher values than the FAG monitor. No correction is applied for the difference between both types of monitor.

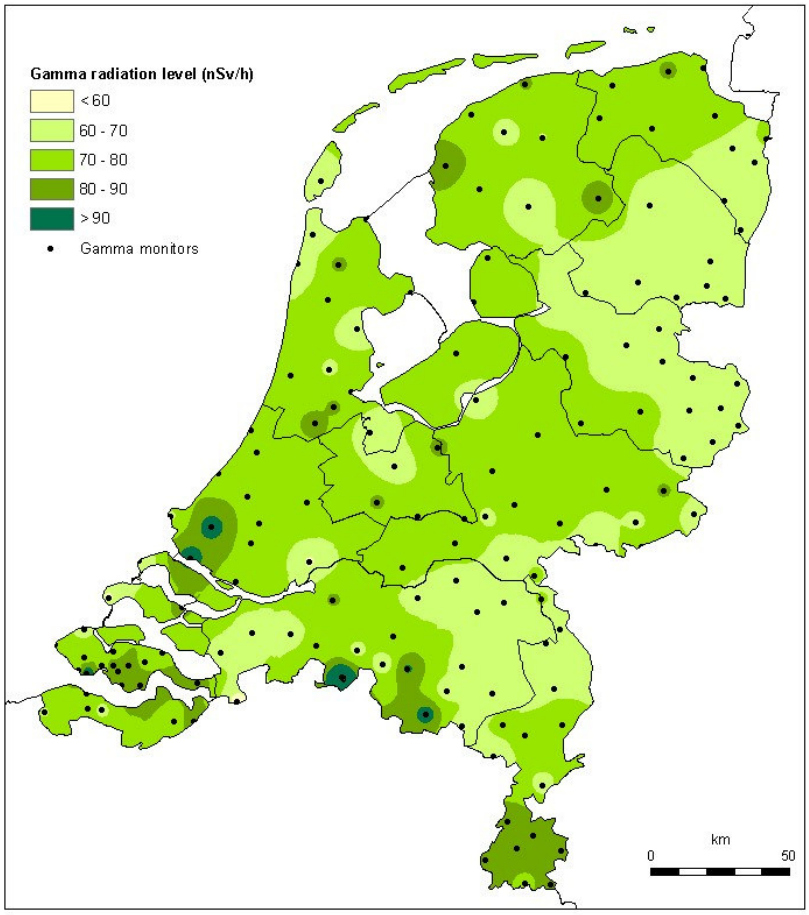


Figure 4.3: Spatial variation in the average ambient dose equivalent rate in 2004. The dots represent the locations of the dose equivalent rate monitors.

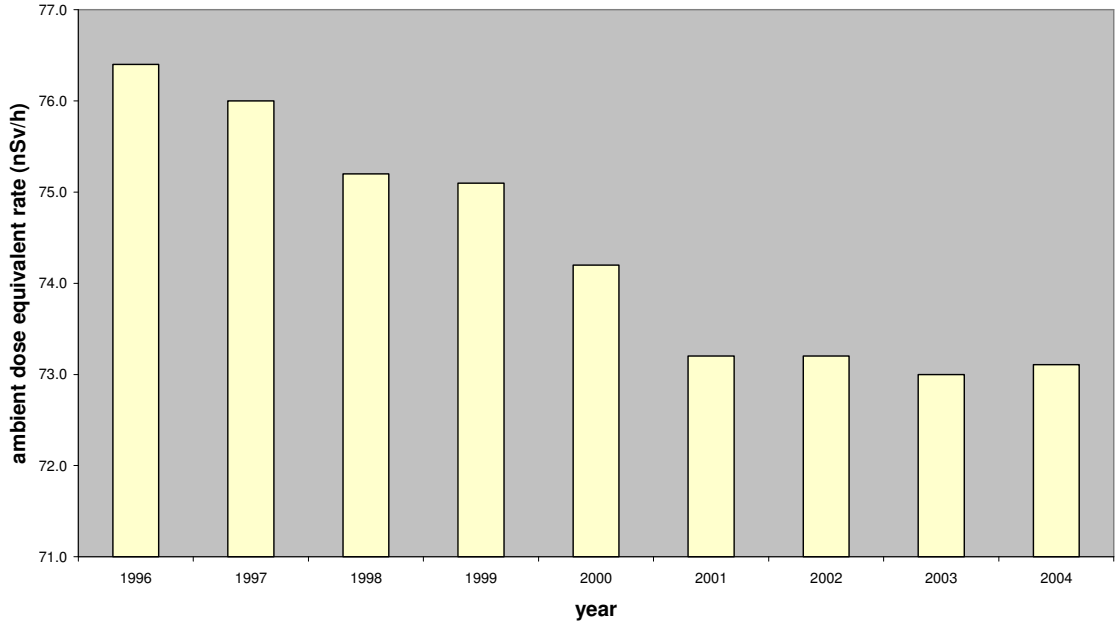


Figure 4.4: Yearly averages of the ambient dose equivalent rate.

previous years. The yearly average of the calculated artificial β-activity concentration does not deviate significantly from zero.

Between 1996 and 2003 the analysis of the ambient dose equivalent rate has been based on the set of 163 stations. The yearly averaged ambient dose equivalent rate in 2004 is calculated using 149 stations. The remaining 14 stations were not operational. Ten of these stations are part of the so-called ring around the nuclear power plant Dodewaard. The power plant stopped operation in March 1997. The last of the nuclear fuel was removed in April 2003. Therefore these stations are dismantled or will be dismantled in the near future. From 2004 onwards the analysis of the ambient dose equivalent rate has been based on the set of 153 stations.

For the ambient dose equivalent rate the yearly averaged measured value was 73.1 $nSv.h^{-1}$. It is assumed that this value is an overestimate of 5 to 10 $nSv.h^{-1}$. *Figure 4.5* shows the influence of the 11-year solar cycle on the cosmogenic contribution to the effective dose rate, which is related to the ambient dose equivalent rate. The decrease in the ambient dose equivalent rate (as given by the NMR) during 1996 to 2003 (*Figure 4.4*) might be related to the decrease in the cosmogenic contribution. However the increase in the cosmogenic contribution during 2004 does not result in an increase in the ambient dose equivalent rate (*Figure 4.4*).

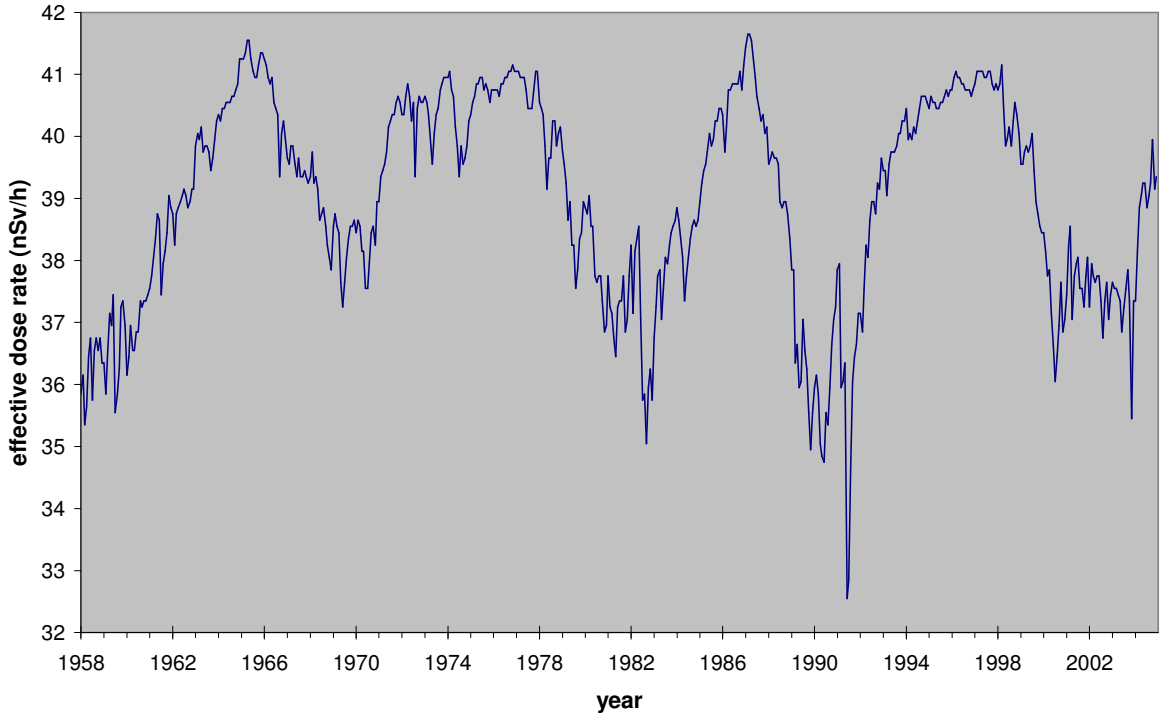


Figure 4.5: Cosmogenic contribution to the effective dose rate (at sea level), influenced by the solar cycle. Location 51°26' north latitude and 3°43' eastern longitude, air pressure 1019 hPa. Figure derived from data supplied by Office of Aerospace Medicine [41]. In previous reports [6, 33] an error has been made be presenting this data as ambient dose equivalent rate, it should be presented as effective dose rate.

5. Surface water and seawater

5.1 Introduction

The Institute for Inland Water Management and Waste Water Treatment (RIZA) and the National Institute for Coastal and Marine Management (RIKZ) regularly monitor the concentration of a number of radioactive nuclides in surface water and seawater. The monitoring program presented here forms only part of the 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 [42, 43, 44].

The locations presented in this report have been chosen to represent the major inland waters and seawater. The 2004 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 random times.

Table 5.1: Monitoring program for the determination of radioactive nuclides in surface water in 2004.

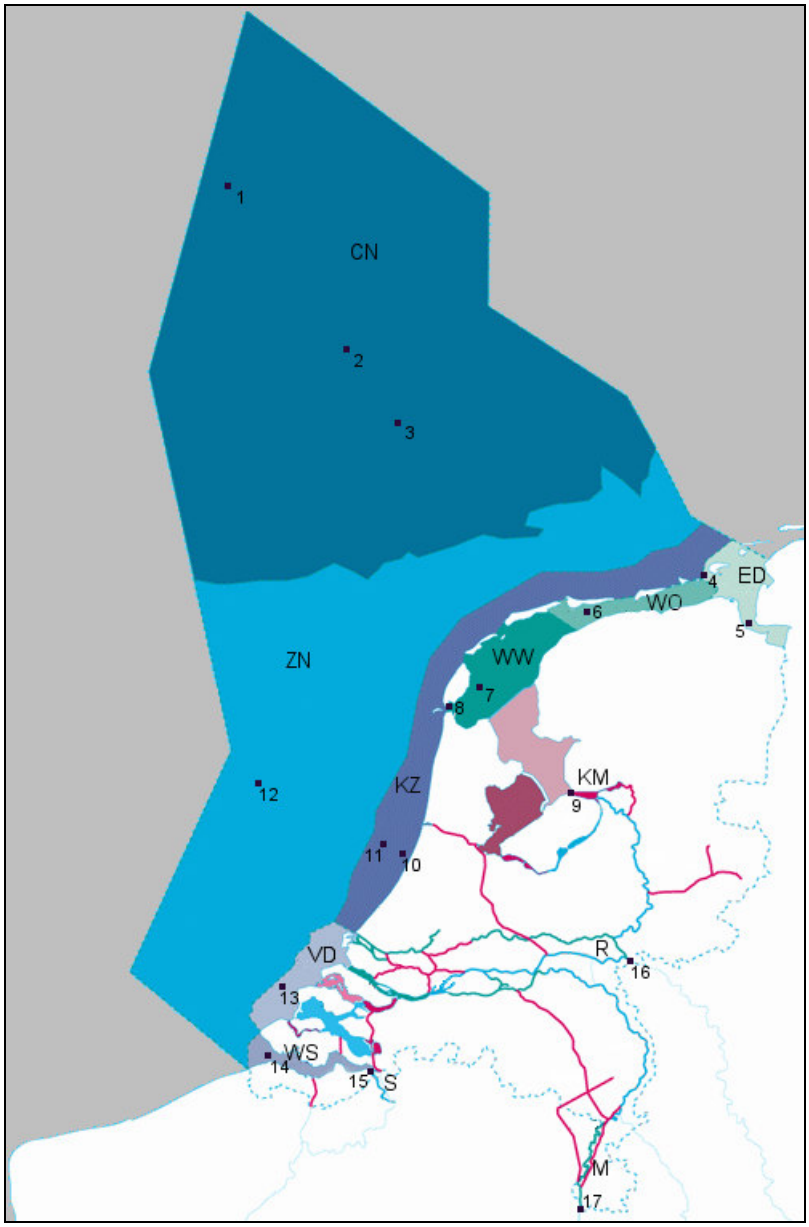
Location	Parameter	Compartment	Monitoring frequency (per year)
Meuse	Residual β	Water	13
(Eijsden)	^{3}H	Water	13
	^{137}Cs	Suspended solids	52
Rhine	Residual β	Water	13
(Lobith)	^{3}H	Water	13
	^{137}Cs	Suspended solids	13
Scheldt	Residual β	Water	13
(Schaar van Ouden Doel)	^{3}H	Water	6
	^{137}Cs	Suspended solids	13
Ketelmeer West	^{137}Cs	Suspended solids	6

The results for surface water are presented in *Tables A11* and *A12* and in *Figures 5.2 to 5.7*. The results for seawater are presented in *Tables A13* and *A14* and in *Figures 5.8* to *5.19*.
The samples were analysed at the RIZA laboratory in Lelystad. The radioactive nuclides were determined according to standard procedures [43] and [45]. In the Netherlands target values are in use for radioactive materials in surface water, which are given in the Fourth memorandum on water management (“Vierde Nota waterhuishouding”) [46]. The yearly averages are compared with these target values.

Table 5.2: Monitoring program for the determination of radioactive nuclides in seawater in 2004.

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

(1) Number indicates distance from shore. For example Noordwijk 2 means Noordwijk 2 km offshore.
(2) Normally 4 times per year. Not all measurements could be performed due to insufficient amount of collected suspended solids.



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:

KM	=	Ketelmeer
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	=	Ketelmeer West
10	=	Noordwijk 2
11	=	Noordwijk 10
12	=	Noordwijk 70
13	=	Schouwen 10
14	=	Vlissingen Boei
15	=	Schaar van Ouden Doel
16	=	Lobith
17	=	Eijsden

Noordwijk 2 means Noordwijk 2 km offshore.

Figure 5.1: Overview of monitoring locations for the monitoring program in surface water and in seawater. Terschelling 135 km offshore and Terschelling 100 km offshore were the old monitoring locations for the Central North Sea 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 [43].

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 Meuse, Rhine and Scheldt are monitored at Eijsden, Lobith and Schaar van Ouden Doel, respectively.

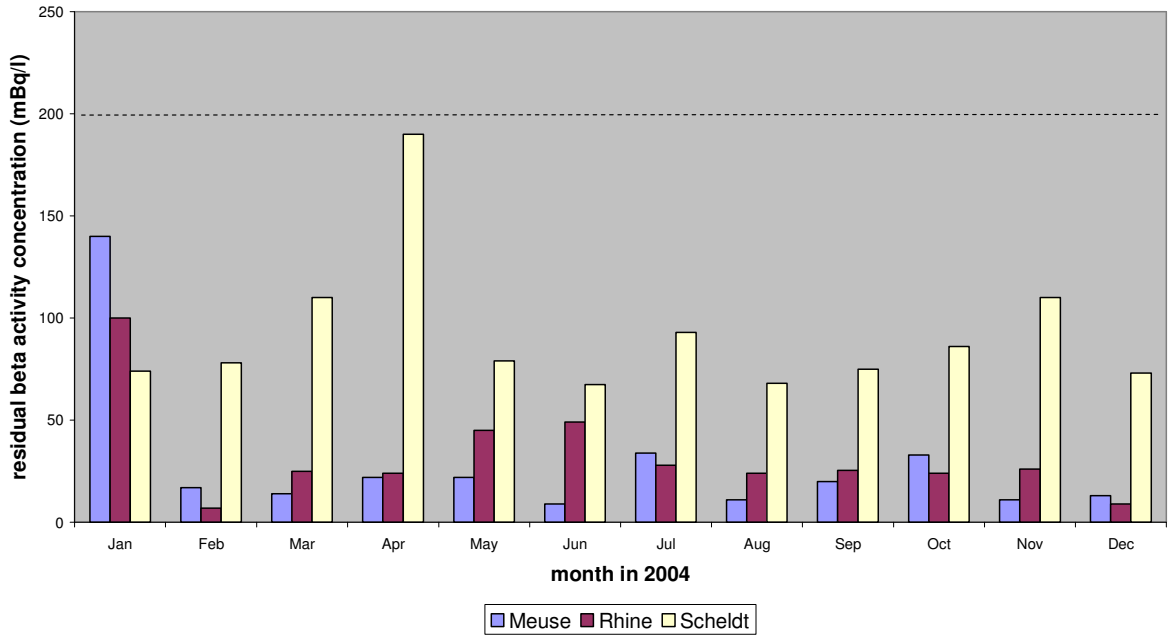


Figure 5.2: The residual β-activity concentration in 2004 for the Meuse, Rhine and Scheldt, with yearly averages of 27, 32 and 90 mBq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value [46].

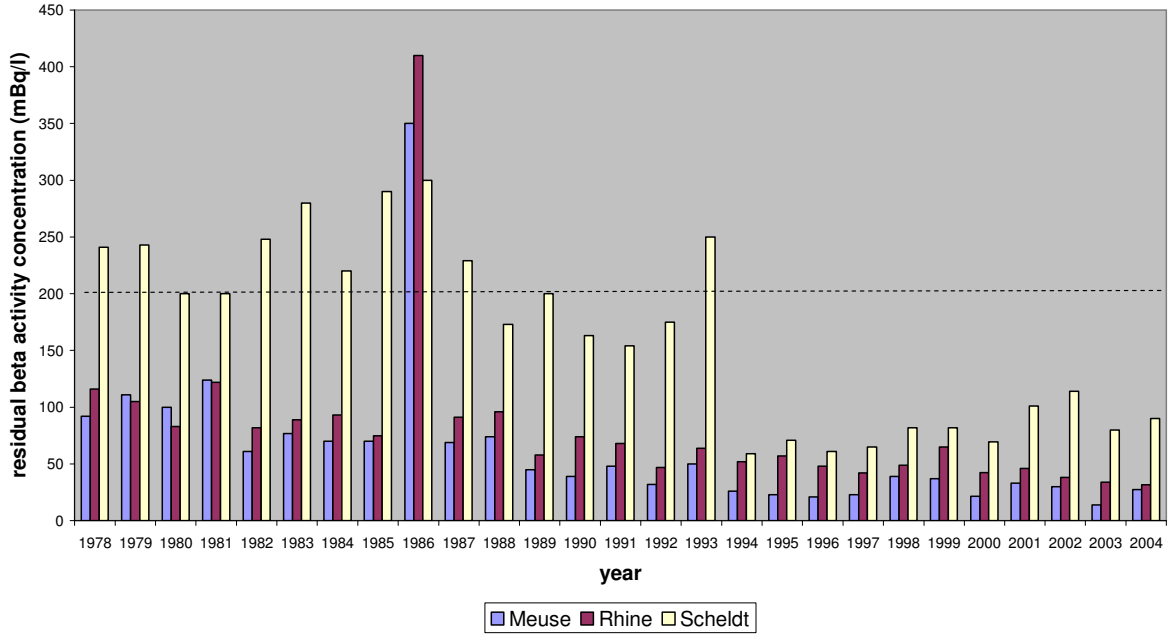


Figure 5.3: Yearly averaged residual β-activity concentrations.

The yearly averaged concentrations of residual β in 2004 are within the range of those in previous years. The averaged residual β-concentrations are below the target value of

200 mBq·L^{-1}. Residual β in the 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 [43]. Therefore, no change in trend is shown for the Meuse and the Rhine.

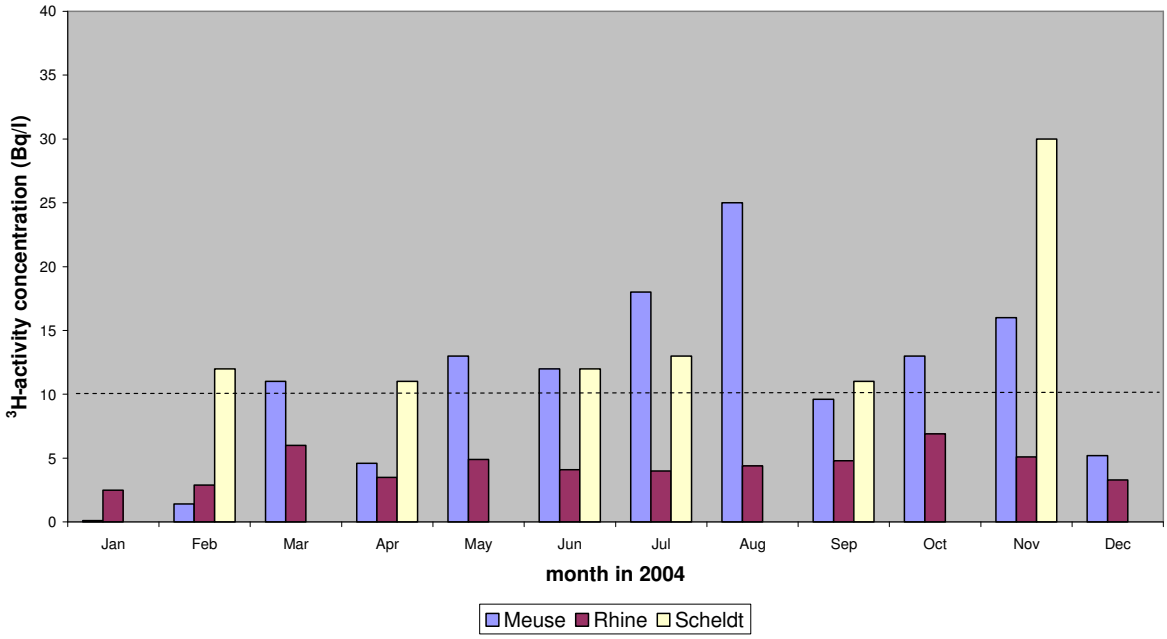


Figure 5.4: The ^{3}H-activity concentration in 2004 for Meuse, Rhine and Scheldt, with yearly averages of 11.8, 4.4 and 14.8 Bq·L^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value [46].

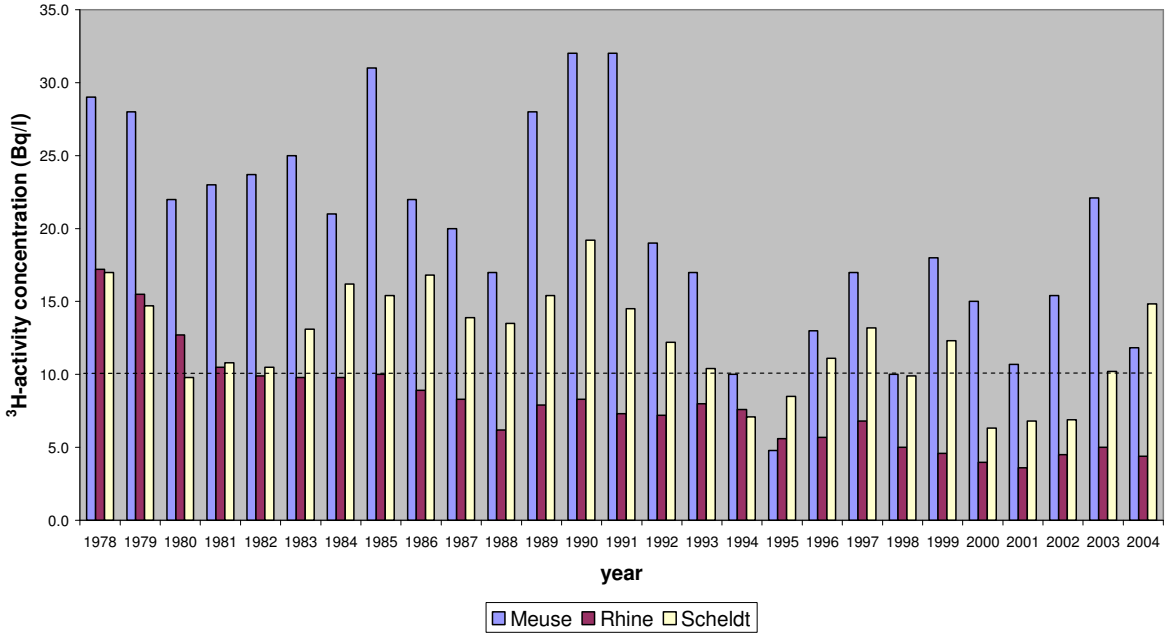


Figure 5.5: Yearly averaged ^{3}H-activity concentrations.

The ^{3}H-activity in the Meuse and the Scheldt exceeded the target value (10 Bq·L^{-1}) 8 out 13, respectively 6 out of 6 times. The elevated levels of ^{3}H in the Meuse (*Figure 5.4*) 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-concentrations in 2004 are within the range of those in

previous years. In 2004 the yearly averaged ^{3}H-concentration in the Meuse and the Scheldt (11.8 respectively 14.8 Bq·L^{-1}) are above the target value of 10 Bq·L^{-1}.

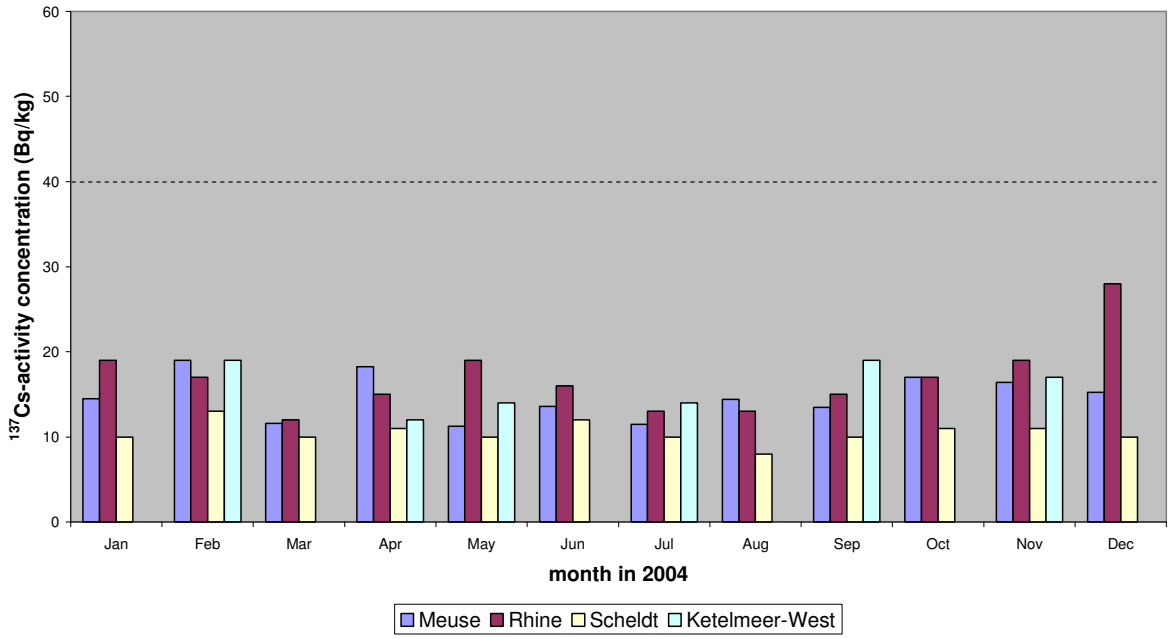


Figure 5.6: The ^{137}Cs-activity concentration in suspended solids in 2004 for the Meuse, Rhine, Scheldt and Ketelmeer-West with yearly averages of 15, 17, 11 and 16 Bq·kg^{-1}, respectively. Averaged values are shown in case of multiple measurements per month. The dotted line represents the target value [46].

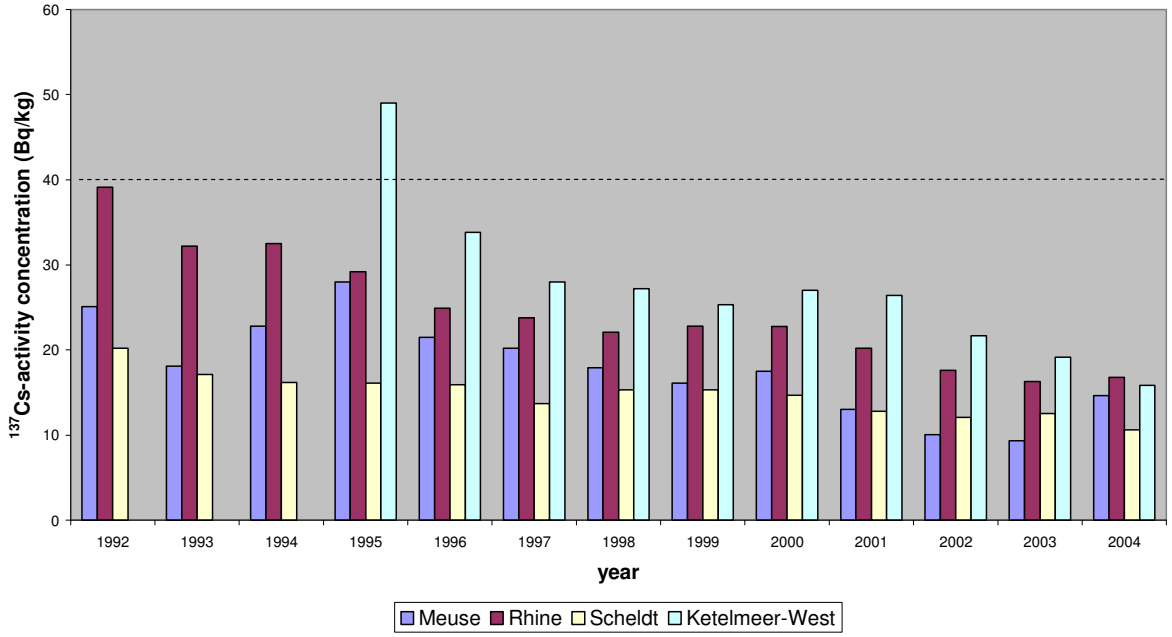


Figure 5.7: Yearly averaged ^{137}Cs-activity concentrations in suspended solids. Data on Ketelmeer-West are available since 1995.

The yearly averaged concentrations of ^{137}Cs in 2004 are within the range of those in previous years. The yearly averaged ^{137}Cs-concentrations are below the target value of 40 Bq·kg^{-1}. Except for 2004 the yearly averaged concentration of ^{137}Cs is consistently higher at

Ketelmeer-West compared to that at Lobith. This indicates an extra contribution besides the one currently originating from the Rhine, which can be explained by the following. Ketelmeer serves as a sink for Rhine sediment and thus contains a large amount of sediment deposited in previous years. A considerable amount of sediment, containing ^{137}Cs originating from the Chernobyl accident, resuspends in the relatively shallow Ketelmeer due to wind influences [47].

5.3 The results for seawater

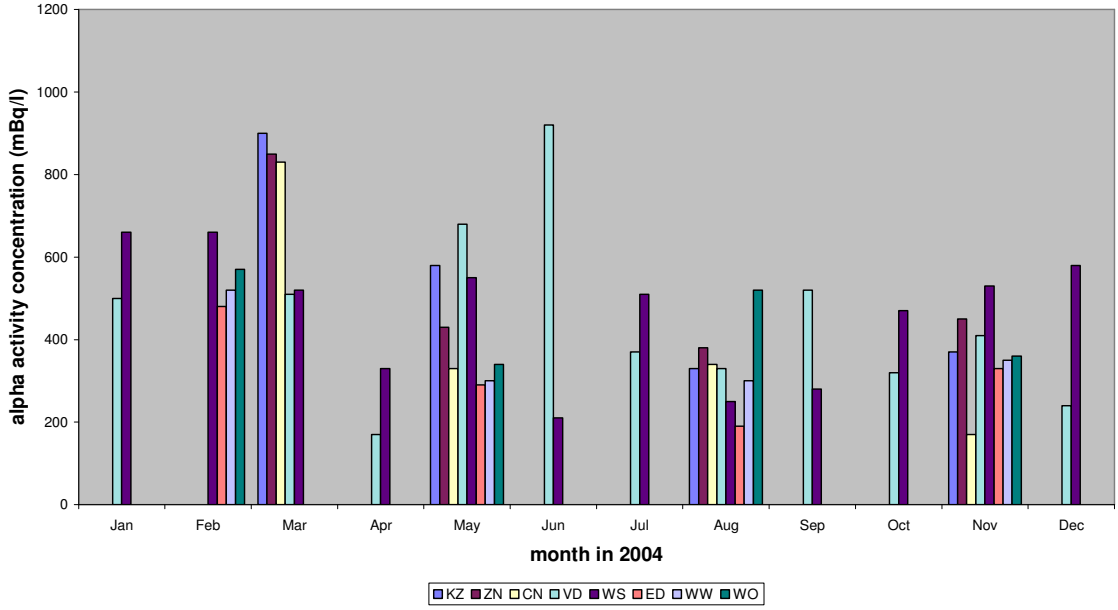


Figure 5.8: The gross α-activity concentration in seawater in 2004. The yearly averages for the Coastal area (KZ), Southern North Sea (ZN), Central North Sea (CN), Delta Coastal Waters (VD), Westerscheldt (WS), Eems-Dollard (ED), Wadden Sea West (WW) and Wadden Sea East (WO) are 540, 530, 420, 450, 460, 320, 370 and 450 mBq·L^{-1}, respectively.

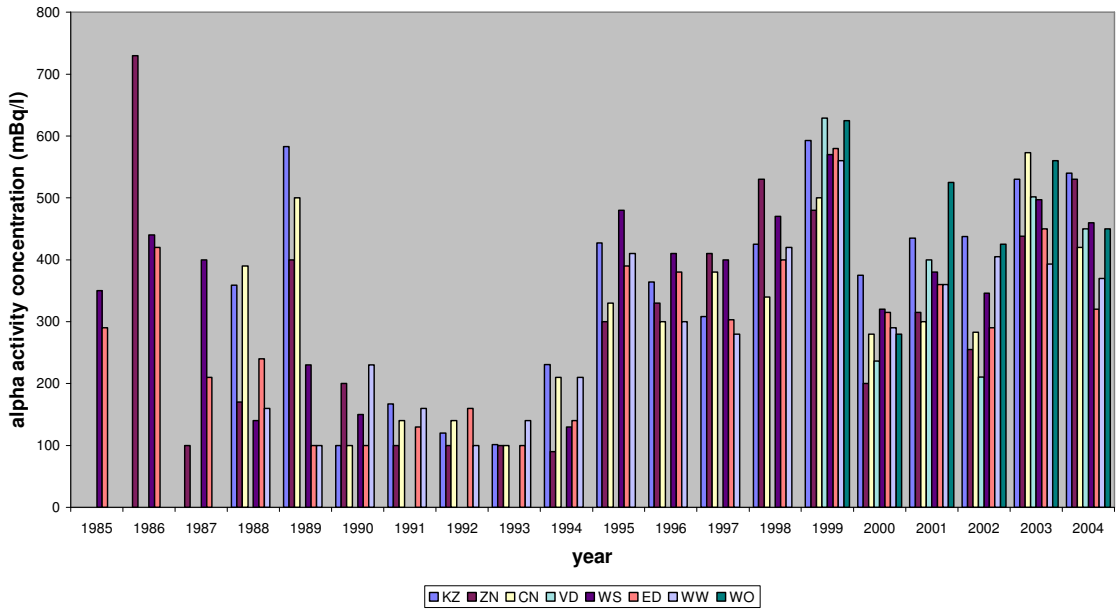


Figure 5.9: Yearly averaged gross α-activity concentrations.

Gross α and residual β are indicative parameters [43]. 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 in the period 1985-1997 are explained elsewhere [43]. The results of 2004 are within the range of those in the period 1995-2003.

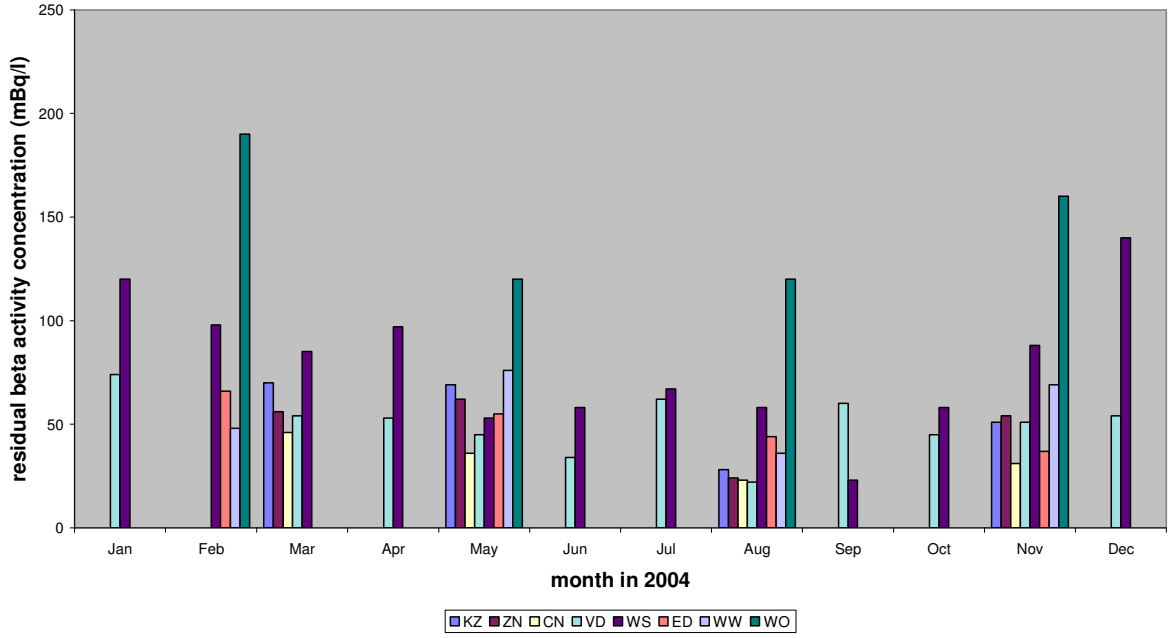


Figure 5.10: The residual β-activity concentration in seawater in 2004. The yearly averages for the Coastal area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East are 54, 49, 34, 50, 79, 50, 57 and 148 mBq·L^{-1}, respectively.

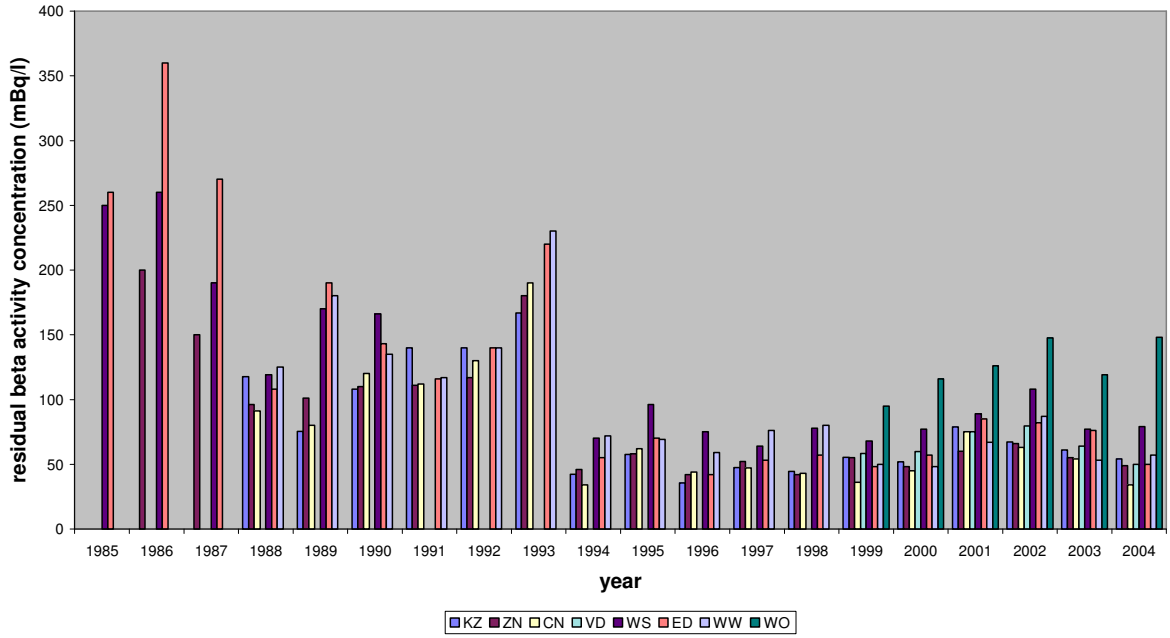


Figure 5.11: Yearly averaged residual β-activity concentrations.

Residual β 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 [43]. The yearly averaged concentrations of residual β in 2004 are within the range of those in the period 1994-2003.

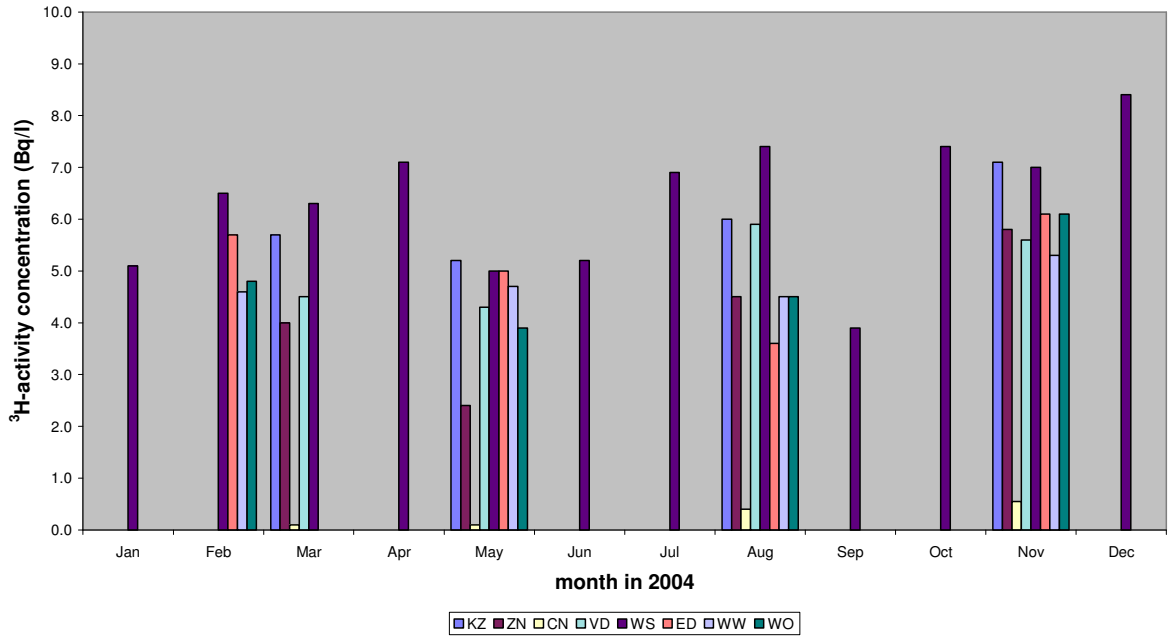


Figure 5.12: The ^{3}H-activity concentration in seawater in 2004. The yearly averages for the Coastal area, Southern North Sea, Central North Sea, Delta Coastal Waters, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East are 6.0, 4.2, 0.3, 5.1, 6.4, 5.1, 4.8 and 4.8 Bq·L^{-1}, respectively.

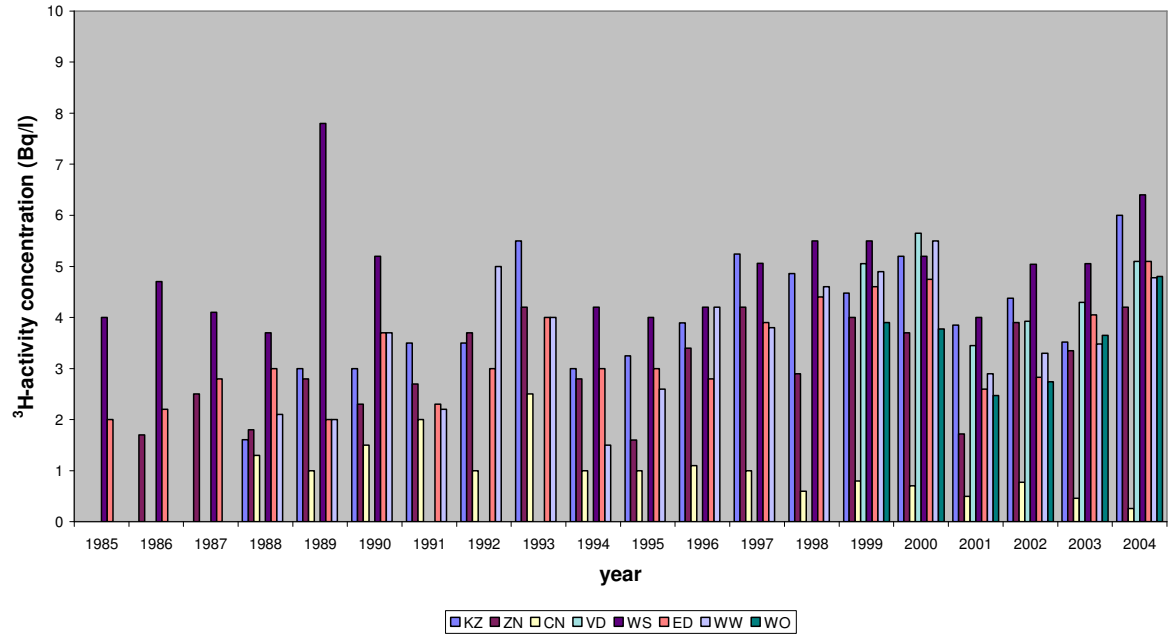


Figure 5.13: Yearly averaged ^{3}H-activity concentrations.

Nuclear power plants discharge the nuclides ^{3}H and ^{137}Cs. Nuclear fuel reprocessing plants discharge the nuclides ^{3}H and ^{90}Sr. Discharges by the research centre at Doel (Belgium) and the nuclear power plants at Doel and Borssele (the Netherlands) are monitored in the Westerscheldt (WS). The impact of reprocessing plants at Sellafield (England) and Le Havre (France) is monitored in the Central North Sea (CN) and Southern North Sea (ZN), respectively [43]. The impact of both sources (nuclear power and reprocessing plants) is monitored indirectly in the Delta Coastal Waters (VD). The yearly averaged concentrations of ^{3}H in 2004 are within the range of those in previous years.

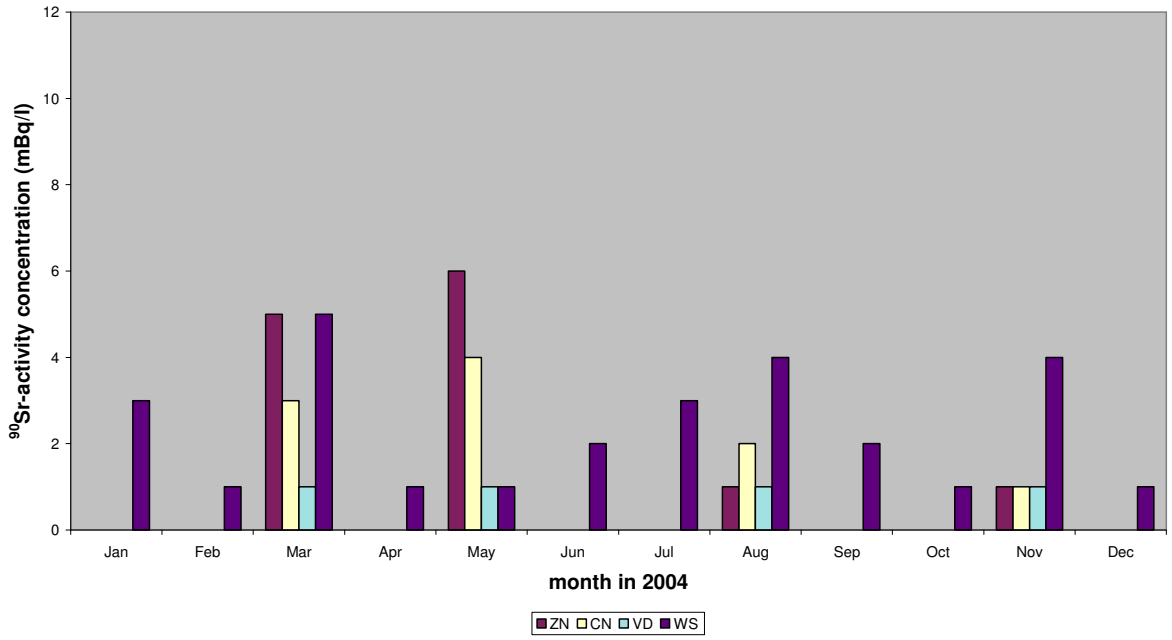


Figure 5.14: The ^{90}Sr-activity concentration in seawater in 2004. The yearly averages for the Southern North Sea, Central North Sea, Delta Coastal Waters and Westerscheldt are 3, 3, <1 and 2 mBq·L^{-1}, respectively.

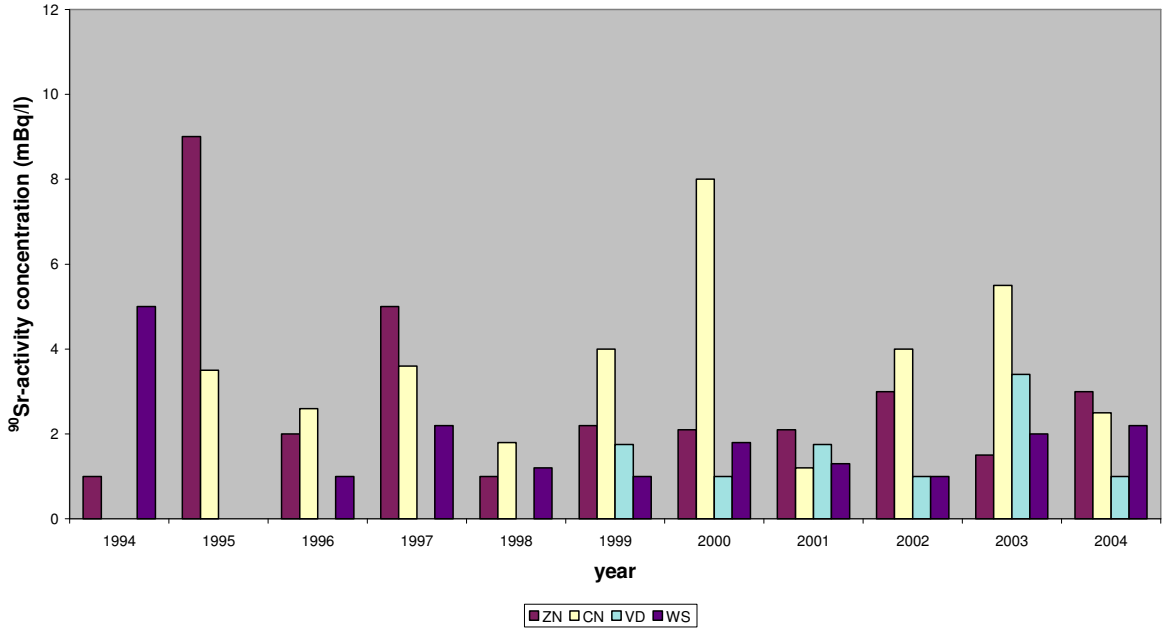


Figure 5.15: Yearly averaged ^{90}Sr-activity concentrations.

The yearly averaged concentrations of ^{90}Sr in 2004 are within the range of those in previous years.

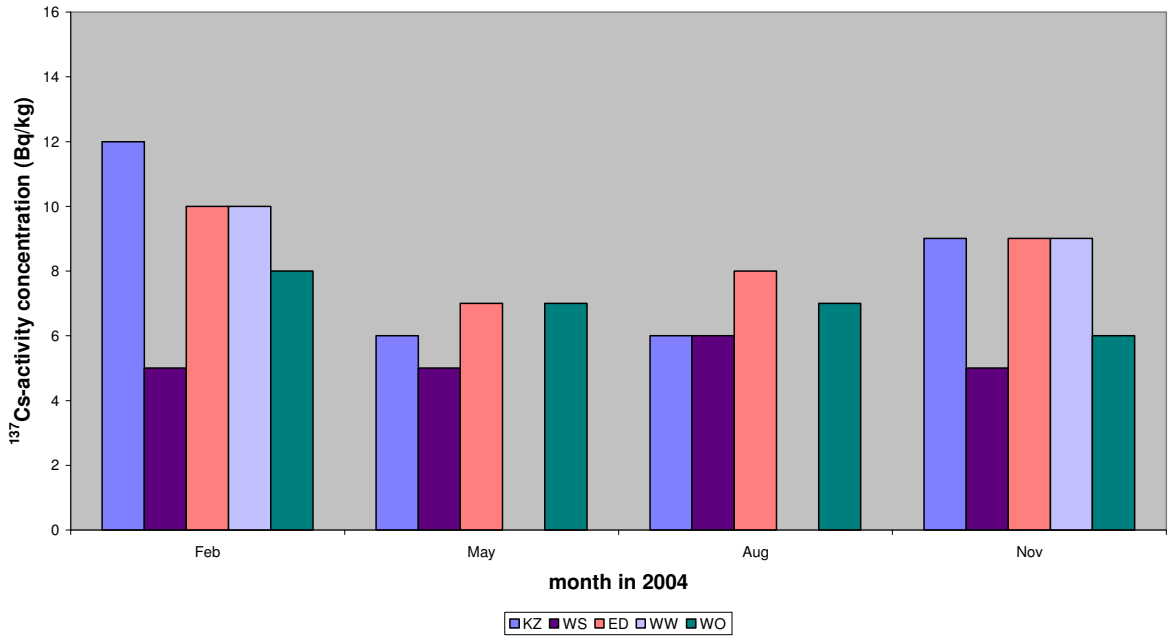


Figure 5.16: The ^{137}Cs-activity concentration in suspended solids in seawater in 2004. The yearly averages for the Coastal area, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East are 8, 5, 9, 10 and 7 Bq·kg^{-1}, respectively. Data were not available for some samples taken due to insufficient amount of collected suspended solids (May and August for Wadden Sea West).

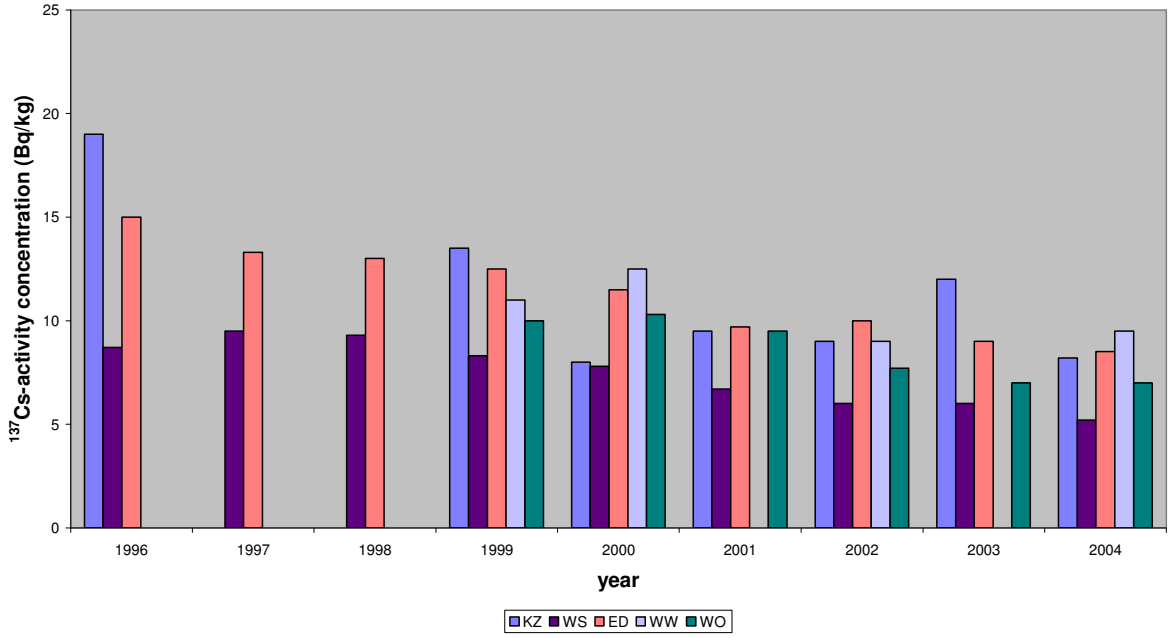


Figure 5.17: Yearly averaged ^{137}Cs-activity concentrations in suspended solids.

The yearly averaged concentrations of ^{137}Cs in 2004 are within the range of those in previous years. In 2001 and 2003 data were not available for Wadden Sea West due to insufficient amount of collected suspended solids.

The nuclide ^{210}Po originates from the uranium decay chain and is discharged by the phosphate processing industry and production platforms for oil and gas [43]. 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.

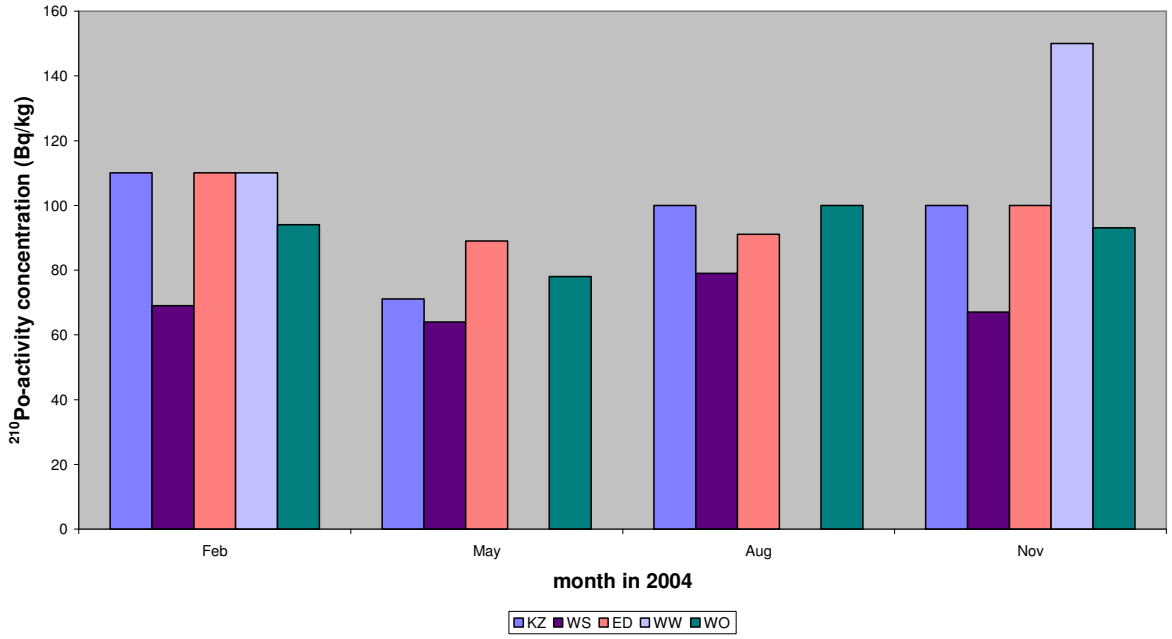


Figure 5.18: The ^{210}Po-activity concentration in suspended solids in seawater in 2004. The yearly averages for the Coastal area, Westerscheldt, Eems-Dollard, Wadden Sea West and Wadden Sea East are 95, 70, 98, 130 and 91 Bq·kg^{-1}, respectively. Data were not available for some samples taken due to insufficient amount of collected suspended solids (May and August for Wadden Sea West).

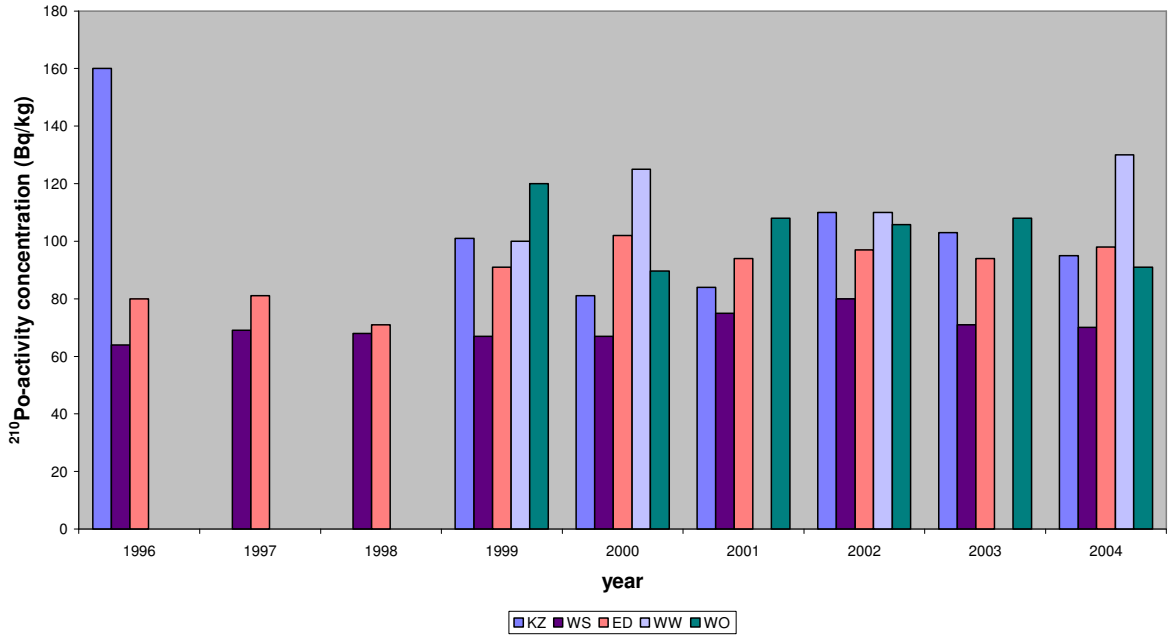


Figure 5.19: Yearly averaged ^{210}Po-activity concentrations in suspended solids.

The yearly averaged concentrations of ^{210}Po in 2004 are within the range of those in previous years. In 2001 and 2003 data were not available for Wadden Sea West due to insufficient amount of collected suspended solids.

6. Water for human consumption

In the Netherlands, water pumping-stations monitor raw input water for ^{3}H-, gross β- and residual β-activity. The monitoring frequency is from once to 26 times per year depending on the volume of water produced. The results for 2004 are presented in *Table 6.1*. For gross β almost a hundred analyses were performed divided over 13 pumping stations. For residual β and ^{3}H hunderds of analyses were performed divided over a much larger number of pumping stations.

Table 6.1 Analyses on drinking water in 2004.

Parameter	**^{3}H**	**Residual β**	**Gross β**
No. of analyses	619	410	91
No. of pumping stations	209	144	13
Average value	< 5 $Bq \cdot L^{-1}$	< 0.3 $Bq \cdot L^{-1}$	< 0.2 $Bq \cdot L^{-1}$
Maximum value (No.) [(1)]	15 $Bq \cdot L^{-1}$ (1)	< 0.3 $Bq \cdot L^{-1}$ (410)	0.24 $Bq \cdot L^{-1}$ (4)

[(1)] *Number of results with the maximum value is given between brackets.*

The results are within the range of those in previous years [6, 33]. Since there is almost no ^{40}K present, gross β- and residual β-activities are equal.

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.

7. Milk

Until 1997 RIVM monitored radioactivity in milk under authority of the Chief Veterinary Inspectorate for Public Health of the Ministry of Health, Welfare and Sport.
Because of the low levels of radioactivity found in the milk samples, the Chief Veterinary Inspectorate for Public Health of the Ministry of Health, Welfare and Sport decided to stop the monitoring program in 1998. This is not in compliance with the Euratom recommendation [1], in which it is recommended to monitor gamma emitters and ^{90}Sr in milk samples taken from dairies.

8. Food

Radioactivity is measured in food suspected to contain more than the normal activity concentrations. This is not in compliance with the Euratom recommendation [1], in which it is recommended to monitor gamma emitters and ^{90}Sr in mixed diets.

The measurements are performed by the Food and Consumer Product Safety Authority. Measurements were carried out according to standard procedures [49, 50]. The results are presented in *Table 8.1*. None of the samples exceeded the set limit [51].

8.1 Honey

In total 182 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 samples of heather honey contained ^{137}Cs. The activity varied from 4 up to 233 $Bq \cdot kg^{-1}$.

8.2 Game and poultry

In total 59 samples of game and poultry were analysed. Measurable quantities of activity were found in 2 samples of game. Two samples of roe contained 5 respectively 12 $Bq \cdot kg^{-1}$.

8.3 Other products

Radioactivity was not detected in some other products, amongst which dried mushrooms, fruit, flavourings, tea and cattle feed.

Table 8.1 Results of analysis of food for ^{134}Cs and ^{137}Cs.

Product	Number of samples	Number of positive samples	^{134}Cs ($Bq \cdot kg^{-1}$)	^{137}Cs ($Bq \cdot kg^{-1}$)
Honey	182	8	n.d.	4 - 233
Game and poultry	59	2	n.d.	5 - 12
Dried mushrooms	6	0	n.d.	n.d.
Fruit	1	0	n.d.	n.d.
Flavourings	5	0	n.d.	n.d.
Tea	12	0	n.d.	n.d.
Cattle feed	32	0	n.d.	n.d.

n.d. = not detectable

9. Conclusions

The ^{3}H-activity concentration in the Meuse exceeded the target value (10 Bq·L^{-1}) in eight out of thirteen samples taken. The yearly average (11.8 Bq·L^{-1}) is within range of previous years. The ^{3}H-activity concentration in the Scheldt exceeded the target value in all of the six samples taken. The yearly average (14.8 Bq·L^{-1}) is within range of previous years. The results of all other radioactivity measurements are within range of previous years.

The Dutch monitoring program does not fully comply with the recommendations of the European Union, mainly concerning the measurement of milk and food.

References

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

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

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

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

[5] NEN, 1991. Bepaling van de kunstmatige totale α-, kunstmatige totale β-activiteit en gammaspectrometrie van luchtfilters en berekening van de volumieke activiteit van de bemonsterde lucht. NEN Delft, NVN 5636.

[6] G.J. Knetsch (ed), 2004. Monitoring of radiation in the environment in the Netherlands. Results in 2003. RIVM Bilthoven, Report no. 861020010.

[7] A.C. Koolwijk, F.C.M. Mattern, R.M.S. Drost, A. Ockhuizen, 1988. Onderzoek naar de radioactiviteit in luchtstof te De Bilt. Resultaten over 1986. RIVM Bilthoven, Report no. 248202007.

[8] F.J. Aldenkamp, R.M.S. Drost, A.C. Koolwijk, P.J.M. Kwakman, A.P.P.A. van Lunenburg, A. Ockhuizen, R.B. Tax, M.H. Tijsmans, L.J. de Vries, P.J.M. van Westerlaak, 1993. Milieurapportage 1993 IV. Monitoring of radiation in atmosphere, water and a food chain. Results in the Netherlands in 1992. RIVM Bilthoven, Report no. 749204014.

[9] S. Sugihara, N. Momoshima, Y. Maeda, S. Osaki, 2000. Variation of atmospheric ^{7}Be and ^{210}Pb depositions at Fukuoka, Japan. IRPA 10th congress, internetsite: www.irpa.net/irpa10/cdrom/00822.pdf (July 2003).

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

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

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

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

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

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

[16] Solar Cycle Progression, July 2004. Internetsite: www.sec.noaa.gov/solarcycle.

[17] R.C.G.M Smetsers and R.O. Blaauboer, 1997. A dynamic compensation method for natural ambient dose rate based on 6 years data from the Dutch Radioactivity Monitoring Network. Radiat. Prot. Dosim. 69 (1), 19-31.
[18] S. I. Dusha-Gudym, 1992. Forest fires on the areas contaminated by radionuclides from the Chernobyl nuclear power plant accident. International Forest Fire News 7. Internetsite: www.fire.uni-freiburg.de (July 2003).
[19] KNMI database, July 2003. Internetsite: www.knmi.nl.
[20] T. Hantke, F.J. Aldenkamp, R.M.W. Overwater, H. Slaper, 1998. De jacht op een ^{137}Cs-wolk in Zuid Europa – "aftermath" van een ongeval in Algeciras. NVS Nieuws 23 (4).
[21] UNSCEAR, 2000. Sources and effects of ionizing radiation. Volume 1: Sources.
[22] E.A. Bondietti, C. Papastefanou, C. Rangarajan, 1987. Aerodynamic size associations of natural radioactivity with ambient aerosols. In: Radon and its Decay Products: Occurrence, Properties and Health Effects, ACS Symp. Ser. No. 331, P.K. Hopke (Ed.), American Chemical Society, Washington DC, 377-397.
[23] T. Suzuki, Y. Maruyama, N. Nakayama, K. Yamada, K. Ohta, 1999. Measurement of ^{210}Po/^{210}Pb activity ratio in size fractionated aerosols from the coast of the Japan sea. Atmospheric Environ. 33, 2285-2288.
[24] T. Tokieda, K. Yamanaka, K. Harada, S. Tsunogai, 1996. Seasonal variations of residence time and upper atmospheric contribution of aerosols studied with Pb-210, Bi-210, Po-210 and Be-7. Tellus, 48B, 690-702.
[25] G. Lambert, P. Bristeau, G. Polian, 1976. Emission and enrichments of Radon daughters from Etna volcano magma. Geophys. Res. Lett. 3 (12), 724-726.
[26] J. Sato, T. Doi, T. Segawa, S. Sugawara, 1994. Seasonal variation of atmospheric concentrations of ^{210}Pb and ^{7}Be at Tsukuba, Japan, with a possible observation of ^{210}Pb originating from the 1991 eruption of Pinatubo volcano, Phillippines. Geochem. J. 28, 123-129.
[27] J.P. Beks, D. Eisma, J. van der Plicht, 1998. A record of atmospheric ^{210}Pb deposition in the Netherlands. Sci. Total Environ. 222, 35-44.
[28] J. Sato, 2003. Natural radionuclides in volcanic activity. Appl. Radiat. Isotop. 58, 393-399.
[29] G. Lambert, B. Ardouin, G. Polian, 1982. Volcanic ouput of long-lived Radon daughters. J. Geophys. Res. 87 (C13), 11103-11108.
[30] E.Y. Nho, B. Ardouin, M.F. Le Cloarec, M. Ramonet, 1996. Origins of ^{210}Po in the atmosphere at Lamto, Ivory Coast: biomass burning and Saharan dust. Atmospheric Environ. 30 (22), 3705-3714.
[31] M.A. Mélières, M. Pourchet, S. Richard, 2003. Surface air concentration and deposition of lead-210 in French Guiana: two years of continuous monitoring. J. Environ. Radioactivity 66, 261-269.
[32] P.G. Appleby, A.O. Koulikov, L. Camarero, M. Ventura, 2002. The input and transmission of fall-out radionuclides through Redó, a high mountain lake in the Spanish Pyrenees. Water, Air & Soil Pollution: Focus 2, 19-31.
[33] G.J. Knetsch (ed), 2003. Monitoring of radiation in the environment in the Netherlands. Results in 2002. RIVM Bilthoven, Report no. 861020005.
[34] KNMI, 2005. Maandoverzicht van het weer in Nederland, december 2004. De Bilt, 101^{e} jaargang, nummer 12.

[35] L.H. Vaas, F.C.M. Mattern, R.M.S. Drost, P. Glastra, A.C. Koolwijk, A. Ockhuizen, 1989. Onderzoek naar de radioactiviteit van neerslag. Resultaten over 1986. RIVM Bilthoven, Report no. 248701005.
[36] L.H. Vaas, F.C.M. Mattern, R.M.S. Drost, P. Glastra, A.C. Koolwijk, A. Ockhuizen, 1989. Onderzoek naar de radioactiviteit van neerslag. Resultaten over 1987. RIVM Bilthoven, Report no. 248701006.
[37] C. de Hoog, S.T. van Tuinen, F.J. Aldenkamp, 2002. The National Radioactivity Monitoring Network. The second generation (in Dutch). NVS Nieuws 2002/2, p. 32-36.
[38] R.O. Blaauboer and R.C.G.M. Smetsers, 1996. Variations in outdoor radiation levels in the Netherlands. Thesis University of Groningen, Groningen.
[39] C. de Hoog en R.B. Tax, 2003. Achtergronddocument bij NMR integrale rapportage 2002.
[40] R.C.G.M. Smetsers, L.J. de Vries, A.P.P.A. van Lunenburg, F.J. Aldenkamp, 1996. National radioactivity monitoring network (LMR): Data report 1993–1995. RIVM Bilthoven, Report no. 610056028.
[41] Office of Aerospace Medicine, November 2003. Internetsite: http://www.cami.jccbi.gov/AAM-600/Radiation/600radio.html.
[42] RIZA and RIKZ, July 2005. Internetsite: www.watermarkt.nl.
[43] E.J. de Jong en O.C. Swertz, 2000. Radioactieve stoffen in de zoute wateren. RIKZ, Den Haag, Report no. RIKZ/2000.041.
[44] L.J. Gilde, K.H. Prins, C.A.M. van Helmond, 1999. Monitoring zoete rijkswateren. RIZA Lelystad, Report no. 99.004.
[45] E.J. de Jong, W. Lutthmer, B. Munster, 1995. Onderzoek naar radioactieve stoffen in Rijkswateren. Resultaten 1992. RIZA, Lelystad.
[46] Ministerie V&W, 1998. Vierde Nota waterhuishouding. Den Haag.
[47] J.E.M. Beurskens, C.G.C. Dekker, J. Jonkhoff, L. Pomstra, 1995. Microbial dechlorination of hexachlorobenzene in a sedimentation area of the Rhine river. In: Microbial transformation of chlorinated aromatics in sediments (dissertation), Wageningen.
[48] F.M. Versteegh, F.W. van Gaalen, B.A. Baumann, E. Smit, L. Vaas, 1995. Resultaten van het meetprogramma drinkwater 1994 voor parameters uit het Waterleidingbesluit en enkele aanvullende parameters. RIVM Bilthoven, Report no. 731011009.
[49] Keuringsdienst van Waren Oost, 1998. Werkvoorschrift CHE01-OT802, Keuringsdienst van Waren Oost, Bepaling van de activiteit van gammastraling uitzendende nucliden in een telmonster met halfgeleiderspectrometrie. Nijmegen.
[50] Keuringsdienst van Waren Oost, 2003. Werkvoorschrift CHE01-WV143, Keuringsdienst van Waren Oost, Bepaling van de activiteit van gammastraling uitzendende nucliden in een telmonster met de LMRV voedselmonitor. Zutphen.
[51] EEC, 1990. Council Regulation on the conditions governing imports of agricultural products originating in third countries following the accident at the Chernobyl nuclear power-station. EEC Brussels, No. 737/90.
[52] Voedsel en Waren Autoriteit/Keuringsdienst van Waren, 2005. Radiologisch jaarverslag 2004. Zutphen.

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

[54] Letter to the State Health Inspectorate of the Ministry of Housing, Spatial Planning and Environment, January 13th, 1997. Reference no. 23/97 LSO Le/Ald/jdk. Onderzoek naar de slechte resultaten in 1995 van de bepaling van ^{210}Po en ^{210}Pb in natte en droge depositie. RIVM Bilthoven.

Appendix A: Result tables

Table A1: Weekly results of gross α- and gross β-activity concentrations in air dust sampled with a HVS at RIVM in 2004.

Week [1] Number	Gross α mBq.m^{-3}	Gross β mBq.m^{-3}		Week [1] number	Gross α mBq.m^{-3}	Gross β mBq.m^{-3}	
1	0.058	0.350	± 0.019	27	0.041	0.221	± 0.016
2	0.035	0.171	± 0.013	28	0.051	0.223	± 0.016
3	0.028	0.227	± 0.016	29	0.07	0.35	± 0.02
4	0.027	0.220	± 0.016	30	0.040	0.273	± 0.019
5	0.038	0.41	± 0.03	31	0.036	0.57	± 0.04
6	0.031	0.200	± 0.015	32	0.07	0.85	± 0.05
7	0.044	0.40	± 0.03	33	0.051	0.42	± 0.03
8	0.036	0.274	± 0.019	34	0.040	0.32	± 0.02
9	0.055	0.37	± 0.02	35	0.045	0.30	± 0.02
10	0.040	0.50	± 0.03	36	0.07	0.66	± 0.04
11	0.046	0.38	± 0.03	37	0.046	0.49	± 0.03
12	0.014	0.193	± 0.014	38	0.027	0.36	± 0.02
13	0.046	0.50	± 0.03	39	0.031	0.185	± 0.013
14	0.024	0.253	± 0.018	40	0.058	0.36	± 0.02
15	0.021	0.285	± 0.019	41	0.036	0.40	± 0.03
16	0.032	0.33	± 0.02	42	0.035	0.277	± 0.019
17	0.022	0.48	± 0.03	43	0.06	0.45	± 0.03
18	0.061	0.51	± 0.03	44	0.042	0.39	± 0.03
19	0.031	0.41	± 0.03	45 [2]	0.039	0.278	± 0.019
20	0.035	0.34	± 0.02	46	0.033	0.191	± 0.014
21	0.033	0.29	± 0.02	47 [2]	0.047	0.267	± 0.019
22	0.06	0.45	± 0.03	48 [2]	0.044	0.38	± 0.03
23	0.07	0.47	± 0.03	49 [2]	0.14	0.38	± 0.02
24	0.029	0.248	± 0.017	50 [2]	0.10	1.19	± 0.08
25	0.020	0.205	± 0.015	51 [2]	0.031	0.31	± 0.02
26	0.032	0.273	± 0.019	52 [2]	0.064	0.259	± 0.015
				Average	0.04 [3]	0.367	± 0.004 [4]
				SD [5]	0.02		0.17

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

[2] Due to problems with the high volume sampler sampling occurred with a lower flow (about one third of regular flow) during 0.5 to 1.5 day of the week and in case of week 50, 51 and 52 didn't occur at all during 1, 0.5 and 1 day, respectively.

[3] Due to large uncertainties caused by variations in dust thickness on the filters, gross α-activity concentrations in air dust are given as indicative values [5].

[4] The error in the yearly average is equal to the square root of the sum of the squared weekly errors divided by the number of weeks. Errors are given as 1σ.

[5] SD is the standard deviation of the weekly results. Errors are given as 1σ.

Table A2: Detection limits ($\mu Bq \cdot m^{-3}$) in the residue measurement of air dust sampled during a seven days sampling period with a HVS at RIVM in 2004. Measurements were carried out on a coaxial detector with a ten days delay between sampling and start of measurement, a counting time of 100,000 seconds and a sample volume of about 50,000 m^3. The detection limits are higher than before 2000 [53] due to a different detector set-up.

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

(1) Due to the relatively short half-life of ^{24}Na and the long delay between the sampling and the measurement this nuclide cannot be determined in the residue measurement on the coaxial detector. Therefore, the detection limit for the filter measurement on the coaxial detector is given (3 days delay time, 100,000 seconds counting time).
(2) Due to the sample preparation procedure the volatile nuclide ^{131}I cannot be determined in the residue measurement on the coaxial detector. Therefore, the detection limit for the filter measurement on the coaxial detector is given (3 days delay time, 100,000 seconds counting time).

Table A3: Weekly results of ^{7}Be-, ^{137}Cs- and ^{210}Pb-activity concentrations in air dust sampled with a HVS at RIVM in 2004. Empty fields indicate that the value was below the detection limit given in Table A2.

Week number	Period	^{7}Be µBq·m^{-3}			^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}		
1	31/12-09/01	2500	±	200		400	±	40
2	09/01-16/01	2900	±	300		109	±	18
3	16/01-23/01	1930	±	170		220	±	30
4	23/01-30/01	2600	±	200		220	±	20
5	30/01-06/02	3900	±	300		470	±	40
6	06/02-13/02	2500	±	200		250	±	30
7	13/02-20/02	3200	±	300		480	±	50
8	20/02-27/02	2700	±	200		280	±	30
9	27/02-05/03	3100	±	300		390	±	40
10	05/03-12/03	3300	±	300		540	±	50
11	12/03-19/03	3000	±	300		420	±	40
12	19/03-26/03	1670	±	150		175	±	18
13	26/03-02/04	3900	±	300		510	±	50
14	02/04-09/04	2500	±	200		260	±	30
15	09/04-16/04	3800	±	300		270	±	30
16	16/04-23/04	3900	±	300		310	±	30
17	23/04-29/04	3700	±	300		540	±	50
18	29/04-07/05	3800	±	300		530	±	50
19	07/05-14/05	3700	±	300		380	±	40
20	14/05-21/05	4400	±	400		290	±	30
21	21/05-28/05	3000	±	300		250	±	30
22	28/05-04/06	5000	±	400		470	±	50
23	04/06-11/06	3700	±	300		510	±	50
24	11/06-18/06	2800	±	200		210	±	20
25	18/06-25/06	2500	±	200		200	±	20
26	25/06-02/07	3500	±	300		230	±	20

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Table A3: Continued

Week number	Period	^{7}Be µBq·m^{-3}			^{137}Cs µBq·m^{-3}	^{210}Pb µBq·m^{-3}		
27	02/07-09/07	2900	±	300		183	±	19
28	09/07-16/07	2700	±	200		180	±	30
29	16/07-23/07	3300	±	300		330	±	30
30	23/07-30/07	3900	±	300		250	±	20
31	30/07-06/08	5600	±	500		680	±	60
32	06/08-13/08	6400	±	600		830	±	70
33	13/08-20/08	4000	±	300		350	±	30
34	20/08-27/08	3700	±	300		280	±	30
35	27/08-03/09	3800	±	300		270	±	30
36	03/09-10/09	5200	±	400		740	±	70
37	10/09-17/09	4000	±	400		500	±	50
38	17/09-24/09	4000	±	300		260	±	20
39	24/09-01/10	1740	±	150		170	±	20
40	01/10-08/10	4100	±	400		330	±	30
41	08/10-15/10	2700	±	200		370	±	30
42	15/10-22/10	1770	±	150		213	±	19
43	22/10-29/10	3500	±	300		400	±	40
44	29/10-05/11	2110	±	190		510	±	50
45 [(1)]	05/11-12/11	2800	±	200		370	±	30
46	12/11-19/11	2900	±	200		180	±	20
47 [(1)]	19/11-26/11	2500	±	200		180	±	20
48 [(1)]	26/11-03/12	1770	±	160		410	±	40
49 [(1)]	03/12-10/12	2120	±	190		420	±	40
50 [(1)]	10/12-15/12	4200	±	400		1480	±	130
51 [(1)]	16/12-24/12	2900	±	300		270	±	30
52 [(1)]	24/12-31/12	2500	±	200		174	±	18
	Average	3280	±	40 [(2)]		370	±	6 [(2)]
	SD [(3)]			1000				200

[(1)] Due to problems with the high volume sampler sampling occurred with a lower flow (about one third of regular flow) during 0.5 to 1.5 day of the week and in case of week 50, 51 and 52 didn't occur at all during 1, 0.5 and 1 day, respectively.

[(2)] The error in the yearly average is equal to the square root of the sum of the squared weekly errors divided by the number of weeks. Errors are given as 1σ.

[(3)] SD is the standard deviation of the weekly results. Errors are given as 1σ.

Table A4: Precipitation per month and ^{3}H-, long-lived gross α- and gross β-activity in deposition sampled at RIVM in 2004.

Month	Precipitation mm	^{3}H [1] Bq·m^{-2}	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}
January	115.8	<191	1.1 ± 0.3	6.3 ± 0.5
February	88.2	<145	1.8 ± 0.3	8.4 ± 0.7
March	41.6	<69	<1.0	6.3 ± 0.5
April	31.7	<52	1.6 ± 0.3	4.6 ± 0.4
May	50.5	<84	1.8 ± 0.3	6.7 ± 0.5
June	51.8	<86	1.4 ± 0.3	5.8 ± 0.5
July	127.8	<250	1.5 ± 0.3	7.8 ± 0.6
August	124.0	<243	1.4 ± 0.3	7.8 ± 0.6
September	65.1	<127	1.7 ± 0.3	8.9 ± 0.7
October	52.1	<102	n/a [2]	n/a [2]
November	78.8	<154	1.9 ± 0.3	6.7 ± 0.5
December	47.3	<93	0.95 ± 0.14	4.1 ± 0.3
Total	875	<1600	16.2 ± 0.9 [3]	73.5 ± 1.8 [3]

[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 (1.7-2.0 Bq·l^{-1}).
[2] No data available due to a very hygroscopic sample.
[3] The error in the sum is equal to the square root of the sum of the squared monthly errors. Errors are given as1σ.

Table A5: Yearly totals [1] for long-lived gross α-, gross β- and ^{3}H-activity in deposition for 1983-2004.

Year	Precipitation mm	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}	^{3}H Bq·m^{-2}
1983	869	40	120	2100
1984	868	25	130	2610
1985	767	30	140	3800
1986	825	45	18000	2400
1987	975	24 [2] ± 1	85 [2] ± 3	2630
1988	887	36 ± 2	103 ± 3	1700 ± 40
1989	706	43 ± 1	89 ± 3	1560 ± 130
1990	756	68 ± 1	121 ± 4	1360 ± 120
1991	699	48 ± 1	85 ± 1	1060 ± 50
1992	946	44 ± 1	87 ± 1	1440 ± 50
1993	886	54.3 ± 0.7	87.9 ± 0.8	1310 ± 30
1994	1039	52.0 ± 0.7	91.2 ± 1.0	1210 ± 30
1995	724	39 ± 4	95 ± 8	970 ± 40
1996	626	16.4 ± 1.5	67 ± 5	970 ± 50
1997	760	23.1 ± 1.3	87 ± 3	1160 ± 60
1998	1238	31.1 ± 1.3	106 ± 3	1200 ± 110
1999	916	25.5 ± 1.0	84 ± 2	1530 ± 110
2000	935	35.2 ± 1.3	104 ± 3	<1390
2001	1053	23.9 ± 1.0	97 ± 3	<2420
2002	965	20.6 ± 0.9	97 ± 2	<1630
2003	605	15.8 ± 0.9	70 ± 2	<1020
2004	875	16.2 [3] ± 0.9	73.5 [3] ± 1.8	<1600

[1] Errors are given as 1σ. *[2] Introduction of new method.* *[3] Yearly total is based upon 11 months.*

Table A6: Monthly values of ^{210}Po-activity [1] in deposition sampled at RIVM in 2004.

Month	^{210}Po Bq·m^{-2}		
January	0.39	±	0.10
February	<0.44		
March	0.61	±	0.10
April	<0.34		
May	<0.58		
June	<0.44		
July	0.53	±	0.13
August	1.04	±	0.13
September	0.98	±	0.07
October	0.61	±	0.08
November	0.92	±	0.10
December	0.56	±	0.04
Total	7.4	±	0.3 [2]

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

[2] *The error in the sum is equal to the square root of the sum of the squared monthly errors. Errors are given as1σ.*

Table A7: Yearly totals [1] for ^{7}Be, ^{137}Cs, ^{210}Pb- and ^{210}Po-activity in deposition for 1985-2004.

Year	^{7}Be [2] Bq·m^{-2}		^{137}Cs [2] Bq·m^{-2}		^{210}Pb [2] Bq·m^{-2}		^{210}Pb [3] Bq·m^{-2}		^{210}Po [3] Bq·m^{-2}	
1985	980		<5		-		-		-	
1986	>1040		3360		-		15		3	
1987	1330	± 50	12.3		-		52		6	
1988	1200	± 50	<6		-		110	± 3	25	± 1
1989	740	± 40	<3.05		-		94	± 7	24	± 4
1990	810	± 36	<5.5		-		85	± 4	16	± 2
1991	760	± 1	1.35	± 0.03	93	± 1	56	± 1	10	± 1
1992	1130	± 30 [4]	0.69	± 0.03 [4]	117	± 3 [4]	83	± 5	11	± 1
1993	1090	± 20	0.80	± 0.03	105	± 2	78	± 3	6.0	± 0.6
1994	1320	± 30	0.38	± 0.02	118	± 3	82	± 3	12.7	± 0.7
1995	993	± 16	0.28	± 0.02	96	± 2	- [5]		- [5]	
1996	920	± 20	0.55	± 0.03	65	± 2	57	± 3	9	± 2
1997	1090	± 30	0.121	± 0.014	67	± 2	80	± 3	<10	
1998	1840	± 50	0.60	± 0.03	163	± 4	91	± 4	<16	
1999	1580	± 30	1.22	± 0.06	158	± 4	- [6]		<5.1	
2000	1500	± 30	-		177	± 6	-		<7.8	
2001	1480	± 30	-		88	± 4	-		9.0	± 0.4
2002	1510	± 30	-		125	± 5	-		7.5	± 1.0
2003	1020	± 20	-		93	± 4	-		5.1	± 0.6
2004	1330	± 30	0.31	± 0.09	68	± 4	-		7.4	± 0.3

[1] *Errors are given as 1σ.*

[2] *Data from γ-spectroscopy.*

[3] *Data from α-spectroscopy.*

(-) No analysis.

[4] *Results corrected compared to previous reports.*

[5] *Result rejected [54].*

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

Table A8: Weekly values of ^{7}Be-, ^{137}Cs- and ^{210}Pb-activity (1) deposition sampled at RIVM in 2004. Empty fields indicate that the value was below the detection limit (0.7, 0.1 and 0.9 Bq·m^{-2} for ^{7}Be, ^{137}Cs and ^{210}Pb, respectively).

Week Number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{137}Cs Bq·m^{-2}	^{210}Pb Bq·m^{-2}
1	31/12-09/01	15.0	20 ± 3		1.4 ± 0.6
2	09/01-16/01	42.5	43 ± 5		2.1 ± 0.7
3	16/01-23/01	42.5	32 ± 4		2.7 ± 0.7
4	23/01-30/01	15.8	18 ± 2		
5	30/01-06/02	39.6	64 ± 8		3.5 ± 1.0
6	06/02-13/02	30.0	70 ± 8		3.4 ± 0.7
7	13/02-20/02	2.6	7.5 ± 1.2		
8	20/02-27/02	16.0	16 ± 2		
9	27/02-05/03	0.0	1.8 ± 0.5		
10	05/03-12/03	6.1	13 ± 3		1.6 ± 0.5
11	12/03-19/03	5.3	24 ± 3		2.6 ± 0.7
12	19/03-26/03	29.3	34 ± 4		1.8 ± 0.5
13	26/03-02/04	0.9	5.7 ± 1.2		
14	02/04-09/04	19.0	33 ± 4		1.9 ± 0.5
15	09/04-16/04	1.3	7.4 ± 1.2		1.9 ± 0.7
16	16/04-23/04	4.0	11.5 ± 1.5		1.7 ± 0.6
17	23/04-29/04	7.5	25 ± 3		2.9 ± 0.5
18	29/04-07/05	3.0	12.8 ± 1.9		2.4 ± 0.6
19	07/05-14/05	11.2	7.1 ± 1.2		
20	14/05-21/05	0.2	8.6 ± 1.5		2.3 ± 0.6
21	21/05-28/05	1.6	5.8 ± 0.9		
22	28/05-04/06	34.5	51 ± 6		2.2 ± 0.7
23	04/06-11/06	1.6	4.6 ± 0.9		
24	11/06-18/06	2.5	8.3 ± 1.3		
25	18/06-25/06	46.0	63 ± 8		4.6 ± 0.9
26	25/06-02/07	1.7	11.7 ± 1.6		

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Table A8: Continued.

Week Number	Period	Precipitation mm	^{7}Be Bq·m^{-2}		^{137}Cs Bq·m^{-2}		^{210}Pb Bq·m^{-2}	
27	02/07-09/07	65.0	68	± 8			3.1	± 0.7
28	09/07-16/07	25.3	33	± 4			2.4	± 0.7
29	16/07-23/07	30.5	37	± 4			3.3	± 0.7
30	23/07-30/07	7.0	11.2	± 1.4				
31	30/07-06/08	0.0	2.8	± 0.5				
32	06/08-13/08	30.6	39	± 5			3.1	± 1.0
33	13/08-20/08	36.9	56	± 7			2.0	± 0.5
34	20/08-27/08	31.5	49	± 6				
35	27/08-03/09	25.0	34	± 4				
36	03/09-10/09	0.0	3.6	± 0.7				
37	10/09-17/09	12.1	18	± 2				
38	17/09-24/09	33.5	80	± 10	0.11	± 0.04	2.5	± 0.7
39	24/09-01/10	19.5	36	± 4			1.5	± 0.5
40	01/10-08/10	14.5	34	± 4			2.1	± 0.6
41	08/10-15/10	0.2	2.2	± 0.8				
42	15/10-22/10	23.0	19	± 3			2.0	± 0.6
43	22/10-29/10	14.4	19	± 3				
44	29/10-05/11	5.4	15.5	± 1.9				
45	05/11-12/11	7.5	11.2	± 1.6				
46	12/11-19/11	42.0	68	± 8			2.8	± 0.8
47	19/11-26/11	14.8	26	± 3			1.8	± 0.7
48	26/11-03/12	9.2	16	± 2			1.5	± 0.4
49	03/12-10/12	1.3	2.6	± 1.1	0.20	± 0.08		
50	10/12-17/12	5.1	8.0	± 1.3				
51	17/12-24/12	15.5	17	± 2			0.9	± 0.4
52	24/12-31/12	25.5	28	± 3				
	Total	875	1330	± 30 [(2)]	0.31	± 0.09 [(2)]	68	± 4 [(2)]

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

[(2)] *The error in the sum is equal to the square root of the sum of the squared weekly errors. Errors are given as 1σ.*

Table A9: Yearly averaged results in 2004 for α-activity concentration in air and ambient dose equivalent rate, as measured by the NMR stations equipped with aerosol monitors.

Station	No. [1]	α-Activity concentration Bq.m^{-3}	Ambient dose equivalent rate nSv.h^{-1}
Kollumerwaard [2]	972	2.9	-
Valthermond [3]	974	2.8	73
Vlaardingen	976	3.0	87
Braakman [2]	978	3.3	-
Huijbergen [2]	980	3.7	-
Houtakker	982	3.2	67
Wijnandsrade	984	6.6	82
Eibergen	986	3.5	71
De Zilk [2]	988	2.4	-
Wieringerwerf [2]	990	2.4	-
Vredepeel	992	3.5	70
Biddinghuizen [2]	994	3.2	-
Wageningen [2]	996	3.9	-
Bilthoven	998	2.8	71

[1] The number of the station has changed in respect to previous years. The location remains the same.
[2] Ambient dose equivalent rate monitor not operational or unreliable.
[3] The station formerly known as Witteveen.

Table A10: The yearly average results for ambient dose equivalent rate for the NMR stations in 2004.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Den Burg	1001	69	Hooglanderveen	1046	82
Den Oever	1003	71	Harderwijk	1050	67
Julianadorp	1004	62	Wijk bij Duurstede	1056	78
Petten	1006	63	Rhenen	1061	77
Kolhorn	1007	82	Nieuwegein	1062	81
Egmond aan Zee [1]	1009	-	Apeldoorn	1066	75
Heerhugowaard	1011	73	Heerenveen	1071	63
Haarlem-Noord	1014	73	Oosterwolde	1072	85
Nederhorst den Berg	1015	62	Bergum	1074	70
Enkhuizen	1018	71	Witmarsum	1076	89
Oosthuizen	1019	66	Sneek	1077	72
Zaandam	1021	69	St. Jacobiparochie	1081	75
Gouda	1024	79	Holwerd	1082	80
Dordrecht	1027	59	Leeuwarden	1085	67
Zuid-Beijerland	1028	75	Zwolle-Zuid	1087	73
Pijnacker	1032	79	Ommen	1093	64
Rotterdam Crooswijk	1033	74	Hardenberg	1095	64
Rotterdam Waalhaven	1034	77	Assen	1097	63
Maasvlakte	1035	69	Rutten	1099	76
Maassluis	1037	96	Lelystad	1103	74
Hellevoetsluis	1038	95	Urk	1105	74
Ouddorp	1039	62	Eemshaven	1106	74
Wekerom	1041	72	Uithuizen	1107	81
Wageningen	1043	68	Wagenborgen	1109	71

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Table A10: Continued.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Winschoten	1110	70	Reuver	1188	74
Ter Apel	1111	65	Nederweert	1189	72
Stadskanaal	1112	67	Heythuisen	1190	73
Nieuweschans	1113	71	Mariahoop	1191	67
Bellingwolde	1114	62	Stramproy	1192	64
Groningen	1116	71	Arnhem-Oosterbeek	1193	74
Leens	1117	77	Leiden	1196	79
Grijpskerk	1118	76	Hulst	1197	73
Meppel	1125	64	Terneuzen (1)	1199	-
Hoogeveen	1126	61	Sluis	1201	69
Steenwijksmoer	1129	65	Vlissingen	1202	78
Nieuw Amsterdam	1130	70	Halsteren	1204	65
Nw. Schoonebeek/ Weiteveen	1131	63	Oud-Gastel	1206	65
Emmen	1132	69	Goes	1207	75
Borne	1135	69	Bruinisse	1209	81
Hengelo (Gld)	1136	70	Burgh-Haamstede	1211	59
Enschede	1139	66	Vrouwenpolder	1212	64
Losser	1140	61	Wemeldinge	1214	79
Oldenzaal	1141	64	Middelburg	1215	74
Westerhaar	1142	65	Westkapelle	1216	70
Rijssen	1143	73	Noordwijk-Binnen	1217	77
's Heerenberg	1144	62	Stein	1219	83
Dinxperlo	1145	79	Maastricht	1220	90
Varsseveld	1146	68	Ravensbos	1221	90
Groenlo	1147	82	Vaals	1222	87
Deventer	1148	76	Gulpen	1223	76
Etten-Leur	1154	67	Kerkrade	1224	89
Den Bosch	1157	66	Hoensbroek	1225	86
Raamsdonkveer	1159	81	Gennep	1228	71
Ulvenhout	1160	71	Elst (Gld) (1)	1229	-
Baarle-Nassau	1161	106	Zevenaar	1230	72
Uden	1162	68	Nijmegen	1231	66
Mill	1163	62	Amstelveen	1233	82
Oss	1167	67	Amsterdam Oost	1234	72
Nuenen	1172	68	Aalsmeer	1236	83
Bergeyk	1174	95	Nispen (1)	1237	-
Waalre	1175	66	Groesbeek	1240	71
Someren (dorp)	1176	65	Tubbergen	1243	69
Oisterwijk	1178	74	Haaksbergen	1244	64
Riel	1179	68	Scheveningen	1247	74
Oostelbeers	1180	92	Zaltbommel	1251	72
Hilvarenbeek	1181	63	IJzendijke	1252	78
Venray	1183	62	Ritthem	1253	103
Nieuw-Bergen	1184	60	Vlissingen-Haven	1254	74
Sevenum	1185	70	Nieuwdorp	1255	84

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Table A10: Continued.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
's Heerenhoek	1256	83	Rilland	1263	84
Driewegen	1257	90	Putte	1264	58
Arnemuiden	1258	72	Nieuw Namen	1265	88
Heinkeszand	1259	86	Denekamp	1278	64
Baarland	1260	87	Winterswijk	1279	67
Biervliet	1261	64	Bilthoven	1280	60
Slijkplaat	1262	77	Maarheze/Gastel	1281	66

(1) *Station was not operational in 2004.*

Table A11: ^{3}H- and residual β-activity concentrations ($mBq \cdot L^{-1}$) in surface water in 2004 as measured by RIZA.

Date		^{3}H	Residual β
Location: Eijsden (Meuse)			
20/01/04	<	100	140
17/02/04		1400	17
16/03/04		11000	14
13/04/04		4600	22
11/05/04		13000	22
08/06/04		12000	9
06/07/04		18000	34
03/08/04		16000	10
31/08/04		34000	12
28/09/04		9600	20
26/10/04		13000	33
23/11/04		16000	11
21/12/04		5200	13
Average		**11800**	**27**
Location: Lobith (Rhine)			
21/01/04		2500	100
18/02/04		2900	7
17/03/04		6000	25
14/04/04		3500	24
12/05/04		4900	45
09/06/04		4100	49
07/07/04		4000	28
04/08/04		4400	24
01/09/04		5700	29
29/09/04		3900	22
27/10/04		6900	24
24/11/04		5100	26
22/12/04		3300	9
Average		**4400**	**32**
Location: Schaar van Ouden Doel (Scheldt)			
12/01/04			74
11/02/04		12000	78
10/03/04			110
07/04/04		11000	190
03/05/04			79
01/06/04		12000	51
29/06/04			84
26/07/04		13000	93
23/08/04			68
20/09/04		11000	75
18/10/04			86
17/11/04		30000	110
15/12/04			73
Average		**14800**	**90**

Table A12: ^{137}Cs-activity concentrations in suspended solids (Bq·kg^{-1}) in surface water in 2004 as measured by RIZA.

Date	^{137}Cs	Date	^{137}Cs
Location: Eijsden (Meuse)		**Location: Ketelmeer-West**	
06/01/04	15	04/02/04	19
12/01/04	13	02/04/04	12
20/01/04	13	27/05/04	14
27/01/04	17	22/07/04	14
03/02/04	12	16/09/04	19
10/02/04	32	10/11/04	17
17/02/04	17	**Average**	**16**
24/02/04	15	**Location: Lobith (Rhine)**	
02/03/04	13	21/01/04	19
09/03/04	10	18/02/04	17
16/03/04	8	17/03/04	12
23/03/04	12	14/04/04	15
30/03/04	15	12/05/04	19
06/04/04	17	09/06/04	16
13/04/04	12	07/07/04	13
20/04/04	16	04/08/04	13
27/04/04	28	01/09/04	15
03/05/04	5	29/09/04	15
11/05/04	18	27/10/04	17
18/05/04	12	24/11/04	19
25/05/04	10	22/12/04	28
01/06/04	7	**Average**	**17**
08/06/04	21	**Location: Schaar van Ouden Doel (Scheldt)**	
15/06/04	17	12/01/04	10
21/06/04	12	11/02/04	13
29/06/04	11	10/03/04	10
06/07/04	8	07/04/04	11
13/07/04	15	03/05/04	10
20/07/04	12	01/06/04	11
28/07/04	11	29/06/04	13
03/08/04	10	26/07/04	10
10/08/04	10	23/08/04	8
17/08/04	18	20/09/04	10
24/08/04	15	18/10/04	11
31/08/04	19	17/11/04	11
07/09/04	14	15/12/04	10
14/09/04	14	**Average**	**11**
21/09/04	11		
28/09/04	15		
05/10/04	20		
12/10/04	14		
19/10/04	13		
26/10/04	21		
02/11/04	17		
09/11/04	18		
16/11/04	14		
23/11/04	15		
30/11/04	18		
07/12/04	16		
14/12/04	13		
21/12/04	15		
28/12/04	17		
Average	**15**		

Table A13: Gross α-, residual β-, ^{3}H- and ^{90}Sr-activity concentrations ($mBq \cdot L^{-1}$) in seawater in 2004 as measured by RIZA.

Date	Gross α	Residual β	^{3}H	^{90}Sr
Location:	**Coastal area**			
11/03/04	900	70	5700	
06/05/04	580	69	5200	
12/08/04	330	28	6000	
16/11/04	370	51	7100	
Average	**540**	**54**	**6000**	
Location:	**Southern North Sea**			
11/03/04	850	56	4000	5
13/05/04	430	62	2400	6
11/08/04	380	24	4500	< 1
16/11/04	450	54	5800	< 1
Average	**530**	**49**	**4200**	**3**
Location:	**Central North Sea**			
10/03/04	830	46	< 100	3
10/05/04	330	36	< 100	4
10/08/04	340	23	400	2
23/11/04	170	31	550	1
Average	**420**	**34**	**260**	**3**
Location:	**Delta Coastal Waters**			
06/01/04	500	74	-	-
15/03/04	500	53	4500	< 1
15/03/04	520	55	-	-
15/04/04	170	53	-	-
13/05/04	680	45	4300	< 1
10/06/04	920	34	-	-
13/07/04	370	62	-	-
12/08/04	330	22	5900	< 1
30/09/04	520	60	-	-
12/10/04	320	45	-	-
15/11/04	410	51	5600	< 1
15/12/04	240	54	-	-
Average	**450**	**50**	**5100**	**< 1**
Location:	**Westerscheldt**			
12/01/04	660	120	5100	3
11/02/04	660	98	6500	1
08/03/04	520	85	6300	5
06/04/04	330	97	7100	< 1
04/05/04	550	53	5000	< 1
01/06/04	280	78	4800	< 1
30/06/04	140	38	5600	3
27/07/04	510	67	6900	3
24/08/04	250	58	7400	4
22/09/04	280	23	3900	2
20/10/04	470	58	7400	< 1
16/11/04	530	88	7000	4
15/12/04	580	140	8400	< 1
Average	**460**	**79**	**6400**	**2**

To be continued on the next page.

Table A13: Continued.

Date Location:	Gross α Eems-Dollard	Residual β	^{3}H	^{90}Sr
17/02/04	480	66	5700	
17/05/04	290	55	5000	
24/08/04	190	44	3600	
10/11/04	330	37	6100	
Average	**320**	**50**	**5100**	
Location:	**Wadden Sea West**			
17/02/04	520	48	4600	
14/05/04	300	76	4700	
13/08/04	300	36	4500	
10/11/04	350	69	5300	
Average	**370**	**57**	**4780**	
Location:	**Wadden Sea East**			
19/02/04	570	190	4800	
12/05/04	340	120	3900	
11/08/04	520	120	4500	
11/11/04	360	160	6100	
Average	**450**	**148**	**4800**	

Table A14: ^{137}Cs- and ^{210}Po-activity concentrations in suspended solids (Bq·kg^{-1}) in seawater in 2004 as measured by RIZA.

Date	**^{137}Cs**	**^{210}Po**
Location:	**Coastal area**	
09/02/04	12	110
10/05/04	6	71
09/08/04	6	100
10/11/04	9	100
Average	**8**	**95**
Location:	**Westerscheldt**	
10/02/04	5	69
04/05/04	5	64
24/08/04	6	79
15/11/04	5	67
Average	**5**	**70**
Location:	**Eems-Dollard**	
12/02/04	10	110
13/05/04	7	89
16/08/04	8	91
04/11/04	9	100
Average	**9**	**98**
Location:	**Wadden Sea West**	
18/02/04	10	110
13/05/04	n/a	n/a
16/08/04	n/a	n/a
08/11/04	9	150
Average	**10**	**130**
Location:	**Wadden Sea East**	
19/02/04	8	94
12/05/04	7	78
11/08/04	7	100
11/11/04	6	93
Average	**7**	**91**

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