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Monitoring of radiation in the environment in the Netherlands Results in 2000

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Abstract

This report presents the results of radioactivity measurements in the environment in the Netherlands carried out by RIVM, RIZA, RIKZ and Inspectorate for Health Protection and Veterinary Public Health in 2000. Measurements of radioactivity have been carried out in airborne particulates, deposition, surface water, seawater, drinking water and food (honey, game, blueberry and mushrooms). Results for ambient dose equivalent rates have been obtained from the National Radioactivity Monitoring Network. No measurements were done in milk. In 2000 no elevated levels of radioactivity were found in the Dutch environment.

Preface

In this 2000 annual report results are presented of measurements on radioactivity in the Dutch environment. 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.
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The National Institute for Coastal and Marine Management (RIKZ)
Data on seawater.
ir. O.C. Swertz

The Inspectorate for Health Protection and Veterinary Public Health (KvW)
Data on foodstuffs.
ing. J.A.M. Geertsen

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Samenvatting

In dit rapport worden de resultaten gegeven van radioactiviteitsmetingen in het Nederlandse milieu in 2000 verricht door RIVM, RIZA, RIKZ en Keuringsdienst van Waren.

De jaargemiddelde totale α- en β-activiteitsconcentraties in luchtstof in Bilthoven waren respectievelijk 0,07 en 0,353 $mBq \cdot m^{-3}$. De jaargemiddelde activiteitsconcentraties in luchtstof van de nucliden ^{7}Be en ^{210}Pb waren respectievelijk 3030 en 248 $\mu Bq \cdot m^{-3}$. De activiteitsconcentratie in luchtstof van ^{137}Cs was beneden de detectielimiet (2 $\mu Bq \cdot m^{-3}$).

De jaarlijkse totale α- en β-activiteit in depositie in Bilthoven bedroeg 35,2 en 104 $Bq \cdot m^{-2}$. De jaarlijkse totale activiteit van de nucliden ^{3}H, ^{7}Be, ^{210}Pb en ^{210}Po in depositie bedroeg respectievelijk < 1390, 1500, 177 en < 7,8 $Bq \cdot m^{-2}$. De jaarlijkse totale activiteit van ^{137}Cs in depositie was beneden de detectielimiet (0,1 $Bq \cdot m^{-2}$).

Voor het omgevingsdosisequivalenttempo was de jaargemiddelde (156 meetlocaties) meetwaarde 74 $nSv \cdot h^{-1}$. Deze waarde bevat een systematische fout (5-10 $nSv \cdot h^{-1}$) waarvoor niet gecorrigeerd is. Voor de totaal α-activiteitsconcentratie in luchtstof was het jaargemiddelde (14 meetlocaties) 2,5 $Bq \cdot m^{-3}$. Het jaargemiddelde voor de berekende kunstmatige totaal β-activiteitsconcentratie in luchtstof week niet significant af van nul.

De jaargemiddelde activiteitsconcentratie van ^{3}H in oppervlaktewater lag tussen 4,0 en 14,7 $Bq \cdot L^{-1}$ en van rest-β tussen 22 en 69 $mBq \cdot L^{-1}$ (3 meetlocaties). De jaargemiddelde activiteit van ^{137}Cs in zwevend stof in oppervlaktewater lag tussen 15 en 27 $Bq \cdot kg^{-1}$ (4 meetlocaties).

De jaargemiddelde activiteitsconcentratie van totaal-α in zeewater lag tussen 120 en 223 $mBq \cdot L^{-1}$ en van rest-β tussen 31 en 77 $mBq \cdot L^{-1}$ (6 meetlocaties).
De jaargemiddelde activiteitsconcentratie van ^{3}H in zeewater lag tussen 0,7 en 5,5 $Bq \cdot L^{-1}$ (6 meetlocaties) en van ^{90}Sr tussen 2 en 8 $mBq \cdot L^{-1}$ (3 meetlocaties). De jaargemiddelde activiteit van ^{137}Cs in zwevend stof in zeewater lag tussen 8 en 13 $Bq \cdot kg^{-1}$ en van ^{210}Po tussen 67 en 125 $Bq \cdot kg^{-1}$ (4 meetlocaties).

Typische waarden die in ruw water voor de drinkwaterproductie gevonden worden, zijn 1-10 $Bq \cdot L^{-1}$ voor ^{3}H-activiteit en 0,1-1 $Bq \cdot L^{-1}$ voor zowel totaal-β als rest-β activiteit. Uit het gelijk zijn van de bereiken voor totaal-β en rest-β blijkt dat in dit water weinig ^{40}K, en dus kalium, aanwezig is.

Van 69 onderzochte honingmonsters bevatte alleen heidehoning radioactiviteit. De som van de ^{134}Cs- en de ^{137}Cs-activiteit lag tussen 49 en 321 $Bq \cdot kg^{-1}$.
Aantoonbare hoeveelheden ^{134}Cs + ^{137}Cs werden ook aangetroffen in enkele monsters wild. Twee monsters wild zwijn bevatten 38 $Bq \cdot kg^{-1}$ respectievelijk 131 $Bq \cdot kg^{-1}$, ree 41 $Bq \cdot kg^{-1}$ en hert 41 $Bq \cdot kg^{-1}$. Alle monsters wild waren afkomstig uit Nederland. In enkele producten zoals bosbes en cantharel was geen radioactiviteit aantoonbaar.

De waarden weken niet significant af met de waarden gevonden in voorgaande jaren. Er zijn in 2000 geen metingen verricht aan melk.

Summary

In this report results are presented of radioactivity measurements in the Dutch environment in 2000 carried out by RIVM, RIZA, RIKZ and Inspectorate for Health Protection and Veterinary Public Health.

The yearly averaged gross α- and gross β-activity concentrations in air dust in Bilthoven were 0.07 and 0.353 $mBq \cdot m^{-3}$ respectively. The yearly averaged activity concentrations in air dust for the nuclides ^{7}Be and ^{210}Pb were 3030 and 248 $\mu Bq \cdot m^{-3}$ respectively. The yearly averaged activity concentration in air dust for ^{137}Cs was below the detection limit (2 $\mu Bq \cdot m^{-3}$).

The yearly total gross α- and gross β-activities deposited in Bilthoven were 35.2 and 104 $Bq \cdot m^{-2}$ respectively. The yearly total activities of the nuclides ^{3}H, ^{7}Be, ^{210}Pb and ^{210}Po in deposition were < 1390, 1500, 177 and < 7.8 $Bq \cdot m^{-2}$ respectively. The yearly total activity of ^{137}Cs in deposition was below the detection limit (0.1 $Bq \cdot m^{-2}$).

For the ambient dose equivalent rate the yearly averaged (156 measurement locations) measured value was 74 $nSv \cdot h^{-1}$. This value has not been corrected for the systematic error (5-10 $nSv \cdot h^{-1}$). The yearly averaged (14 measurement locations) gross α-activity concentration in air dust was 2,5 $Bq \cdot m^{-3}$. The yearly average of the calculated artificial gross β-activity concentration did not deviate significantly from zero.

The yearly averaged activity concentration for ^{3}H in surface water varied between 4.0 and 14.7 $Bq \cdot L^{-1}$ and for residual β between 22 and 69 $mBq \cdot L^{-1}$ (3 measurement locations). The yearly averaged activity of ^{137}Cs in suspended solids in surface water varied between 15 and 27 $Bq \cdot kg^{-1}$ (4 measurement locations).

The yearly averaged activity concentration for gross α in seawater varied between 120 and 223 $mBq \cdot L^{-1}$ and for residual β between 31 and 77 $mBq \cdot L^{-1}$ (6 measurement locations).
The yearly averaged activity concentration for ^{3}H in seawater varied between 0.7 and 5.5 $Bq \cdot L^{-1}$ (6 measurement locations) and for ^{90}Sr between 2 and 8 $mBq \cdot L^{-1}$ (3 measurement locations).
The yearly averaged activity of ^{137}Cs in suspended solids in seawater varied between 8 and 13 $Bq \cdot kg^{-1}$ and for ^{210}Po between 67 and 125 $Bq \cdot kg^{-1}$ (4 measurement locations).

Typical activities found in raw input water for drinking water production were 1-10 $Bq \cdot L^{-1}$ for ^{3}H activity and 0.1-1 $Bq \cdot L^{-1}$ for gross β- and residual β-activity. Because the range for gross β-activity is the same as the range for residual β-activity it can be concluded that there is little ^{40}K, and thus potassium, present in this water.

Of 69 analysed samples of honey only heather honey contained radioactivity. The sum of the ^{134}Cs- and the ^{137}Cs-activity varied between 49 and 321 $Bq \cdot kg^{-1}$.
Measurable quantities of ^{134}Cs + ^{137}Cs were also found in some samples of game. Two samples of wild boar contained 38 $Bq \cdot kg^{-1}$ and 131 $Bq \cdot kg^{-1}$ respectively, roe 41 $Bq \cdot kg^{-1}$ and

deer 41 $Bq \cdot kg^{-1}$. All samples of game originated from the Netherlands. In some products, like blueberry and chanterelle, no radioactivity was detected.

All these values do not differ significantly from those found in previous years. In 2000 no measurements were performed in milk.

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 keep a lookout 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 represents an almost complete survey of measurements on radioactivity in the Dutch environment under normal circumstances in 2000. Secondly, it is aimed at determining compliance of monitoring programs in the Netherlands with the EU recommendation and at assessing omissions. Thirdly, it is the Dutch national report 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.
The results will, in general, be presented in graphs and tables with a minimum amount of text. 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 2000 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 2000 for the determination of radioactive nuclides in air dust.

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

(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 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 are given 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. For this reason, these naturally occurring decay-products do not contribute to the α- and β-activity concentrations.

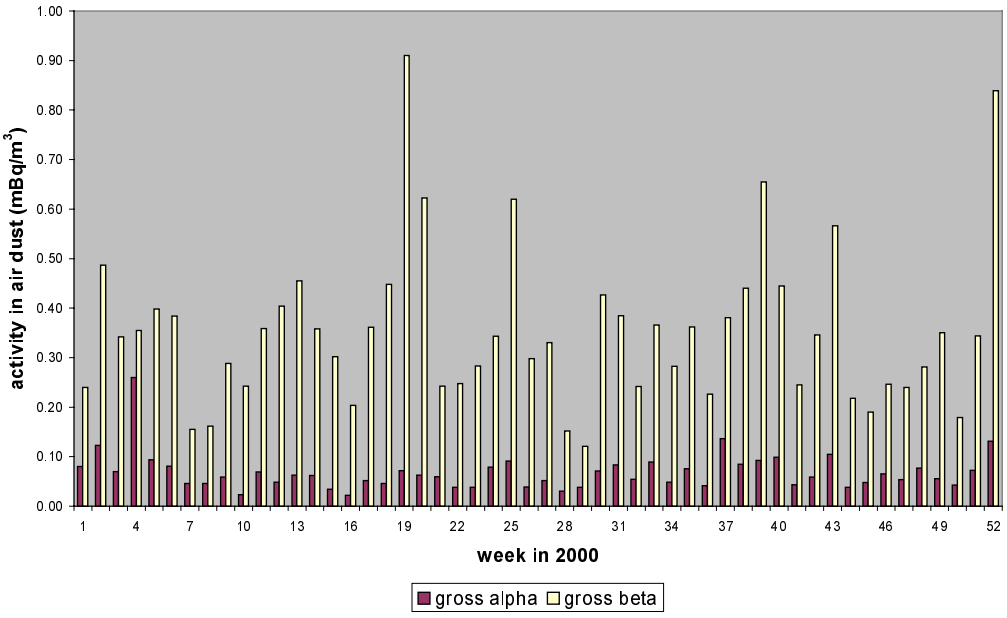


Figure 2.1: Weekly results of gross α- and β-activity concentrations of long-lived nuclides in air dust sampled at RIVM in 2000.

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.

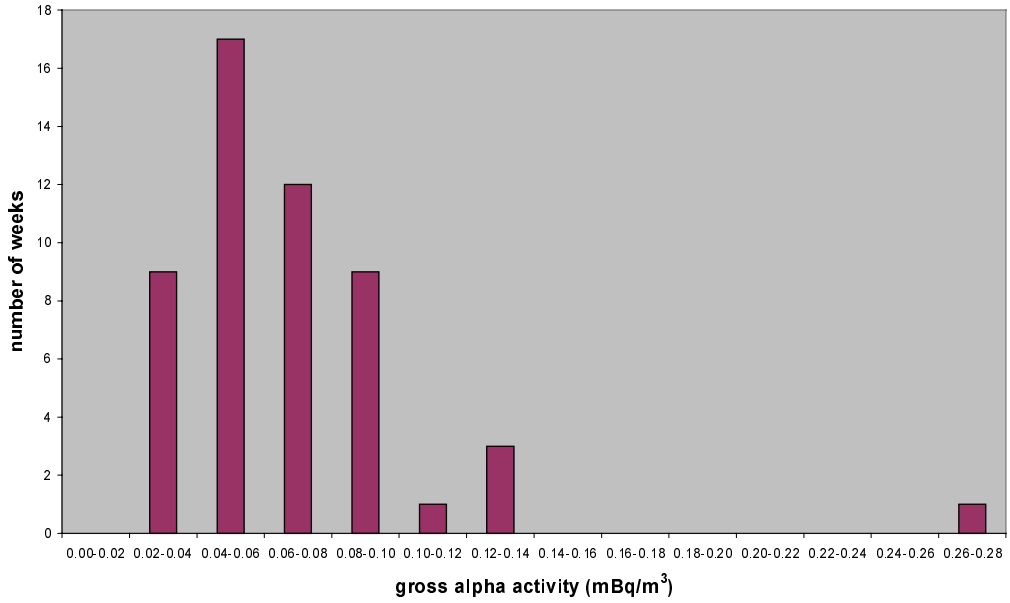


Figure 2.2: Frequency distribution of gross α-activity concentration of long-lived nuclides in air dust collected weekly at RIVM in 2000. Mean concentration is 0.07 (SD=0.04) mBq·m^{-3}. SD is the standard deviation and illustrates the variation in weekly averages during the year.

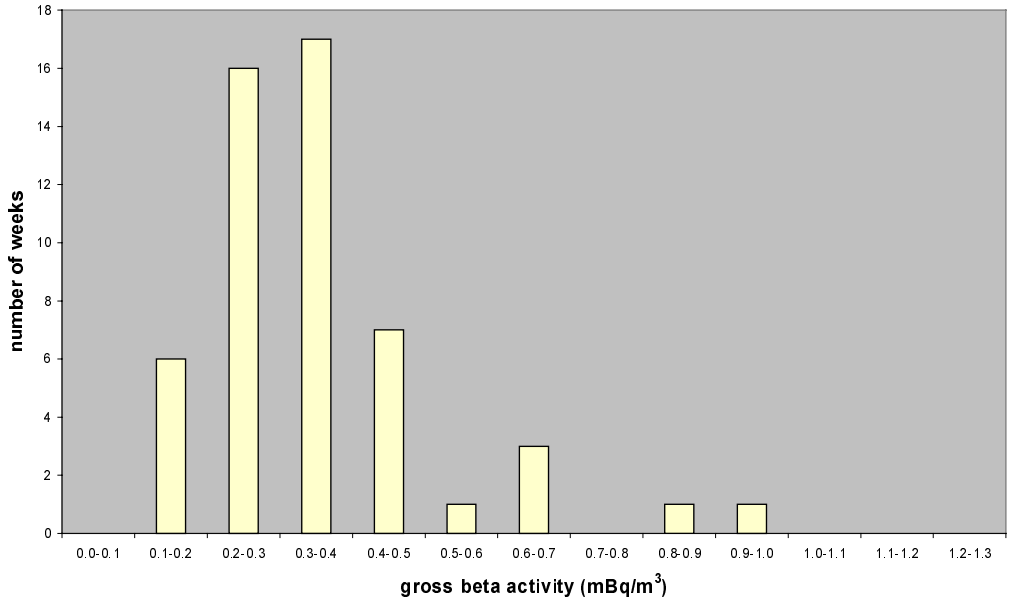


Figure 2.3: Frequency distribution of gross β-activity concentration of long-lived nuclides in air dust collected weekly at RIVM in 2000.
Mean concentration is 0.353± 0.004 (SD=0.16) mBq·m^{-3}.

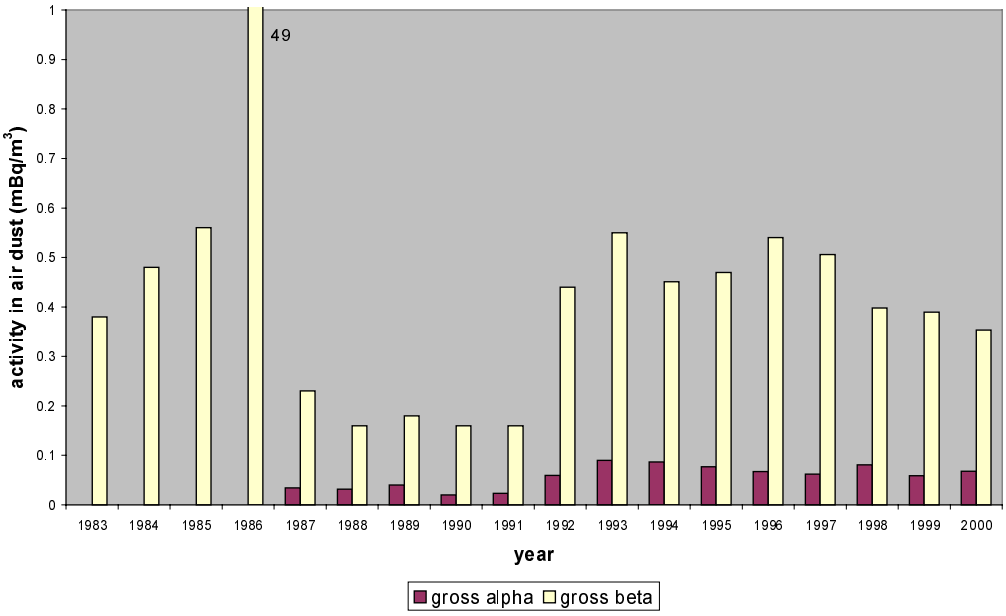


Figure 2.4: Yearly averages of gross α- and gross β-activity concentration of long-lived nuclides in air dust from the outset of the respective monitoring campaigns. The level in 1986 was caused by the accident at the Chernobyl nuclear power plant.

In *Figure 2.4* a change in the trend is shown in 1987. This is caused by a change in the measuring technique since mid 1986 [6]. Due to this change in measuring technique gross α data came available. The year 1992 was the start of a different sampling procedure (sampling of air dust with a High Volume Sampler) and sample treatment which resulted in another change in the trend [7]. The results between mid 1986 and 1992 are underestimated due to the different sampling procedure and sample treatment. The yearly averages of the gross α- and β-activity concentrations of long-lived nuclides in 2000 amount to the same as the results in the period 1992-1999 [8].

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 nuclides ^{7}Be and ^{210}Pb were the only nuclides measured above the detection limits (*Table A3*, *Figure 2.5, 2.6* and *2.7*). In 2000 the detection limit of ^{137}Cs was higher (2.0 μBq·m^{-3}) then usual (0.1 μBq·m^{-3}), due to a different detector set-up. The concentrations found for ^{7}Be and ^{210}Pb in 2000 do not differ significantly from those found in 1992-1999 [8].

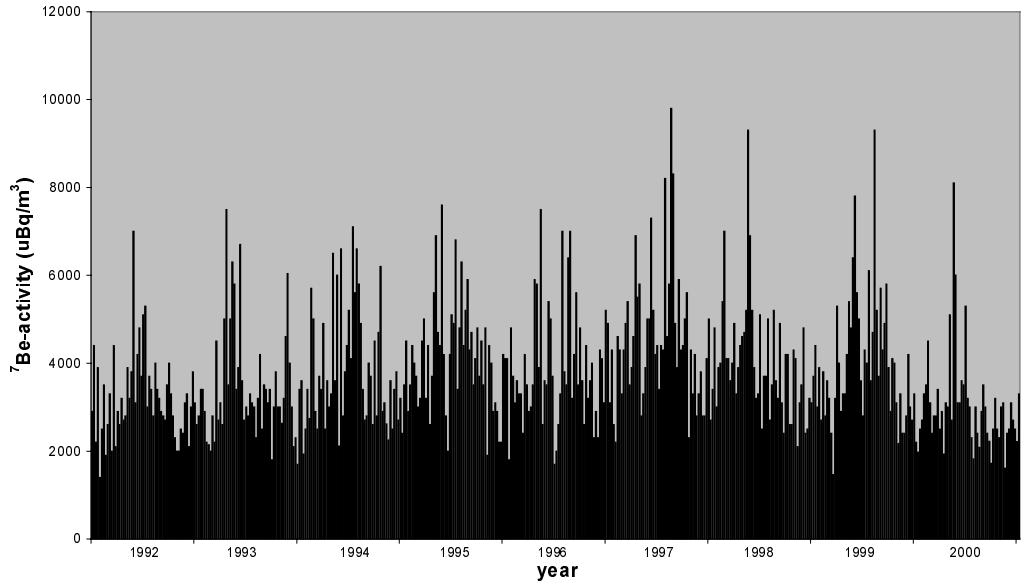


Figure 2.5: Weekly averaged activity concentrations of ^{7}Be in air dust at RIVM in 1992-2000. Yearly average for 2000 is 3030 ± 40 (SD=1100) $\mu Bq \cdot m^{-3}$.

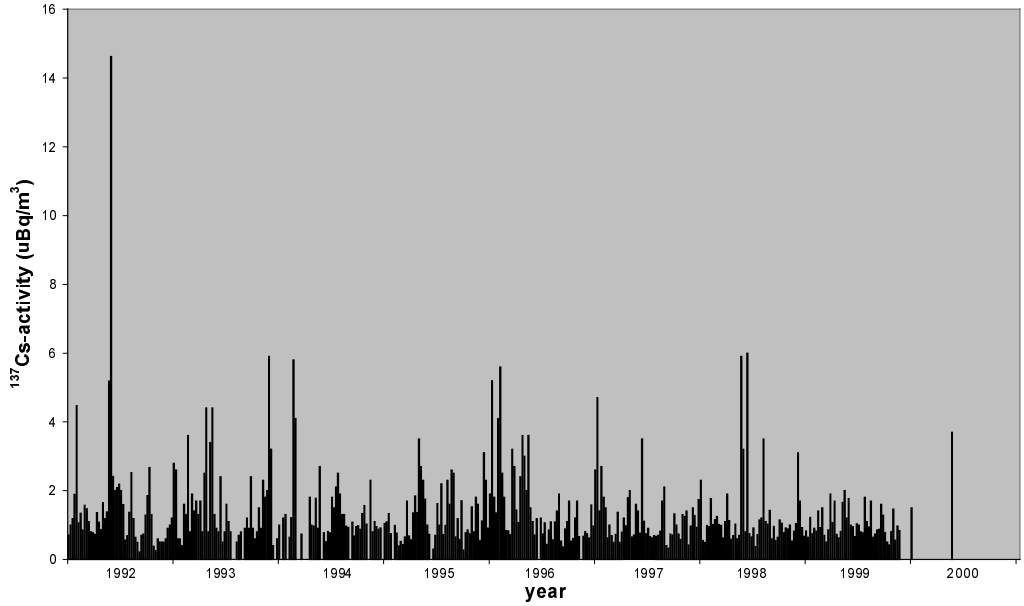


Figure 2.6: Weekly averaged activity concentrations of ^{137}Cs in air dust at RIVM in 1992-2000. In 2000 only one measurement was above the detection limit. The detection limit was higher due to a different detector set-up.

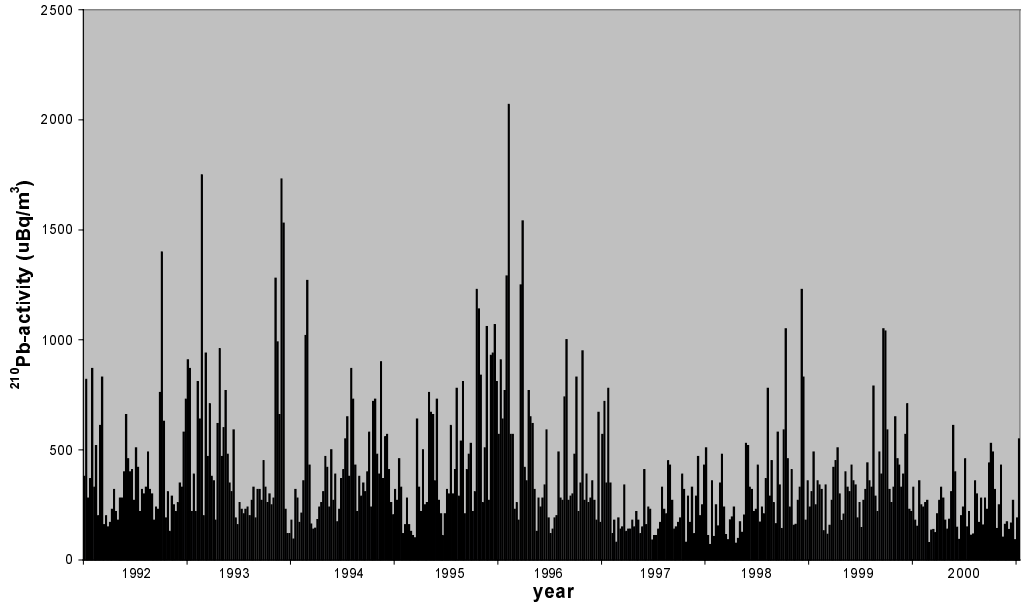


Figure 2.7: Weekly averaged activity concentrations of ^{210}Pb in air dust at RIVM in 1992-2000. Yearly average for 2000 is 248 ± 4 (SD=130) µBq·m^{-3}.

3. Deposition

The 2000 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 (γ-emitters) and monthly (^{3}H, gross α, gross β and ^{210}Po).

Table 3.1: The 2000 monitoring program for the determination of radioactive nuclides in deposition.

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

[(1)] γ-spectroscopic analysis of specific γ-emitting nuclides

3.1 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 35.2 ± 1.3 and 104 ± 3 Bq·m^{-2}, respectively. These values do not differ significantly from those measured since 1987, as illustrated in *Figure 3.2* and *Table A5*.
For gross α and gross β a change in measuring technique occurred around mid 1986 [9], which make it difficult to compare data till 1986 with data after 1986 [10].

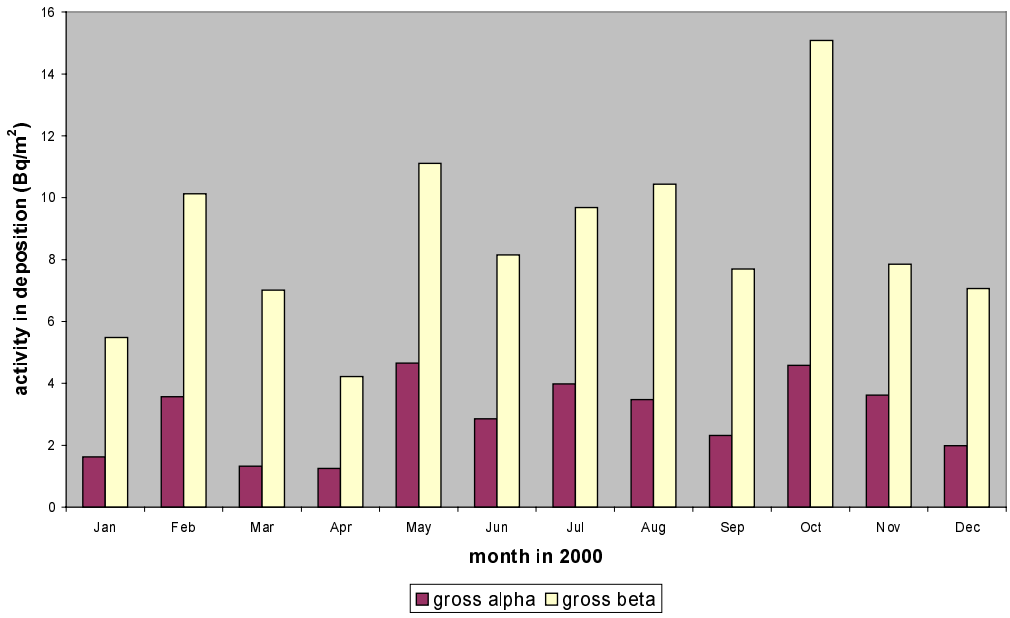


Figure 3.1: Monthly deposited gross α- and gross β-activity of long-lived nuclides at RIVM in 2000.

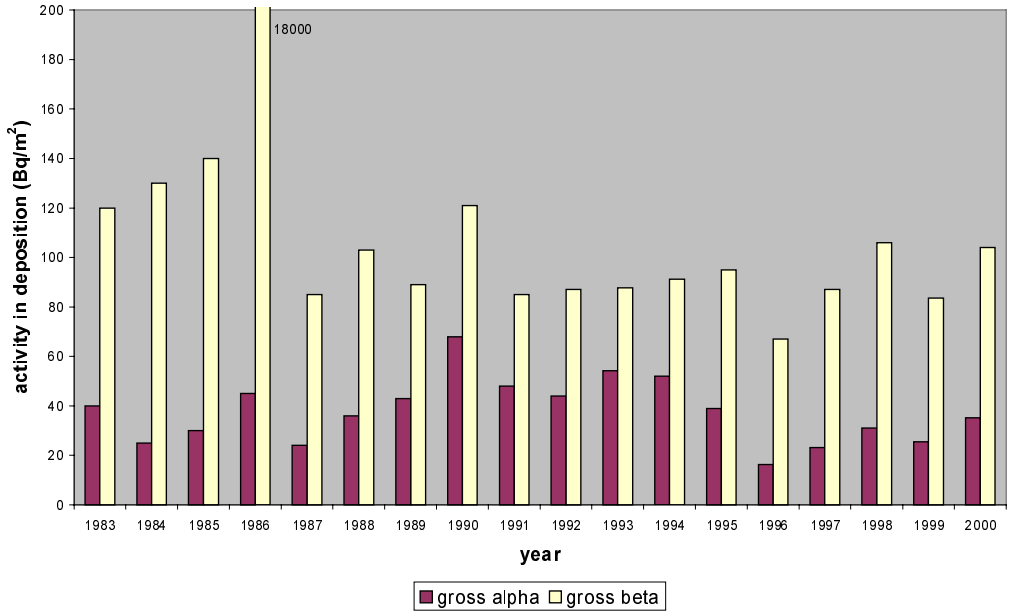


Figure 3.2: Yearly gross α- and gross β-activity of long-lived nuclides deposited at RIVM from 1983 to 2000 (see also Table A5). The 1986 level resulted from the accident at the Chernobyl nuclear power plant.

The monthly deposition of ^{3}H is given in *Table A4*. In 2000 less then 1390 $Bq \cdot m^{-2}$ of ^{3}H was deposited. Nine of the twelve measurements were below detection limit. In those cases the detection limit was used for the calculation of the yearly total.
Figure 3.3 shows the exponential decay of ^{3}H after the end of the atmospheric nuclear weapons tests in the seventies.

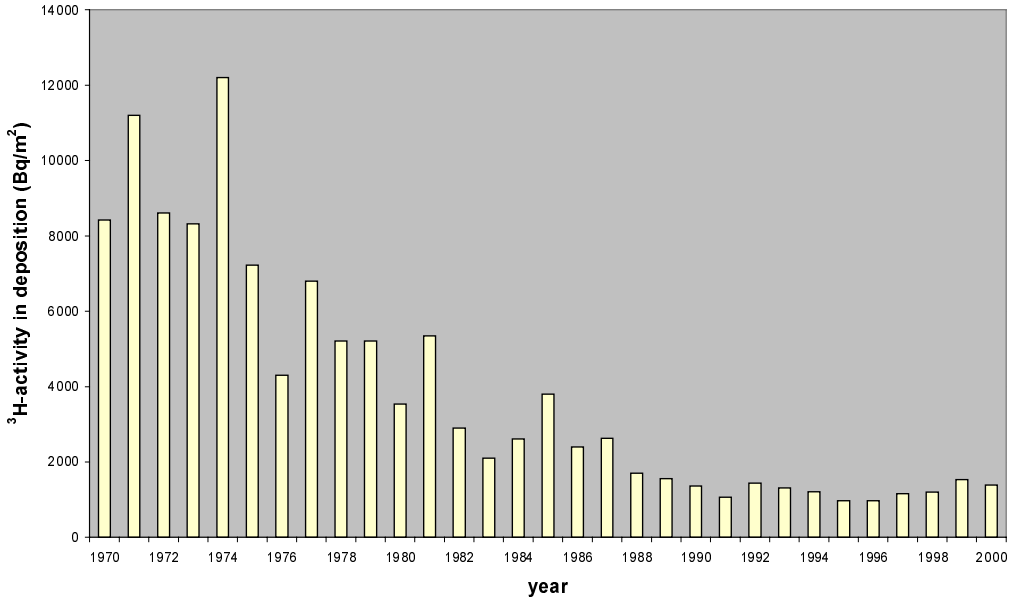


Figure 3.3: Yearly deposition of ^{3}H at RIVM in the period 1970-2000.

The monthly α-spectroscopy results for ^{210}Po are given in *Table A6*. The results for previous years are given in *Table A5*. In 2000 less then 7.8 Bq·m^{-2} of ^{210}Po was deposited. In all but one measurement the detection limit was used for the calculation of the yearly total.

3.2 γ-Emitting nuclides

Detectable quantities of the naturally occurring nuclides ^{7}Be and ^{210}Pb were found, with yearly total depositions of 1500 ± 30 and 177 ± 6 Bq·m^{-2}, respectively. These values do not differ significantly from those in previous years [8, 11]. ^{134}Cs and ^{137}Cs were not found (detection limit is 0,1 Bq·m^{-2} for both nuclides). The weekly results for deposition of ^{7}Be and ^{210}Pb are given in *Table A7*. There is a correlation between the amount of precipitation and the deposition of ^{7}Be as can be seen in *Figure 3.4*.

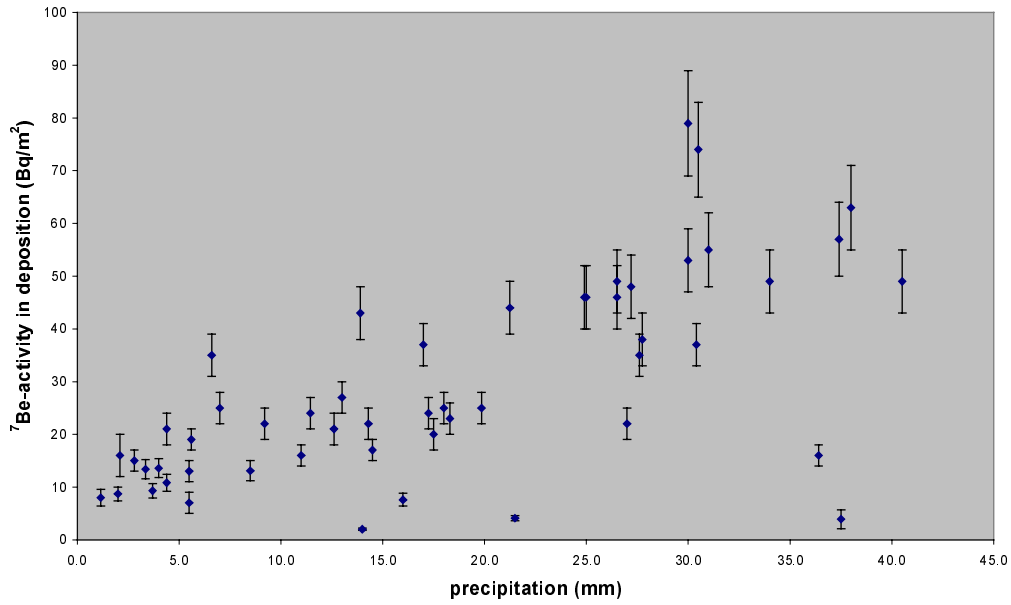


Figure 3.4: The weekly deposition of ^{7}Be at RIVM in 2000 versus precipitation.

4. National Radioactivity Monitoring Network

This chapter presents data on gross α-activity concentrations, artificial gross β-activity concentrations in air and ambient dose equivalent rates as measured by the National Radioactivity Monitoring Network (NMR). The data on gross α and gross β differ in sample size, sampling frequency and analytical procedures from those given in the previous chapter.

In 2000 a reorganisation of the NMR was finished; the network now consists of 163 ambient dose equivalent rate monitors and 14 aerosol monitors for determining gross α- and artificial gross β-activity concentrations [12]. Artificial gross β-activity concentrations are calculated from the difference between the measured gross β-activity concentration and the natural gross β-activity concentration derived from the measured gross α-activity concentration.
Since 1996 the analysis of trends in the ambient dose equivalent rate has been based on this set of 163 stations. 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 163 dose equivalent rate monitors with respect to height and surface covering. The yearly averages before 1996 are calculated from data from the 58 stations of the former LMR (the National Radioactivity Monitoring Network before 1996) [13]. The change from LMR to NMR resulted in lower yearly averages for the ambient dose equivalent rate. This is the result of a higher density of ambient dose equivalent rate monitors and the different locations of these monitors for NMR in respect to LMR.

The data presented in this chapter are based on ten-minute averages. Averages over the year are calculated from these values (*Tables A8* and *A9).* 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. For the correction of data from the LMR locations a conversion equation was used, as presented by Smetsers et al. [13]. This equation gives a correction of -10 $nSv.h^{-1}$ for the lowest dose rate encountered in the Netherlands and a correction of -5 $nSv.h^{-1}$ for the highest dose rate in the Netherlands. No conversion formula has been determined for the 163 dose equivalent rate monitors of the NMR, but the systematic error is expected to be of the same magnitude.

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

Figures 4.2 and *4.4* present the respective yearly averages of gross α-activity concentration and ambient dose equivalent rate from 1990 to 2000.
The yearly averaged ambient dose equivalent rate in 2000 is calculated using 156 stations. The remaining 7 stations were not operational. For the ambient dose equivalent rate the yearly averaged measured value was 74 $nSv \cdot h^{-1}$. This value has not been corrected for the systematic error (5-10 $nSv \cdot h^{-1}$) and does not differ significantly from previous years.

The yearly averaged (14 measurement locations) gross α-activity concentration in air dust was 2,5 $Bq \cdot m^{-3}$. This value does not differ significantly from previous years. The yearly average of the calculated artificial gross β-activity concentration does not deviate significantly from zero.

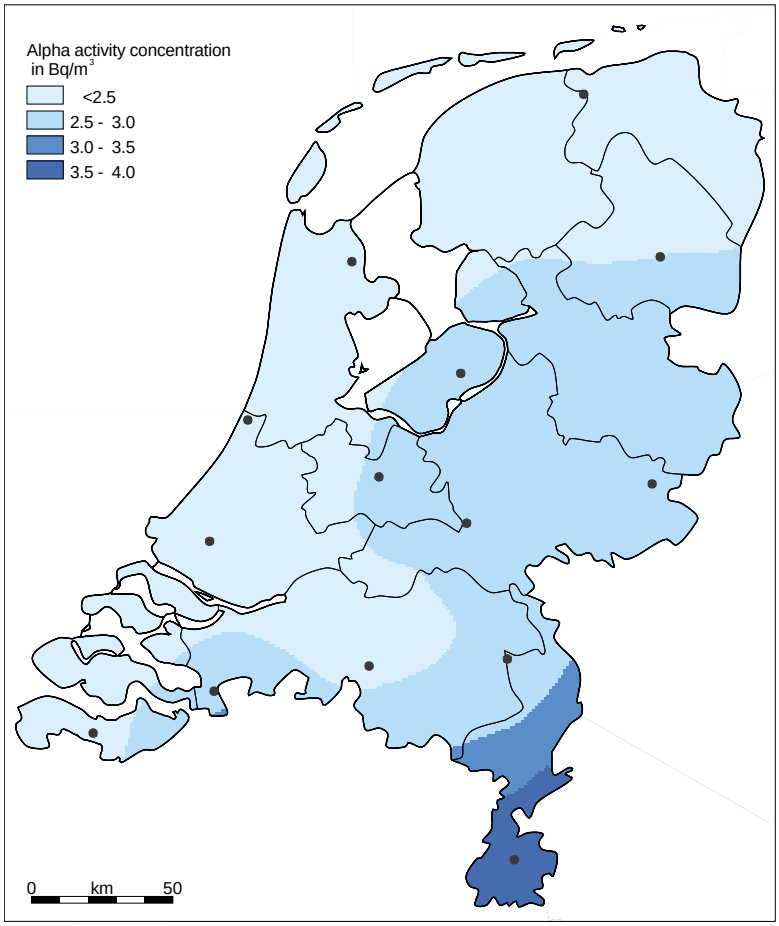


Figure 4.1: Spatial variation in the average gross α-activity concentration in air dust in 2000. The dots represent the locations of the aerosol monitors.

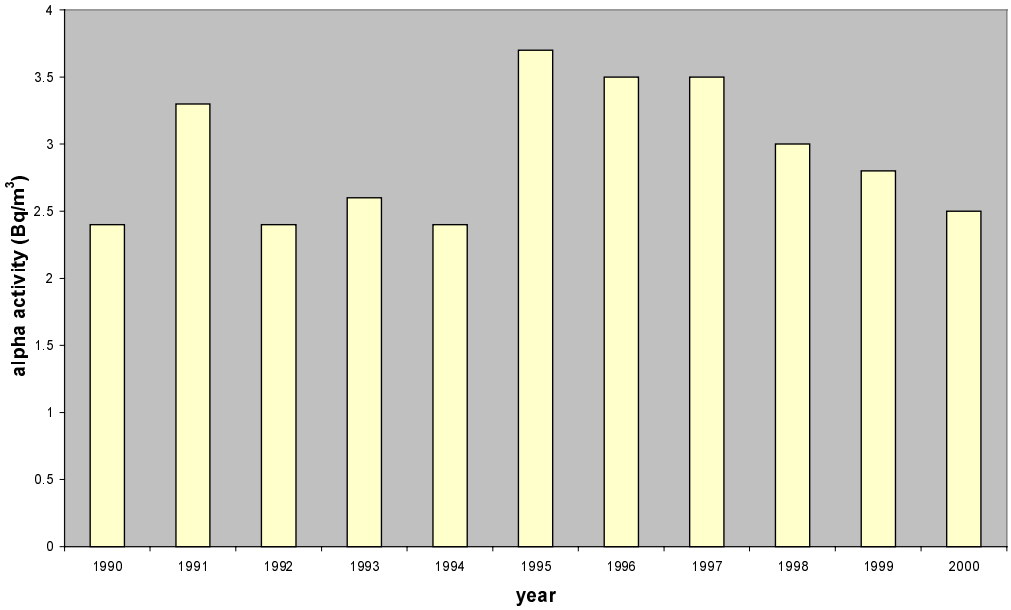


Figure 4.2: Yearly averages for gross α-activity concentration.

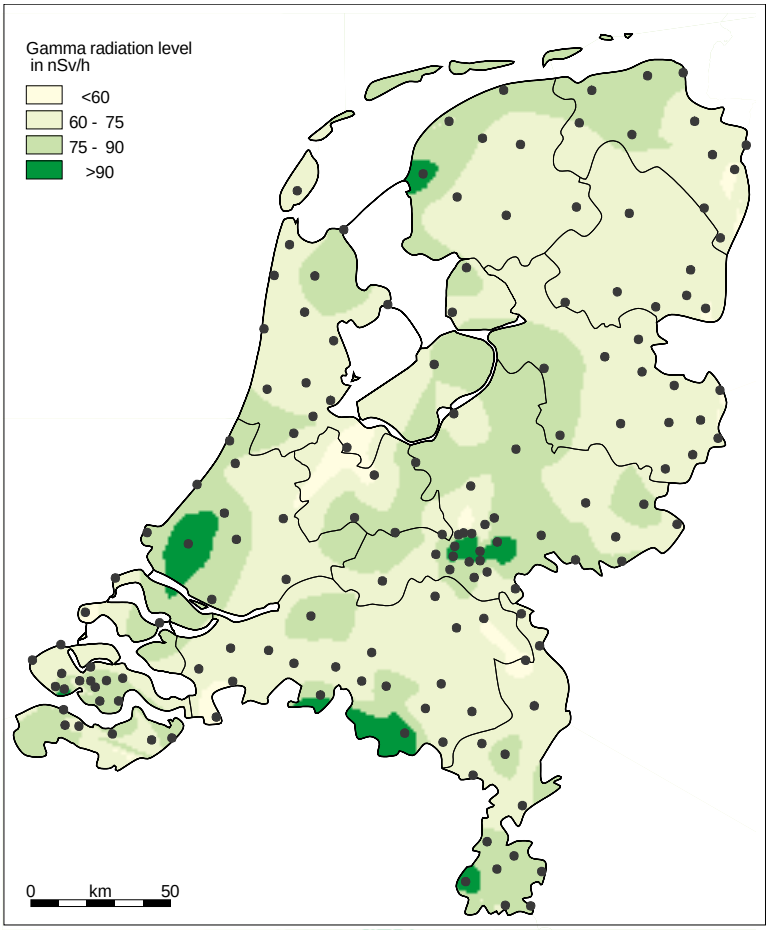


Figure 4.3: Spatial variation in the average ambient dose equivalent rate in 2000. The dots represent the locations of the dose equivalent rate monitors.

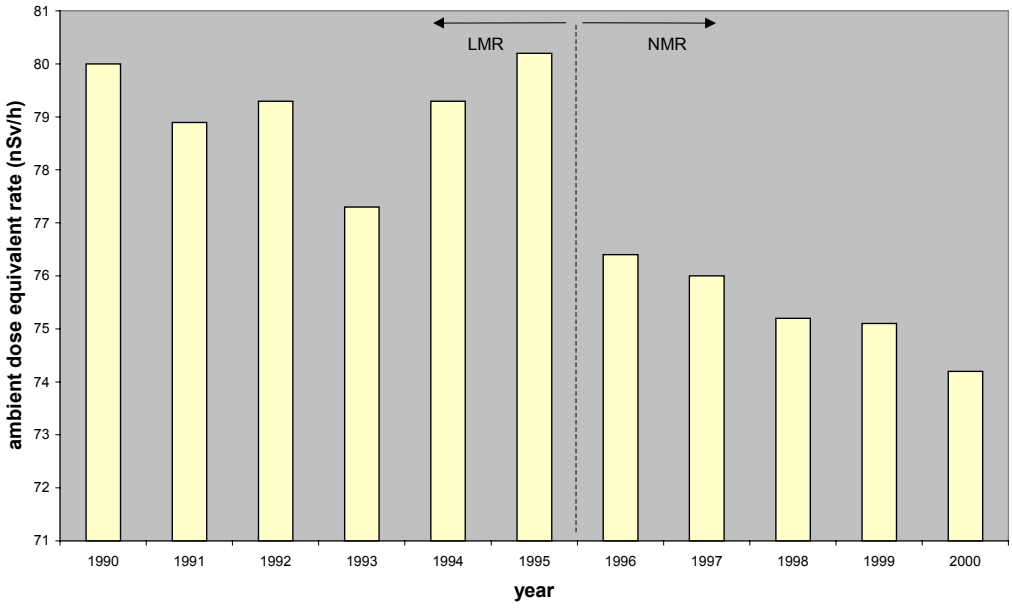


Figure 4.4: Yearly averages of the ambient dose equivalent rate.

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 programme, underlying strategy and results of measurements on radioactivity in Dutch waters are reported elsewhere [14, 15, 16].

The results presented in this report have been chosen to represent the major inland waters and seawater. The 2000 monitoring program is given 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 in time.

Table 5.1: Monitoring programme for the determination of radioactive nuclides in surface water in 2000.

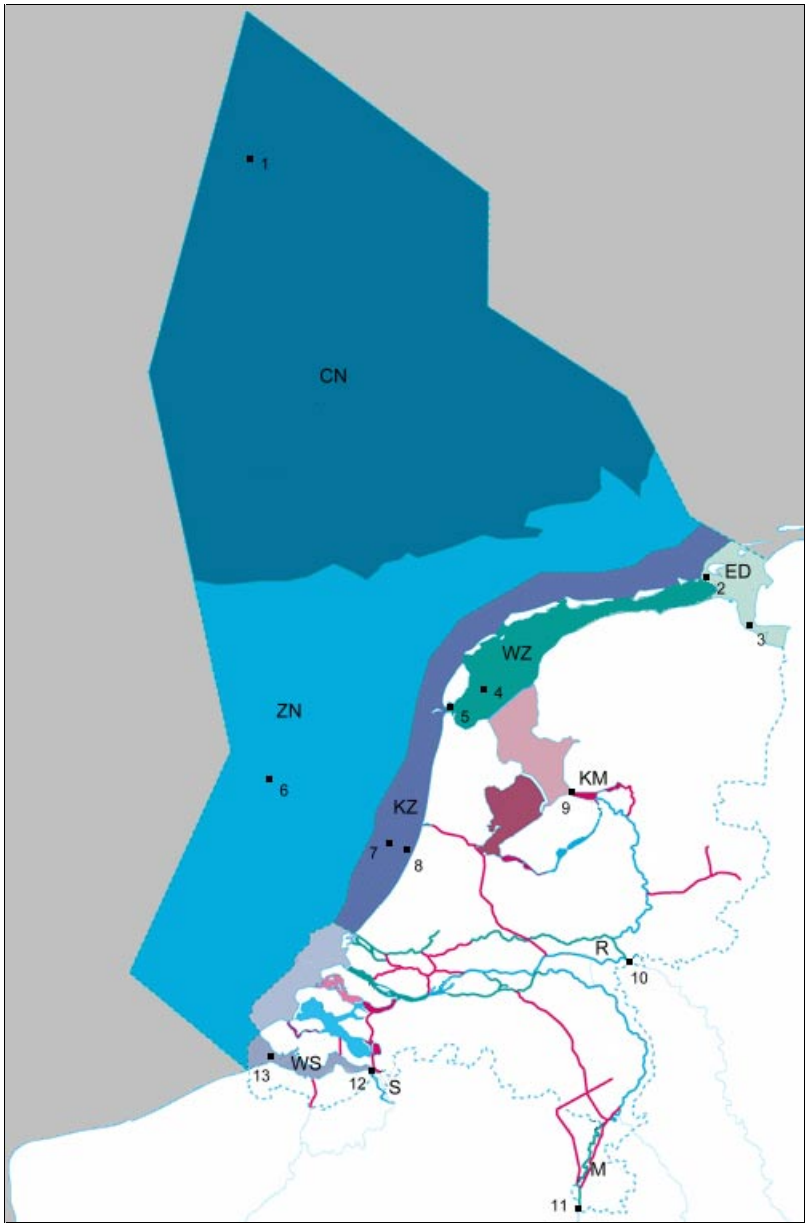
Location	Parameter	Compartment	Monitoring frequency (per year)
Meuse	^{3}H	Water	13
(Eijsden)	Residual β	Water	13
	^{137}Cs	Suspended solids	52
Rhine	^{3}H	Water	12
(Lobith)	Residual β	Water	12
	^{137}Cs	Suspended solids	12
Scheldt	^{3}H	Water	6
(Schaar van Ouden Doel)	Residual β	Water	13
	^{137}Cs	Suspended solids	13
Ketelmeer West	^{137}Cs	Suspended solids	6

The results for surface water are presented in *Tables A10* and *A11* and in *Figures 5.2 to 5.7*. The results for seawater are presented in *Tables A12* and *A13* 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 [15] and [17]. In the Netherlands target values for radioactive materials in surface water are used, which are given in the Fourth memorandum on water management ("Vierde Nota waterhuishouding") [18]. The yearly averages are compared with these target values.

Table 5.2: Monitoring programme for the determination of radioactive nuclides in seawater in 2000.

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

(1) Number indicates distance from shore. For example Noordwijk 2 means Noordwijk 2 km offshore.
(2) Normally 4 times per year.



M	=	Meuse
R	=	Rhine
S	=	Scheldt
KM	=	Ketelmeer
KZ	=	Coastal area
CN	=	Central North Sea
ZN	=	Southern North Sea
WS	=	Westerscheldt
ED	=	Eems-Dollard
WZ	=	Wadden Sea
1	=	Terschelling 235
2	=	Huibergat Oost
3	=	Bocht van Watum
4	=	Doove Balg West
5	=	Marsdiep Noord
6	=	Noordwijk 70
7	=	Noordwijk 10
8	=	Noordwijk 2
9	=	Ketelmeer West
10	=	Lobith
11	=	Eijsden
12	=	Schaar van Ouden Doel
13	=	Vlissingen Boei

Noordwijk 2 means Noordwijk 2 km offshore.

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

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.

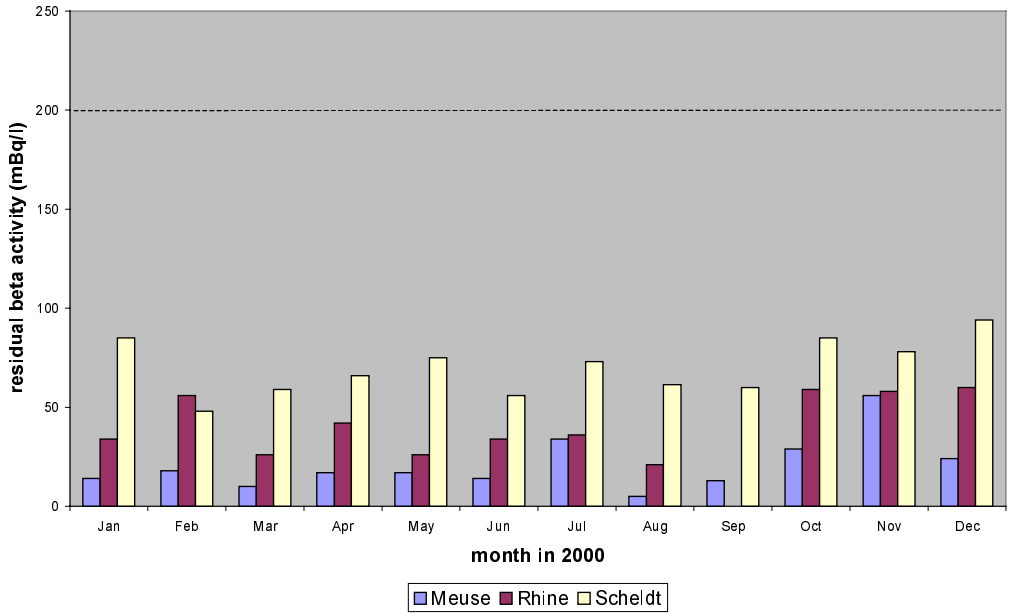


Figure 5.2: The concentration of residual β in 2000 for the Meuse, Rhine and Scheldt, with respective yearly averages of 22, 43 and 69 mBq·L^{-1}. In case of multiple measurements per month averaged values are shown. The dotted line represents the target value [18].

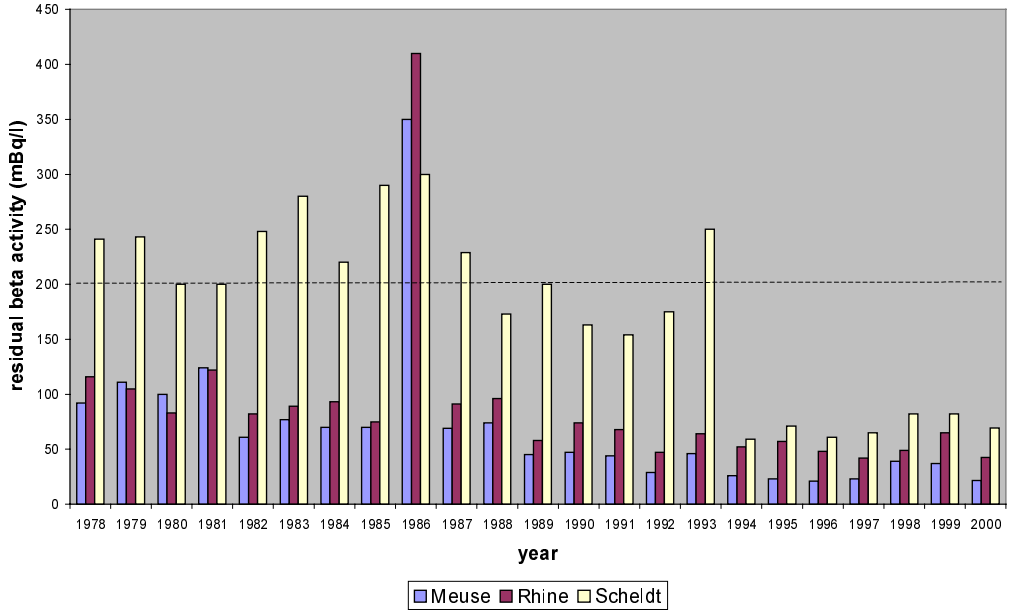


Figure 5.3: Yearly averaged concentration of residual β.

The yearly averaged concentrations of residual β in 2000 do not differ significantly from 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 [15]. Therefore no change in trend is shown for the Meuse and the Rhine.

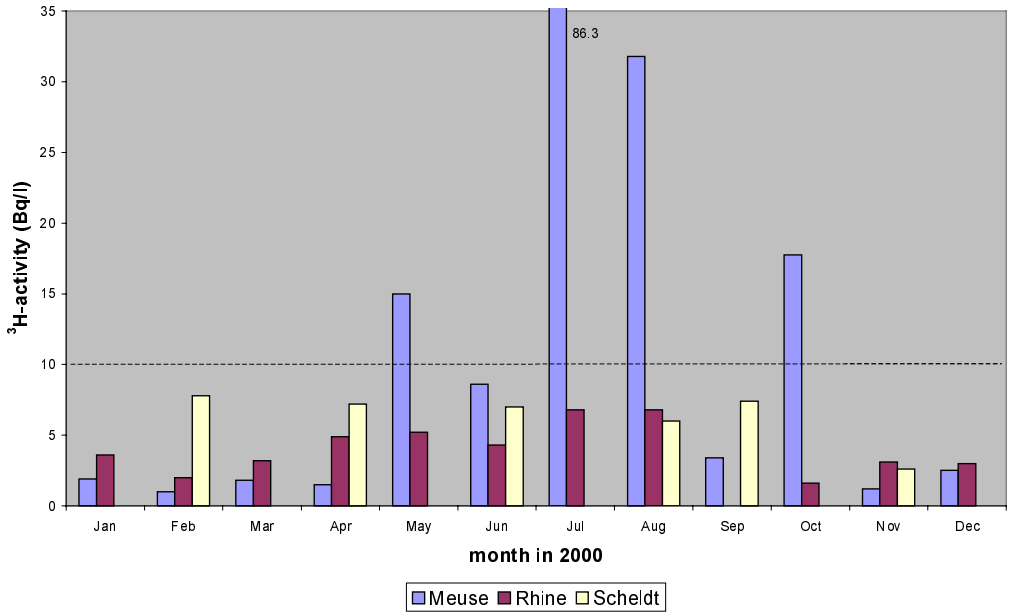


Figure 5.4: The concentration of ^{3}H in 2000 for Meuse, Rhine and Scheldt, with respective yearly averages of 14.7, 4.0 and 6.3 Bq·L^{-1}. In case of multiple measurements per month averaged values are shown.

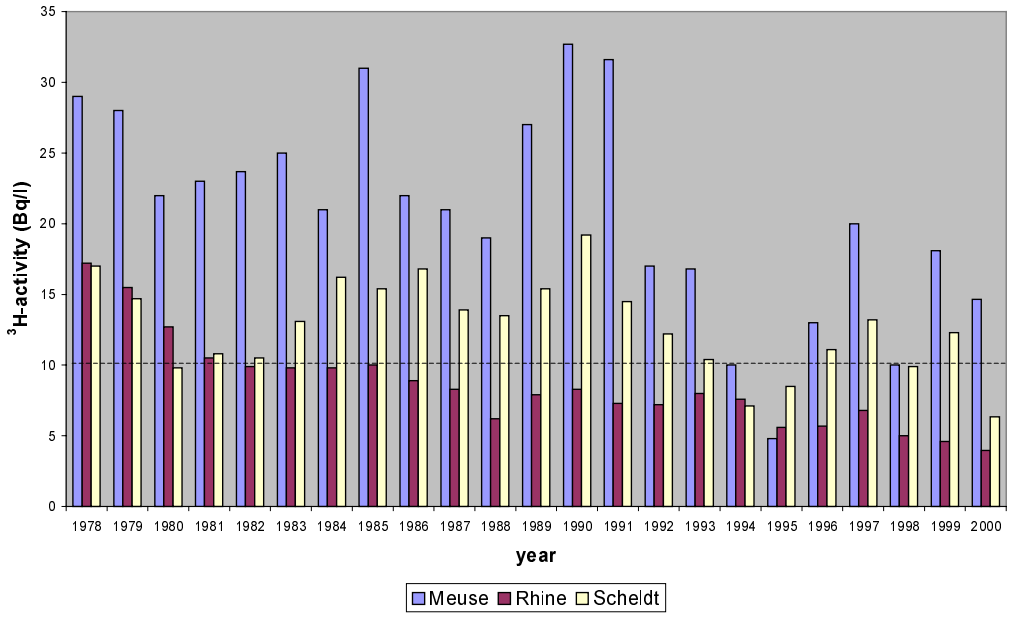


Figure 5.5: Yearly averaged concentration of ^{3}H.

The yearly averaged concentrations of tritium in 2000 do not differ significantly from those in previous years. In 2000 the averaged tritium concentration in the Meuse is above the target value of 10 Bq·L^{-1}.

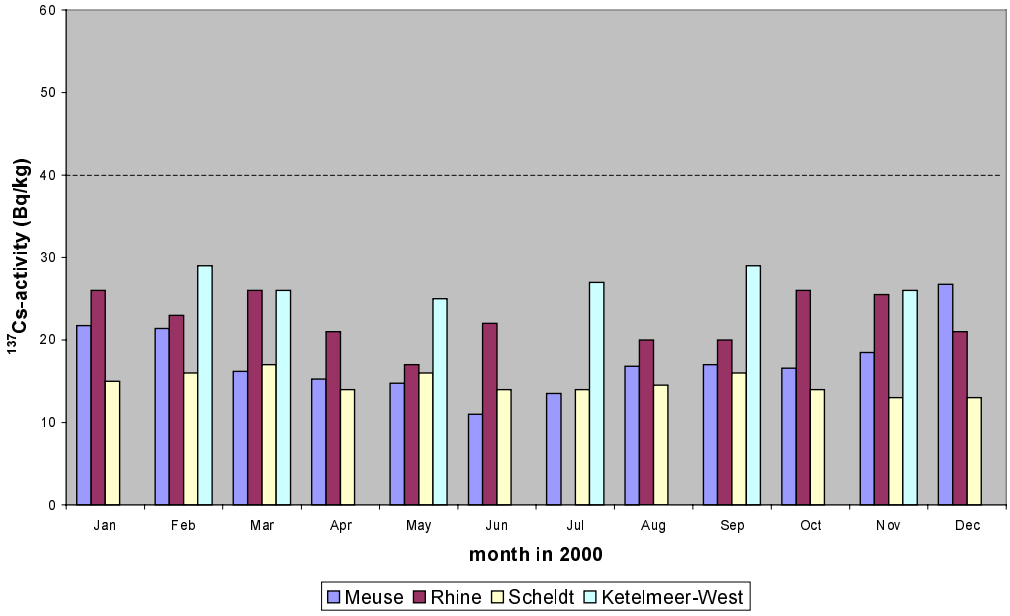


Figure 5.6: The concentration of ^{137}Cs in 2000 for the Meuse, Rhine, Scheldt and Ketelmeer-West with respective averages of 17, 23, 15 and 27 Bq·kg^{-1}. In case of multiple measurements per month averaged values are shown.

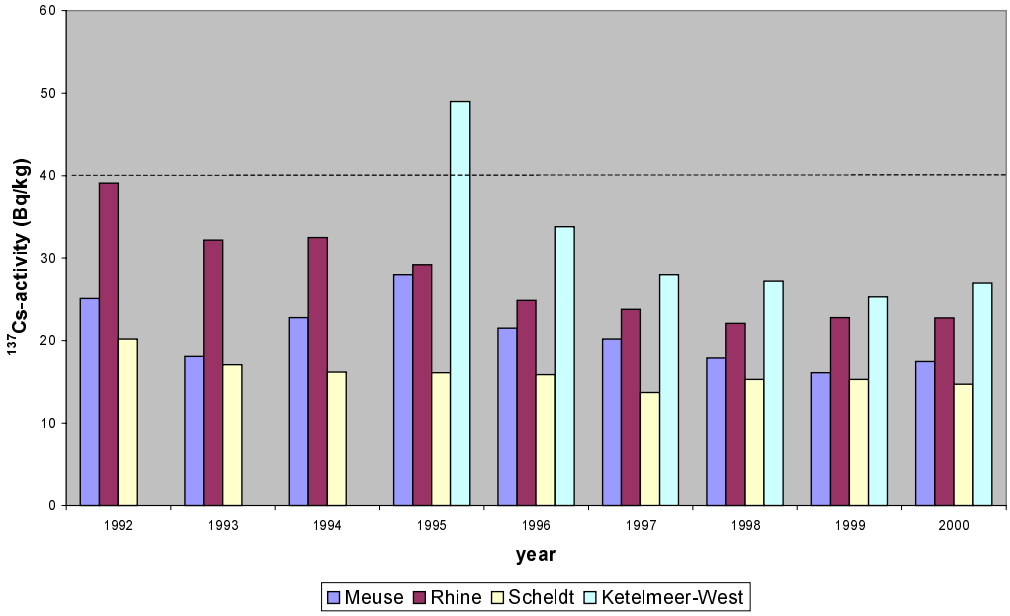


Figure 5.7: Yearly averaged concentration of ^{137}Cs. Data on Ketelmeer-West is available since 1995.

The yearly averaged concentrations of ^{137}Cs in 2000 do not differ significantly from those in previous years. The averaged ^{137}Cs-concentrations are below the target value of 40 Bq·kg^{-1}.

5.3 The results for seawater

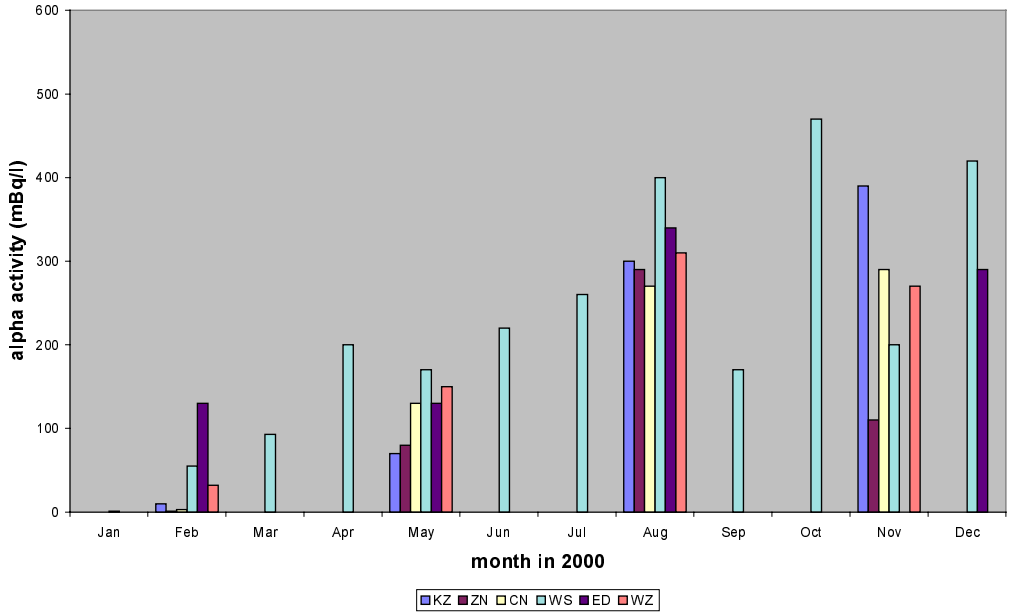


Figure 5.8: The gross α-activity concentration in seawater in 2000. The respective yearly averages for the Coastal area (KZ), Southern North Sea (ZN), Central North Sea (CN), Westerscheldt (WS), Eems-Dollard (ED) and Wadden Sea (WZ) are 193, 120, 173, 222, 223 and 191 mBq·L^{-1}.

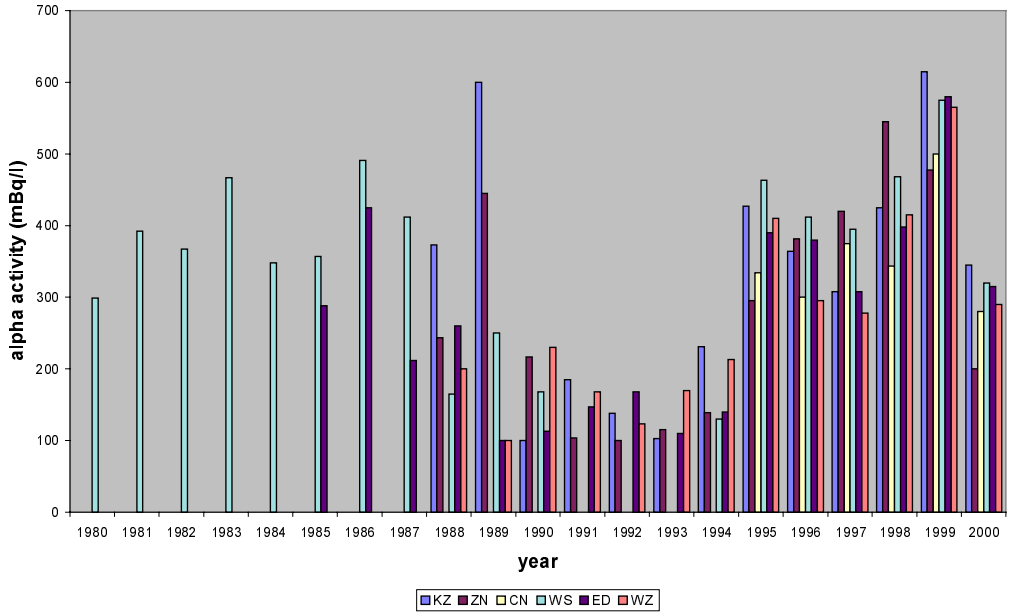


Figure 5.9: Yearly averaged gross α-activity concentrations.

In the first half of 2000 the background of the measuring equipment was unstable and higher then 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 in [15]. Gross α and residual β are indicative parameters [15].

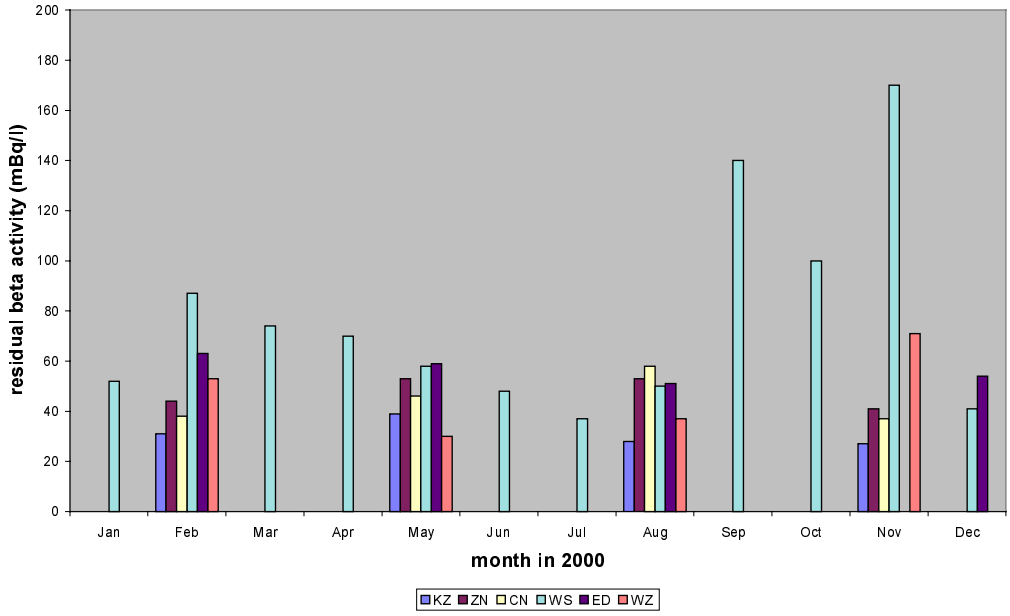


Figure 5.10: The residual β-activity concentration in seawater in 2000. The respective yearly averages for the Coastal area, Southern North Sea, Central North Sea, Westerscheldt, Eems-Dollard and Wadden Sea are 31, 48, 45, 77, 57 and 48 mBq·L^{-1}.

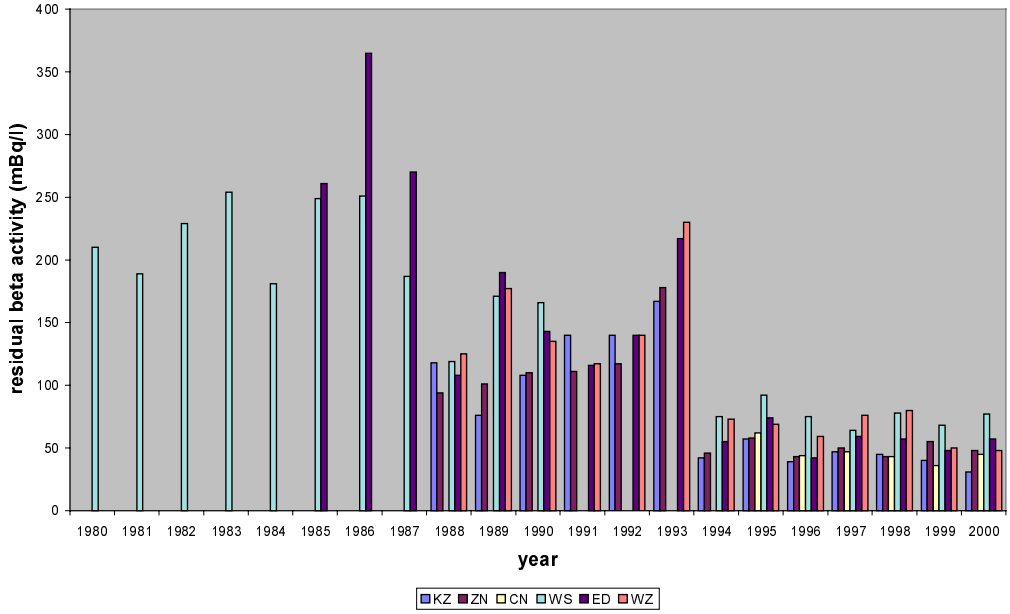


Figure 5.11: Yearly averaged residual β-activity concentrations.

The yearly averaged concentrations of residual β in 2000 do not differ significantly from those in previous years. Residual beta 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 [15].

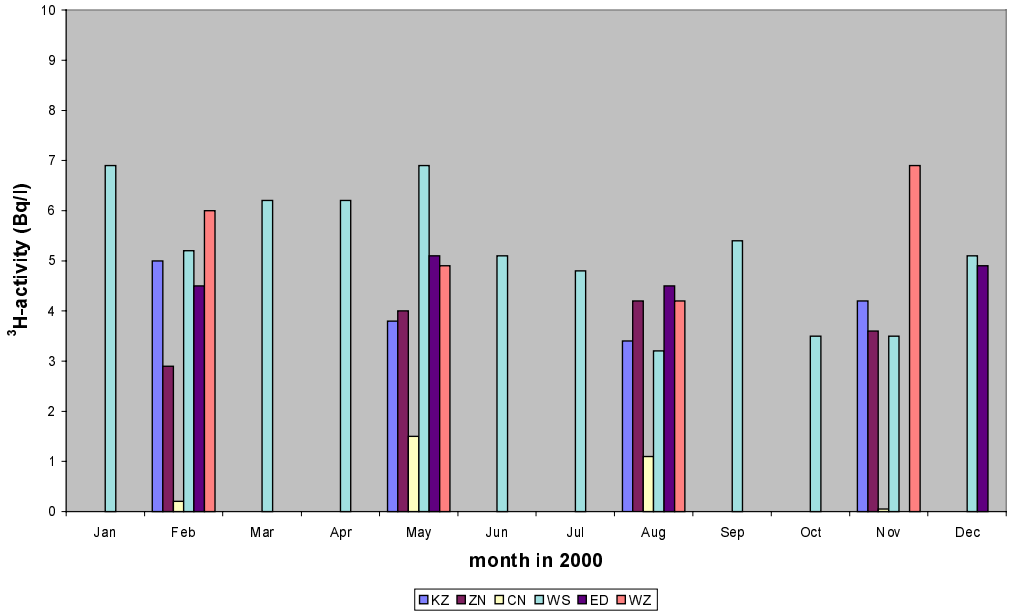


Figure 5.12: The ^{3}H-activity concentration in seawater in 2000. The respective yearly averages for the Coastal area, Southern North Sea, Central North Sea, Westerscheldt, Eems-Dollard and Wadden Sea are 4.1, 3.7, 0.7, 5.2, 4.8 and 5.5 Bq·L^{-1}.

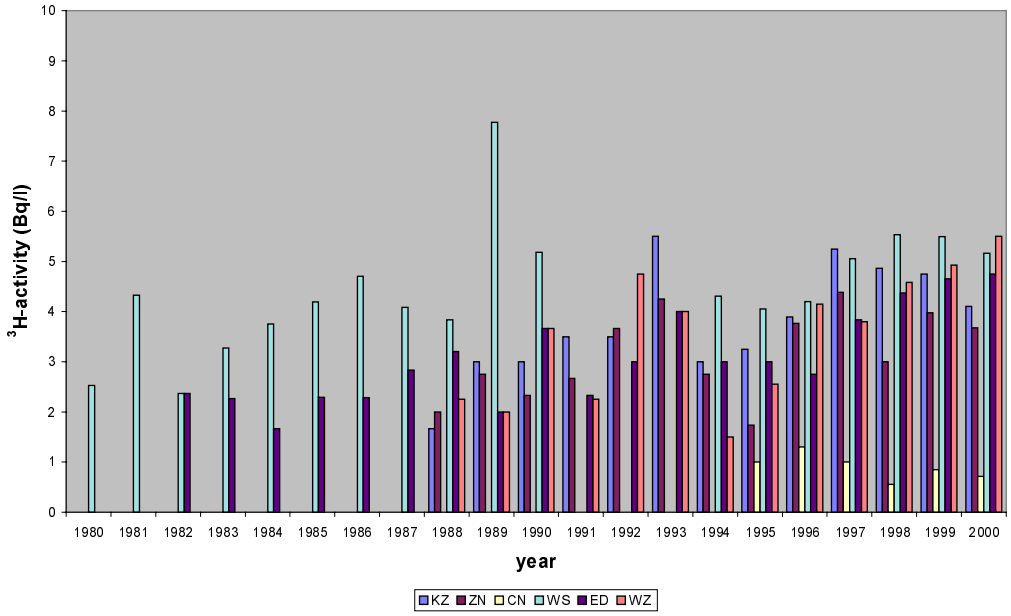


Figure 5.13: Yearly averaged ^{3}H-activity concentrations.

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 [15].

The yearly averaged concentrations of ^{3}H in 2000 do not differ significantly from those in previous years.

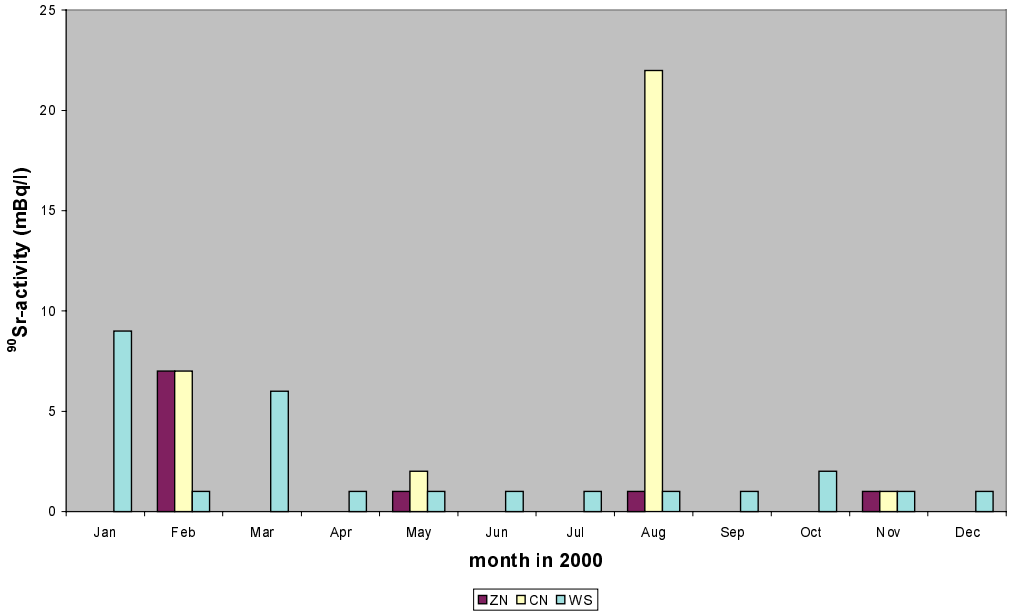


Figure 5.14: The ^{90}Sr-activity concentration in seawater in 2000. The respective yearly averages for the Southern North Sea, Central North Sea and Westerscheldt are 3, 8 and 2 mBq·L^{-1}.

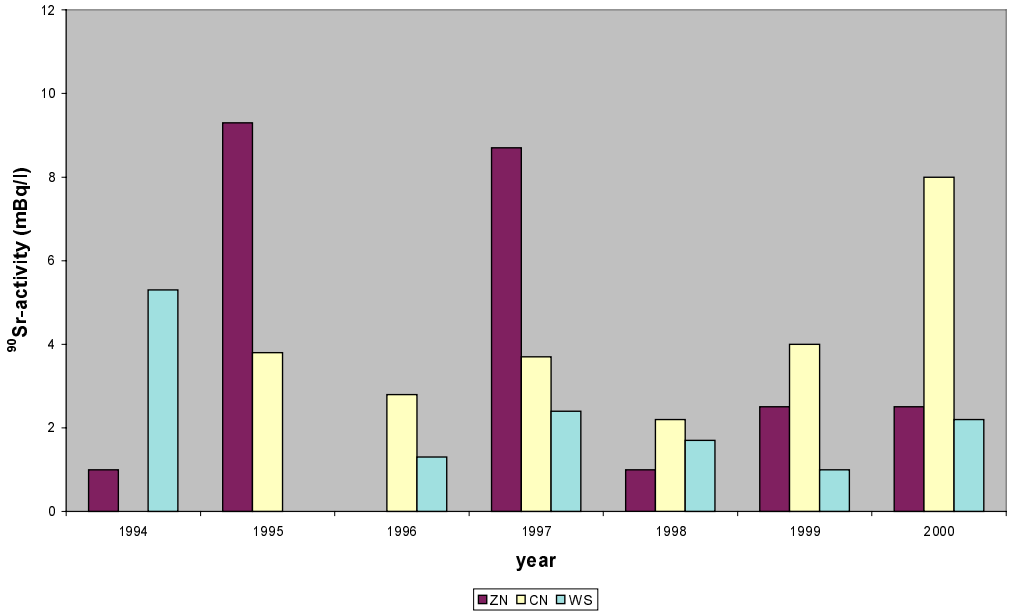


Figure 5.15: Yearly averaged ^{90}Sr-activity concentrations.

The high result of the sample taken on the 15th of August causes the yearly average of the Central North Sea to be higher then in previous years.
For the other locations the yearly averaged concentrations of ^{90}Sr in 2000 do not differ significantly from those in previous years.

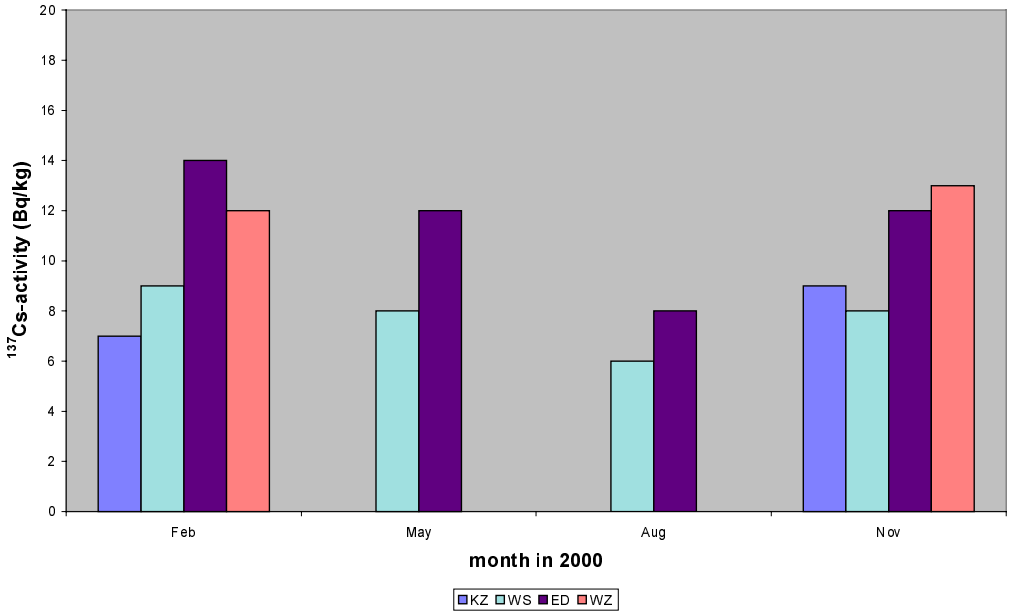


Figure 5.16: The ^{137}Cs-activity concentration in suspended soils in seawater in 2000. The respective yearly averages for the Coastal area, Westerscheldt, Eems-Dollard and Wadden Sea are 8, 8, 12 and 13 Bq·kg^{-1}.

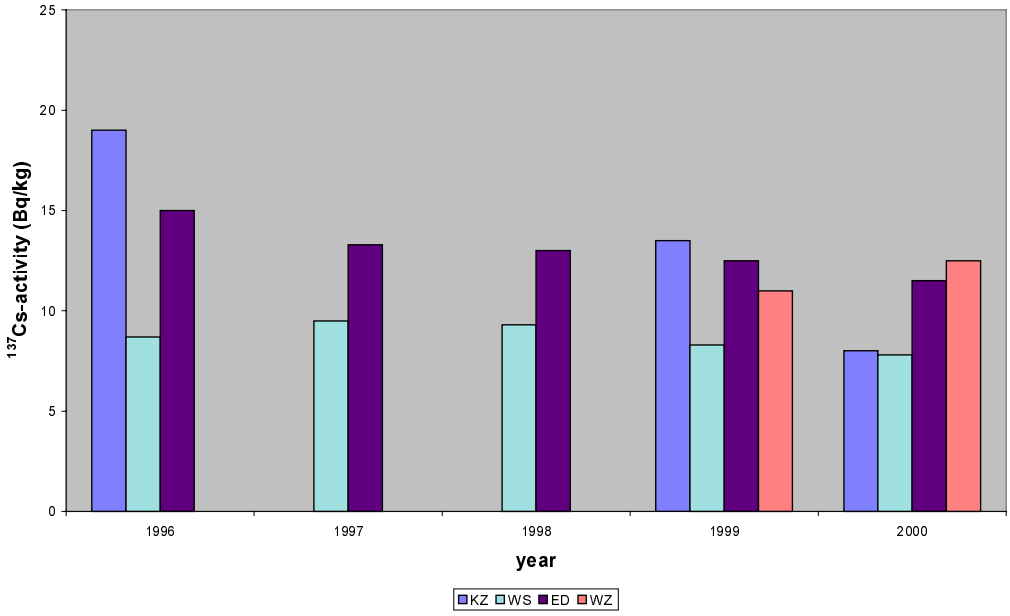


Figure 5.17: Yearly averaged ^{137}Cs-activity concentrations.

The yearly averaged concentrations of ^{137}Cs in 2000 do not differ significantly from those in previous years.

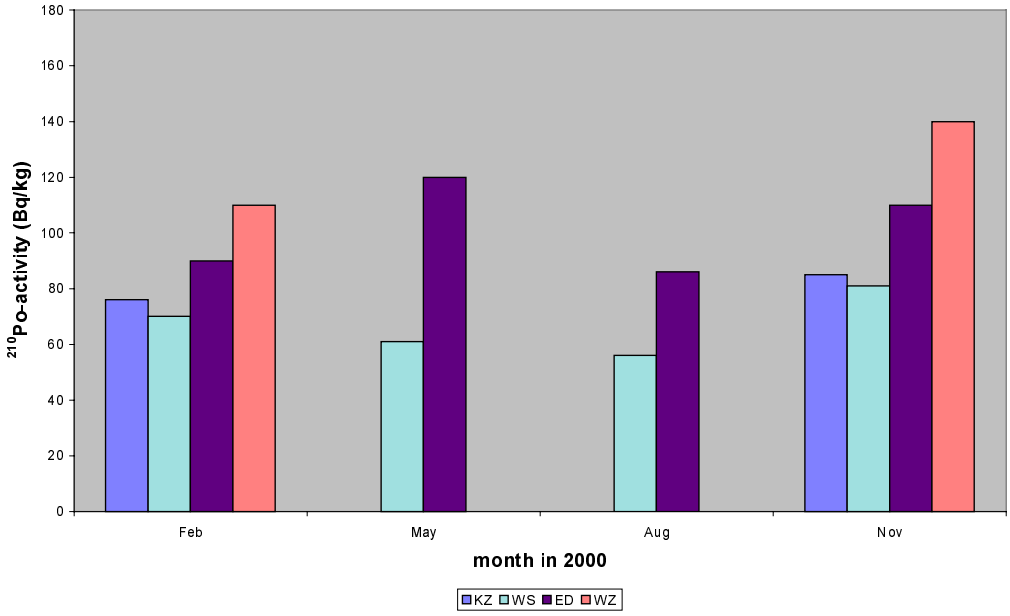


Figure 5.18: The ^{210}Po-activity concentration in suspended soils in seawater in 2000. The respective yearly averages for the Coastal area, Westerscheldt, Eems-Dollard and Wadden Sea are 81, 67, 102 and 125 Bq·kg^{-1}.

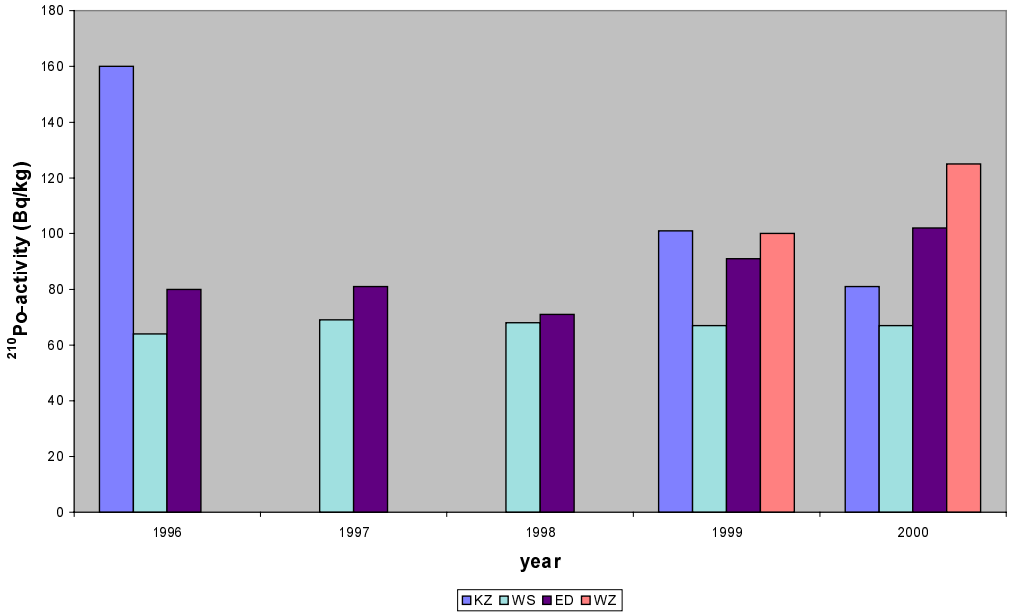


Figure 5.19: Yearly averaged ^{210}Po-activity concentrations.

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 [15]. 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). At the entrance of the Wadden Sea (WZ) activity originating from the North Sea is monitored.

The yearly averaged concentrations of ^{210}Po in 2000 do not differ significantly from those in previous years.

6. Water for human consumption

In the Netherlands, water pumping-stations routinely monitor raw input water for tritium, gross β- and residual β-activity. The monitoring frequency is from one to 20 times per year depending on the volume of water produced. Typical activities are 1-10 $Bq \cdot L^{-1}$ for tritium, and 0.1 – 1 $Bq \cdot L^{-1}$ for both gross β- and residual β-activity, which means there is almost no ^{40}K present.

The activity of natural nuclides, such as ^{226}Ra and ^{222}Rn, in Dutch drinking water is very low. In 1994, a survey of Dutch water was carried out to determine the radon activity [19]. The average concentration was 2.2 $Bq \cdot L^{-1}$ for drinking water produced from groundwater.

7. Milk

Until 1997 RIVM measured radioactivity in milk samples 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. Radioactivity in food

Radioactivity is measured in food suspected to contain more than the normal activity concentrations. The measurements are performed by the Inspectorate for Health Protection and Veterinary Public Health.

8.1 Honey

In total 69 samples of honey were analysed [20]. The results are presented in *Table 8.1*. The activity (sum of ^{134}Cs and ^{137}Cs) was found to be below the limit of 600 Bq·kg^{-1} [21]. All samples of heather honey contained ^{137}Cs. The activity varied from 49 up to 321 Bq·kg^{-1}. Measurements were carried out according to standard procedures [22].

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

Honey variety	Number of samples	^{134}Cs (Bq·kg^{-1})	^{137}Cs (Bq·kg^{-1})
Clover honey	9	n.d.	n.d.
Heather honey	7	n.d.	49 - 321
Lime blossom honey	7	n.d.	n.d.
Acacia honey	6	n.d.	n.d.
Rape honey	5	n.d.	n.d.
Springtime honey	3	n.d.	n.d.
Summertime honey	3	n.d.	n.d.
Sunflower honey	3	n.d.	n.d.
Fruit honey	2	n.d.	n.d.
Buckwheat honey	2	n.d.	n.d.
Other floral honey	22	n.d.	n.d.

n.d. = not detectable

8.2 Other products

Measurable quantities of ^{134}Cs + ^{137}Cs were found in some samples of game. Two samples of wild boar contained 38 Bq·kg^{-1} and 131 Bq·kg^{-1} respectively, roe 41 Bq·kg^{-1} and deer 41 Bq·kg^{-1}. All samples of game originated from the Netherlands.
Some products were sampled within the scope of Customs Importcontrole. No radioactivity was detected in these products, like blueberry and chanterelle.

9. Conclusions

In 2000 no elevated levels of radioactivity in the environment were found. The activity concentrations are back to the levels just before the Chernobyl accident.
In 2000 no measurements were performed in milk. This departs from the Recommendation on the Application of Article 36 of the Euratom Treaty.

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Appendix A

Table A1: Weekly results of gross α- and gross β-activity concentrations in air dust sampled with a HVS at RIVM in 2000.

Week number	Gross α mBq.m^{-3}	Gross β mBq.m^{-3}		Week number	Gross α mBq.m^{-3}	Gross β mBq.m^{-3}	
1	0.08	0.24	± 0.02	27	0.05	0.33	± 0.03
2	0.12	0.49	± 0.04	28	0.03	0.152	± 0.014
3	0.07	0.34	± 0.03	29	0.04	0.121	± 0.012
4	0.26	0.36	± 0.03	30	0.07	0.43	± 0.04
5	0.09	0.40	± 0.03	31	0.08	0.39	± 0.03
6	0.08	0.38	± 0.03	32	0.05	0.24	± 0.02
7	0.05	0.155	± 0.014	33	0.09	0.37	± 0.03
8	0.05	0.162	± 0.015	34	0.05	0.28	± 0.02
9	0.06	0.29	± 0.02	35	0.08	0.36	± 0.03
10	0.02	0.24	± 0.02	36	0.04	0.23	± 0.02
11	0.07	0.36	± 0.03	37	0.14	0.38	± 0.03
12	0.05	0.40	± 0.03	38	0.08	0.44	± 0.04
13	0.06	0.46	± 0.04	39	0.09	0.65	± 0.05
14	0.06	0.36	± 0.03	40	0.10	0.44	± 0.04
15	0.03	0.30	± 0.03	41	0.04	0.25	± 0.02
16	0.02	0.203	± 0.018	42	0.06	0.35	± 0.03
17	0.05	0.36	± 0.03	43	0.10	0.57	± 0.05
18	0.05	0.45	± 0.04	44	0.04	0.218	± 0.019
19	0.07	0.91	± 0.07	45	0.05	0.190	± 0.017
20	0.06	0.62	± 0.05	46	0.07	0.25	± 0.02
21	0.06	0.24	± 0.02	47	0.05	0.24	± 0.02
22	0.04	0.25	± 0.02	48	0.08	0.28	± 0.02
23	0.04	0.28	± 0.02	49	0.06	0.35	± 0.03
24	0.08	0.34	± 0.03	50	0.04	0.179	± 0.016
25	0.09	0.62	± 0.05	51	0.07	0.34	± 0.03
26	0.04	0.30	± 0.03	52	0.13	0.84	± 0.07
				Average	0.07 [(1)]	0.353	± 0.004 [(2)]
				SD [(3)]	0.04		0.16

[(1)] 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].

[(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 A2: Detection limits (μBq·m^{-3}) in the residue measurement on a coaxial detector for a seven days sampling period, ten days delay between sampling and start of measurement, 100,000 seconds counting time and a sample volume of about 50000 m^3. The detection limits are higher then in previous years [8] 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 waiting 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 waiting 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 2000. 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	31/12-07/01	1970	±	170		±		153	±	17
2	07/01-14/01	2500	±	200		±		360	±	30
3	14/01-21/01	2700	±	200		±		250	±	30
4	21/01-28/01	3300	±	300		±		240	±	20
5	28/01-04/02	3500	±	300		±		260	±	30
6	04/02-11/02	4500	±	400		±		270	±	30
7	11/02-18/02	3100	±	300		±		79	±	12
8	18/02-25/02	2400	±	200		±		135	±	16
9	25/02-03/03	2800	±	200		±		138	±	16
10	03/03-10/03	2800	±	200		±		124	±	15
11	10/03-17/03	3400	±	300		±		210	±	20
12	17/03-24/03	2500	±	200		±		270	±	30
13	24/03-31/03	2900	±	300		±		330	±	30
14	31/03-07/04	1930	±	170		±		280	±	30
15	07/04-14/04	3100	±	300		±		180	±	19
16	14/04-21/04	3000	±	300		±		140	±	16
17	21/04-28/04	5100	±	400		±		185	±	19
18	28/04-04/05	2700	±	200		±		310	±	30
19	04/05-12/05	8100	±	700	3.7	±	0.7	610	±	50
20	12/05-19/05	6000	±	500		±		400	±	40
21	19/05-26/05	3100	±	300		±		148	±	16
22	26/05-31/05	3100	±	300		±		93	±	15
23	31/05-09/06	3600	±	300		±		200	±	20
24	09/06-16/06	3500	±	300		±		240	±	30
25	16/06-23/06	5300	±	500		±		460	±	40
26	23/06-30/06	3200	±	300		±		150	±	17

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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	30/06-07/07	3000	±	300	±	220	±	20
28	07/07-14/07	2300	±	200	±	111	±	13
29	14/07-21/07	1820	±	160	±	118	±	14
30	21/07-28/07	3000	±	300	±	360	±	30
31	28/07-04/08	2400	±	200	±	300	±	30
32	04/08-11/08	2080	±	180	±	170	±	18
33	11/08-18/08	2900	±	300	±	280	±	30
34	18/08-25/08	3500	±	300	±	158	±	18
35	25/08-01/09	3000	±	300	±	280	±	30
36	01/09-08/09	2400	±	200	±	230	±	20
37	08/09-15/09	2220	±	190	±	440	±	40
38	15/09-22/09	1720	±	150	±	530	±	50
39	22/09-29/09	2500	±	200	±	490	±	40
40	29/09-06/10	3200	±	300	±	320	±	30
41	06/10-13/10	2500	±	200	±	143	±	16
42	13/10-20/10	2300	±	200	±	250	±	20
43	20/10-27/10	3000	±	300	±	430	±	40
44	27/10-03/11	3100	±	300	±	103	±	14
45	03/11-10/11	1610	±	140	±	162	±	16
46	10/11-17/11	2400	±	200	±	173	±	19
47	17/11-24/11	2500	±	200	±	138	±	16
48	24/11-01/12	3100	±	300	±	167	±	18
49	01/12-08/12	2700	±	200	±	270	±	30
50	08/12-15/12	2500	±	200	±	92	±	13
51	15/12-21/12	2210	±	190	±	190	±	20
52	22/12-29/12	3300	±	300	±	550	±	50
	Average	3030	±	40 [(1)]		248	±	4 [(1)]
	SD [(2)]			1100				130

[(1)] 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.

[(2)] 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 2000.

Month 2000	Precipitation mm	^{3}H Bq·m^{-2}	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}
January	52.1	72 ± 20	1.6 ± 0.4	5.5 ± 0.5
February	124.1	< 149	3.6 ± 0.4	10.1 ± 0.9
March	54.9	< 66	1.3 ± 0.2	7.0 ± 0.7
April	33.6	< 40	1.3 ± 0.2	4.2 ± 0.4
May	65.9	< 79	4.7 ± 0.5	11.1 ± 1.0
June	79.2	< 95	2.9 ± 0.4	8.2 ± 0.8
July	112.3	168 ± 44	4.0 ± 0.4	9.7 ± 0.9
August	35.5	76 ± 16	3.5 ± 0.4	10.4 ± 1.0
September	70.7	< 85	2.3 ± 0.3	7.7 ± 0.7
October	125.1	< 249	4.6 ± 0.5	15.1 ± 1.4
November	105.0	< 178	3.6 ± 0.4	7.9 ± 0.7
December	77.1	< 131	2.0 ± 0.3	7.1 ± 0.7
Total	935	< 1390	35.2 ± 1.3 [(1)]	104 ± 3 [(1)]

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

Table A5: Yearly totals [(1)] for long-lived gross α- and gross β-, ^{3}H-, ^{210}Pb- and ^{210}Po-activity in deposition for 1983 – 2000 [8].

Year	Precipitation mm	Gross α Bq·m^{-2}	Gross β Bq·m^{-2}	^{3}H Bq·m^{-2}	^{210}Pb [(2)] Bq·m^{-2}	^{210}Po [(2)] Bq·m^{-2}
1983	869	40	120	2100	-	-
1984	868	25	130	2610	-	-
1985	767	30	140	3800	-	-
1986	825	45	18000	2400	15	3
1987	975	24 ± 1 [(3)]	85 ± 3 [(3)]	2630	52	6
1988	887	36 ± 2	103 ± 3	1700 ± 40	110 ± 3	25 ± 1
1989	706	43 ± 1	89 ± 3	1560 ± 130	94 ± 7	24 ± 4
1990	756	68 ± 1	121 ± 4	1360 ± 120	85 ± 4	16 ± 2
1991	699	48 ± 1	85 ± 1	1060 ± 50	56 ± 1	10 ± 1
1992	946	44 ± 1	87 ± 1	1440 ± 50	83 ± 5	11 ± 1
1993	886	54.3 ± 0.7	87.9 ± 0.8	1310 ± 30	78 ± 3	6.0 ± 0.6
1994	1039	52.0 ± 0.7	91.2 ± 1.0	1210 ± 30	82 ± 3	12.7 ± 0.7
1995	724	39 ± 4	95 ± 8	970 ± 40	- [(4)]	- [(4)]
1996	626	16.4 ± 1.5	67 ± 5	970 ± 50	57 ± 3	9 ± 2
1997	760	23.1 ± 1.3	87 ± 3	1160 ± 60	80 ± 3	< 10
1998	1238	31.1 ± 1.3	106 ± 3	1200 ± 110	91 ± 4	< 16
1999	916	25.5 ± 1.0	84 ± 2	1530 ± 110	- [(5)]	< 5.1
2000	935	35.2 ± 1.3	104 ± 3	< 1390	-	< 7.8

[(1)] Errors are given as 1σ.
[(2)] Data from α-spectroscopy.
[(3)] Introduction of new method.
[(4)] Result rejected [23].
[(5)] α-spectroscopy analysis of ^{210}Pb stopped in 1999.
(-) No analysis.

Table A6: Monthly values of ^{210}Po-activity [1] in deposition sampled at RIVM in 2000.

Period 2000	**^{210}Po Bq·m^{-2}**
January	< 0.6
February	< 0.8
March	< 0.8
April	< 0.4
May	< 1.0
June	< 0.6
July	0.74 ± 0.18
August	< 0.6
September	< 0.6
October	< 0.8
November	< 0.6
December	< 0.5
Total	< 7.8

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

Table A7: Weekly values of ^{7}Be- and ^{210}Pb-activity [(1)] deposition sampled at RIVM in 2000.

Week Number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{210}Pb Bq·m^{-2}
1	31/12-07/01	17.5	20 ± 3	2.6 ± 0.8
2	07/01-14/01	2.1	16 ± 4	2.3 ± 1.0
3	14/01-21/01	5.5	7 ± 2	2.2 ± 0.7
4	21/01-28/01	5.5	13 ± 2	1.5 ± 0.7
5	28/01-04/02	21.5	4.1 ± 0.5	4.5 ± 1.1
6	04/02-11/02	25.0	46 ± 6	3.7 ± 0.9
7	11/02-18/02	27.6	35 ± 4	3.4 ± 0.8
8	18/02-25/02	34.0	49 ± 6	6.0 ± 1.2
9	25/02-03/03	37.5	3.9 ± 1.8	2.2 ± 1.1
10	03/03-10/03	30.0	79 ± 10	6.3 ± 1.0
11	10/03-17/03	6.6	35 ± 4	5.5 ± 1.0
12	17/03-24/03	4.0	13.6 ± 1.8	2.3 ± 0.7
13	24/03-31/03	14.3	22 ± 3	3.1 ± 0.8
14	31/03-07/04	2.0	8.7 ± 1.3	1.7 ± 0.5
15	07/04-14/04	8.5	13.1 ± 1.9	3.7 ± 0.8
16	14/04-21/04	9.2	22 ± 3	4.7 ± 0.7
17	21/04-28/04	13.9	43 ± 5	2.9 ± 0.7
18	28/04-04/05	2.8	15 ± 2	2.0 ± 0.5
19	04/05-12/05	5.6	19 ± 2	3.4 ± 1.1
20	12/05-19/05	30.5	74 ± 9	7.5 ± 1.2
21	19/05-26/05	27.0	22 ± 3	2.6 ± 1.0
22	26/05-31/05	31.0	55 ± 7	5.9 ± 1.1
23	31/05-09/06	24.9	46 ± 6	5.9 ± 1.1
24	09/06-16/06	4.4	10.8 ± 1.6	3.0 ± 0.8
25	16/06-23/06	4.4	21 ± 3	1.7 ± 0.5
26	23/06-30/06	14.5	17 ± 2	1.4 ± 0.7

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Table A7: Continued.

Week Number	Period	Precipitation mm	^{7}Be Bq·m^{-2}	^{210}Pb Bq·m^{-2}
27	30/06-07/07	30.0	53 ± 6	4.7 ± 0.8
28	07/07-14/07	38.0	63 ± 8	4.1 ± 0.8
29	14/07-21/07	16.0	7.6 ± 1.2	1.0 ± 0.7
30	21/07-28/07	7.0	25 ± 3	2.8 ± 0.7
31	28/07-04/08	21.3	44 ± 5	4.1 ± 0.8
32	04/08-11/08	1.2	8.0 ± 1.6	1.0 ± 0.7
33	11/08-18/08	3.4	13.4 ± 1.8	3.4 ± 0.8
34	18/08-25/08	18.0	25 ± 3	1.7 ± 0.6
35	25/08-01/09	13.0	27 ± 3	4.0 ± 1.1
36	01/09-08/09	26.5	46 ± 6	3.1 ± 0.9
37	08/09-15/09	3.7	9.3 ± 1.4	2.6 ± 0.9
38	15/09-22/09	26.5	49 ± 6	6.8 ± 0.9
39	22/09-29/09	14.0	2.0 ± 0.2	0.19 ± 0.03
40	29/09-06/10	17.0	37 ± 4	3.8 ± 0.5
41	06/10-13/10	27.8	38 ± 5	2.6 ± 0.6
42	13/10-20/10	12.6	21 ± 3	6.4 ± 0.9
43	20/10-27/10	27.2	48 ± 6	9.3 ± 1.3
44	27/10-03/11	40.5	49 ± 6	4.2 ± 0.9
45	03/11-10/11	36.4	16 ± 2	1.7 ± 0.7
46	10/11-17/11	19.9	25 ± 3	1.4 ± 0.8
47	17/11-24/11	30.4	37 ± 4	3.0 ± 0.4
48	24/11-01/12	18.3	23 ± 3	1.6 ± 1.3
49	01/12-08/12	17.3	24 ± 3	2.5 ± 0.8
50	08/12-15/12	37.4	57 ± 7	3.3 ± 0.5
51	15/12-22/12	11.0	16 ± 2	2.3 ± 0.6
52	22/12-29/12	11.5	24 ± 3	3.1 ± 0.5
	Sum	935	1500 ± 30 [2]	177 ± 6 [2]
	SD [3]		19	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.
[3] SD is the standard deviation of the weekly results. Errors are given as 1σ.

Table A8: Yearly averaged results and 5- and 95-percentile values in 2000 for α-activity concentration and ambient dose equivalent rate, as measured by the NMR stations equipped with aerosol monitors.

Station (No.)	α-Activity concentration Bq.m^{-3}			Ambient dose equivalent rate nSv.h^{-1}		
	5-p	Year average	95-p	5-p	Year average	95-p
Vredepeel (131)	0.6	2.7	6.6	67	70	74
Wijnandsrade (133)	0.7	3.9	10.4	82	85	89
Houtakker (230)	0.6	2.4	5.9	68	72	76
Huijbergen (235)	0.7	2.9	7.2	66	69	73
Braakman (318)	0.5	2.3	5.9	73	75	79
Vlaardingen (433)	0.4	1.8	4.6	77	80	84
De Zilk (444)	0.1	1.2	3.5	74	76	79
Wieringerwerf (538)	0.3	2.0	5.4	79	82	85
Bilthoven (627)	0.3	2.6	6.8	68	72	75
Biddinghuizen (631)	0.5	2.6	7.0	84	87	89
Eibergen (722)	0.6	2.8	7.0	68	71	75
Wageningen (724)	0.5	2.7	6.9	90	93	97
Witteveen (928)	0.4	2.5	6.5	65	70	74
Kollumerwaard (934)	0.2	2.2	6.4	81	83	87

Table A9: The yearly average results for ambient dose equivalent rate for the different NMR stations in 2000.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Den Burg	1001	69	Hooglanderveen	1046	81
Den Oever	1003	78	Harderwijk	1050	74
Julianadorp	1004	63	Wijk bij Duurstede	1056	82
Petten	1006	62	Rhenen	1061	75
Kolhorn	1007	81	Nieuwegein	1062	83
Egmond aan Zee	1009	65	Apeldoorn	1066	76
Heerhugowaard	1011	72	Heerenveen	1071	63
Haarlem-Noord	1014	73	Oosterwolde	1072	63
Nederhorst den Berg	1015	57	Bergum	1074	65
Enkhuizen	1018	74	Witmarsum (1)	1076	92
Oosthuizen	1019	71	Sneek	1077	71
Zaandam	1021	67	St. Jacobiparochie	1081	76
Gouda	1024	62	Holwerd	1082	80
Dordrecht	1027	67	Leeuwarden	1085	75
Zuid-Beijerland (1)	1028	78	Zwolle-Zuid (1)	1087	82
Pijnacker	1032	88	Ommen	1093	72
Rotterdam-Crooswijk	1033	80	Hardenberg	1095	74
Maasvlakte	1035	80	Assen	1097	63
Maassluis	1037	96	Rutten	1099	76
Ouddorp	1039	66	Lelystad	1103	75
Wekerom	1041	74	Urk	1105	75
Wageningen	1043	71	Eemshaven	1106	77

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Table A9: Continued.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Uithuizen	1107	78	Sevenum	1185	69
Wagenborgen	1109	71	Nederweert	1189	72
Winschoten	1110	69	Heythuisen	1190	79
Ter Apel	1111	66	Mariahoop	1191	69
Stadskanaal	1112	65	Stramproy	1192	64
Nieuweschans	1113	68	Arnhem-Oosterbeek	1193	78
Bellingwolde	1114	58	Leiden	1196	73
Groningen	1116	77	Hulst	1197	70
Leens	1117	77	Terneuzen	1199	75
Grijpskerk	1118	75	Vlissingen	1202	76
Meppel	1125	70	Halsteren	1204	63
Hoogeveen	1126	63	Oud-Gastel	1206	69
Steenwijksmoer	1129	66	Goes	1207	76
Nieuw Amsterdam	1130	69	Bruinisse	1209	85
Nw. Schoonebeek/ Weiteveen	1131	60	Burgh-Haamstede	1211	59
Emmen	1132	69	Vrouwenpolder	1212	64
Borne	1135	72	Middelburg	1215	75
Hengelo (Gld)	1136	72	Westkapelle (1)	1216	67
Enschede	1139	67	Noordwijk-Binnen	1217	85
Losser	1140	60	Stein	1219	81
Oldenzaal	1141	67	Maastricht	1220	95
Westerhaar	1142	65	Ravensbos	1221	86
Rijssen	1143	69	Vaals	1222	85
's Heerenberg	1144	86	Gulpen	1223	73
Dinxperlo	1145	80	Kerkrade	1224	85
Varsseveld[1]	1146	68	Hoensbroek	1225	85
Groenlo	1147	82	Wijchen	1226	78
Deventer	1148	76	Gennep	1228	72
Etten-Leur	1154	69	Elst (Gld)	1229	95
Raamsdonkveer	1159	80	Zevenaar (1)	1230	82
Ulvenhout	1160	64	Nijmegen	1231	67
Baarle-Nassau	1161	90	Amstelveen	1233	75
Uden	1162	70	Amsterdam Oost	1234	71
Mill	1163	60	Aalsmeer	1236	74
Oss	1167	70	Nispen	1237	60
Nuenen	1172	71	Groesbeek	1240	69
Bergeyk	1174	96	Tubbergen	1243	72
Waalre	1175	68	Haaksbergen	1244	63
Someren (dorp)	1176	69	Scheveningen	1247	84
Oisterwijk	1178	73	Zaltbommel	1251	73
Riel	1179	65	IJzendijke	1252	88
Oostelbeers	1180	82	Ritthem	1253	105
Hilvarenbeek	1181	66	Vlissingen-Haven	1254	73
Venray	1183	59	Nieuwdorp	1255	84
Nieuw-Bergen	1184	62	's Heerenhoek (1)	1256	76

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Table A9: Continued.

Station	No.	Ambient dose equivalent rate nSv.h^{-1}	Station	No.	Ambient dose equivalent rate nSv.h^{-1}
Driewegen	1257	84	Puiflijk [1]	1274	89
Arnemuiden	1258	75	Bergharen	1275	77
Heinkeszand	1259	84	Beuningen	1276	86
Baarland	1260	88	Denekamp	1278	60
Biervliet	1261	68	Winterswijk	1279	70
Slijkplaat	1262	77	Bilthoven	1280	60
Putte	1264	57	Maarheze/Gastel	1281	68
Nieuw Namen	1265	79	Rotterdam Waalhaven [2]	1034	-
Ochten	1266	95	Hellevoetssluis [2]	1038	-
Opheusden	1267	91	Den Bosch [2]	1157	-
Slijk Ewijk	1268	95	Reuver [2]	1188	-
Doorwerth	1269	65	Sluis [2]	1201	-
Randwijk	1270	109	Wemeldinge [2]	1214	-
Beneden Leeuwen	1272	73	Rilland [2]	1263	-
Appeltern	1273	78			

[1] For the calculation of the average over the year (with averages over the day) less days than a month were available for this station.
[2] Station was not operational in 2000.

Table A10: ^{3}H- and residual β-activity concentrations ($mBq \cdot L^{-1}$) in surface water in 2000 as measured by RIZA.

Date	^{3}H	Residual β
Location: Eijsden (Meuse)		
25-01-00	1900	14
22-02-00	1000	18
21-03-00	1800	10
18-04-00	1500	17
16-05-00	15000	17
13-06-00	8600	14
11-07-00	86300	34
08-08-00	31800	5
05-09-00	3400	13
03-10-00	9400	22
31-10-00	26100	36
28-11-00	1200	56
27-12-00	2500	24
Average	**14700**	**22**
Location: Lobith (Rhine)		
26-01-00	3600	34
23-02-00	2000	56
22-03-00	3200	26
19-04-00	4900	42
17-05-00	5200	26
14-06-00	4300	34
12-07-00	6800	36
09-08-00	6800	21
04-10-00	1600	59
01-11-00	4400	65
29-11-00	1800	51
27-12-00	3000	60
Average	**4000**	**43**
Location: Schaar van Ouden Doel (Scheldt)		
17-01-00		85
14-02-00	7800	48
14-03-00		59
10-04-00	7200	66
09-05-00		75
05-06-00	7000	56
04-07-00		73
03-08-00	6000	40
22-08-00		83
18-09-00	7400	60
16-10-00		85
16-11-00	2600	78
19-12-00		94
Average	**6300**	**69**

Table A11: ^{137}Cs-activity concentrations in suspended solids (Bq·kg^{-1}) in surface water in 2000 as measured by RIZA.

Date	^{137}Cs
Location: Eijsden (Meuse)	
05-01-00	17
11-01-00	18
18-01-00	17
25-01-00	35
01-02-00	37
08-02-00	19
15-02-00	19
22-02-00	16
29-02-00	16
02-03-00	13
07-03-00	16
14-03-00	20
21-03-00	16
28-03-00	16
04-04-00	17
11-04-00	18
18-04-00	13
25-04-00	13
09-05-00	15
16-05-00	17
23-05-00	15
30-05-00	12
06-06-00	15
13-06-00	8
20-06-00	9
27-06-00	12
04-07-00	15
11-07-00	8
18-07-00	16
25-07-00	15
01-08-00	20
08-08-00	16
15-08-00	15
22-08-00	17
29-08-00	16
04-09-00	17
12-09-00	15
19-09-00	21
26-09-00	15
03-10-00	18
10-10-00	17
17-10-00	15
24-10-00	17
31-10-00	16
07-11-00	18
14-11-00	16
21-11-00	17
28-11-00	23
05-12-00	17
12-12-00	42
19-12-00	20
27-12-00	28
Average	**17**

Date	^{137}Cs
Location: Ketelmeer-West	
03-02-00	29
30-03-00	26
25-05-00	25
20-07-00	27
14-09-00	29
09-11-00	26
Average	**27**
Location: Lobith (Rhine)	
26-01-00	26
23-02-00	23
22-03-00	26
20-04-00	21
17-05-00	17
14-06-00	22
09-08-00	20
07-09-00	20
04-10-00	26
01-11-00	23
29-11-00	28
27-12-00	21
Average	**23**
Location: Schaar van Ouden Doel (Scheldt)	
20-01-00	15
15-02-00	16
14-03-00	17
10-04-00	14
10-05-00	16
06-06-00	14
04-07-00	14
03-08-00	15
22-08-00	14
19-09-00	16
17-10-00	14
16-11-00	13
20-12-00	13
Average	**15**

Table A12: Gross α-, residual β-, ^{3}H- and ^{90}Sr-activity concentrations ($mBq \cdot L^{-1}$) in seawater in 2000 as measured by RIZA.

Date	Gross α	Residual β	^{3}H	^{90}Sr
Location:	**Coastal area**			
24-02-00	10	31	5000	
24-05-00	70	39	3800	
21-08-00	300	28	3400	
16-11-00	390	27	4200	
Average	**345** (1)	**31**	**4100**	
Location:	**Southern North Sea**			
22-02-00	< 1	44	2900	7
23-05-00	80	53	4000	< 1
16-08-00	290	53	4200	< 1
15-11-00	110	41	3600	< 1
Average	**200** (1)	**48**	**3700**	**< 2**
Location:	**Central North Sea**			
15-02-00	3	38	200	7
16-05-00	130	46	1500	2
15-08-00	270	58	1100	22
14-11-00	290	37	< 50	< 1
Average	**280** (1)	**45**	**700**	**8**
Location:	**Westerscheldt**			
17-01-00	< 1	52	6900	9
14-02-00	55	87	5200	< 1
14-03-00	93	74	6200	6
10-04-00	200	70	6200	< 1
24-05-00	170	58	6900	< 1
20-06-00	220	48	5100	< 1
24-07-00	260	37	4800	< 1
21-08-00	400	50	3200	1
18-09-00	170	140	5400	< 1
16-10-00	470	100	3500	2
15-11-00	200	170	3500	< 1
19-12-00	420	41	5100	< 1
Average	**320** (1)	**77**	**5200**	**< 2**
Location:	**Eems-Dollard**			
18-02-00	130	63	4500	
15-05-00	130	59	5100	
11-08-00	340	51	4500	
11-12-00	290	54	4900	
Average	**315** (1)	**57**	**4800**	
Location:	**Wadden Sea**			
17-02-00	32	53	6000	
15-05-00	150	30	4900	
10-08-00	310	37	4200	
22-11-00	270	71	6900	
Average	**290** (1)	**48**	**5500**	

(1) In the first half of 2000 the background of the measuring equipment was unstable and higher then 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.

Table A13: ^{137}Cs- and ^{210}Po-activity concentrations in suspended solids (Bq·kg^{-1}) in seawater in 2000 as measured by RIZA.

Date	**^{137}Cs**	**^{210}Po**
Location:	**Coastal area**	
24-02-00	7	76
15-05-00	n/a	n/a
14-08-00	n/a	n/a
30-11-00	9	85
Average	**8**	**81**
Location:	**Westerscheldt**	
16-02-00	9	70
08-05-00	8	61
30-08-00	6	56
20-11-00	8	81
Average	**8**	**67**
Location:	**Eems-Dollard**	
25-02-00	14	90
08-05-00	12	120
04-08-00	8	86
17-11-00	12	110
Average	**12**	**102**
Location:	**Wadden Sea**	
18-02-00	12	110
16-05-00	n/a	n/a
11-08-00	n/a	n/a
23-11-00	13	140
Average	**13**	**125**

n/a = not available

Appendix B Mailing list

1	-	10	Directeur Stoffen, Afvalstoffen en Straling
11	-	19	Regionaal Inspecteur VROM-Inspectie Regio Zuid-West
20			Hoofd afdeling Handhaving Algemeen van de VROM-Inspectie
21			plv. Directeur-Generaal Milieubeheer
22	-	36	Rijksinstituut voor Integraal Zoetwaterbeheer en Afvalwaterbehandeling
37	-	51	Rijksinstituut voor Kust en Zee
52			Dr. Ir. G. Kleter, Veterinair Inspecteur Algemene Directie Keuringsdienst van Waren
53	-	57	Algemene Directie Keuringsdienst van Waren
58			Directeur Keuringsdienst van Waren Zutphen
59			Hoofd Signalering Veterinaire Producten Keuringsdienst van Waren Zutphen
60	-	62	Keuringsdienst van Waren Zutphen
63			European commission, D.G. ENV.C.1 - Radiation Protection Unit
64			Depot van Nederlandse publicaties en Nederlandse bibliografie
65			ir. W. Cramer, VROM/DGM/BWL
66			Directie RIVM
67			Directeur Sector Milieurisico's en Externe Veiligheid
68			Hoofd van het Laboratorium voor Stralingsonderzoek
69			Hoofd van de afdeling Monitoring en Meetmethoden van het Laboratorium voor Stralingsonderzoek
70			Auteur
71			Mw. ir. J.F.M. Versteegh, RIVM/IEM
72			SBC/Communicatie
73			Bureau Rapportenregistratie
74			Bibliotheek RIVM
75			Bibliotheek LSO
76	-	86	Bureau Rapportenbeheer
87	-	110	Reserve exemplaren ten behoeve van het Laboratorium voor Stralingsonderzoek