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NATIONAL INSTITUTE OF PUBLIC HEALTH AND THE ENVIRONMENT (RIVM)
BILTHOVEN, THE NETHERLANDS

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**Monitoring of radiation in the atmosphere and
a food chain.**

Results in the Netherlands in 1995.

Laboratory of Radiation Research

September 1996

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PREFACE

This 1995 annual report presents the results of radiation measurements in the Netherlands by the Laboratory of Radiation Research (LSO) of the National Institute of Public Health and the Environment (RIVM). The measurements are part of the National Measurement Programme (NMP) of the Coordinating Committee for the Monitoring of Radioactive and Xenobiotic Substances (CCRX) in the Netherlands. This report also presents the data of the National Radioactivity Monitoring Network (LMR) in 1995. This data is not included in the NMP.

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ABSTRACT

This 1995 annual report presents the results of radiation measurements in the Netherlands by the Laboratory of Radiation Research (LSO) of the National Institute of Public Health and the Environment (RIVM). The measurements are part of the National Measurement Programme (NMP) of the Coordinating Committee for the Monitoring of Radioactive and Xenobiotic Substances (CCRX) in the Netherlands. The NMP is considered essential for an adequate assessment of radioactivity in the biosphere. The programme of RIVM/LSO includes samples of airdust and deposition taken at the RIVM premises in Bilthoven. Samples of grass and milk were taken from the surroundings of nuclear installations in the Netherlands and on Dutch territory in the vicinity of such installations situated abroad. An overall country milk sample from four milk factories in the Netherlands was also analysed. This report also presents the data of the National Radioactivity Monitoring Network (LMR) in 1995. This data is not included in the NMP.

In 1995, the yearly average gross α - and gross β -activity concentration of airdust was 0.077 ± 0.001 (SD 0.04) and 0.471 ± 0.002 (SD 0.25) $\text{mBq}\cdot\text{m}^{-3}$, where SD illustrates the variation in weekly and monthly averages during the year. These values are comparable to those of 1992, 1993 and 1994. The γ -spectrometric analysis was performed on airdust sampled with a high volume sampler. For ^7Be , ^{137}Cs and ^{210}Pb the yearly average activity concentrations were 4100 ± 50 (SD 1200), 1.25 ± 0.03 (SD 0.8) and 470 ± 7 (SD 300) $\mu\text{Bq}\cdot\text{m}^{-3}$. The yearly total gross α - and gross β -activity of the deposition in Bilthoven was 39 ± 4 and 95 ± 8 $\text{Bq}\cdot\text{m}^{-2}$, and the deposition of ^3H was 970 ± 40 $\text{Bq}\cdot\text{m}^{-2}$. The total activity of ^{137}Cs in deposition was 0.28 ± 0.02 $\text{Bq}\cdot\text{m}^{-2}$ and of ^{210}Pb 96.1 ± 1.6 $\text{Bq}\cdot\text{m}^{-2}$. These activities are comparable with those of previous years. The ^{210}Po -analysis results by means of α -spectroscopy are rejected.

The yearly average concentrations of ^{137}Cs and ^{90}Sr in consumer milk from a nationwide sample mix was 0.07 ± 0.02 and 0.035 ± 0.001 $\text{Bq}\cdot\text{L}^{-1}$, respectively, which are about equal to that of the previous years.

The aerosol monitors of the LMR measure the gross α -activity including radon progeny. For the gross α -activity concentration values in the range of 0.2 - 14.5 $\text{Bq}\cdot\text{m}^{-3}$ were found (5-percentile - 95-percentile values), with an average value across the country of 3.7 $\text{Bq}\cdot\text{m}^{-3}$. This value is considerably higher than the values found in previous years, which can be explained by the extreme weather conditions in the summer and autumn of 1995. No 'man-made' β -activity was measured with the LMR monitors. The dose-equivalent rate measured with the monitors of the LMR macro-stations was in the range of 65.5 - 97 $\text{nSv}\cdot\text{h}^{-1}$ (5-percentile - 95 percentile values). The average value of 80.2 $\text{nSv}\cdot\text{h}^{-1}$ was in good agreement with the averages of the previous years.

SAMENVATTING

In dit jaarverslag over 1995 zijn de resultaten weergegeven van de metingen van radioactiviteit in milieumonsters uitgevoerd door het Laboratorium voor Stralingsonderzoek (LSO) van het Rijksinstituut voor Volksgezondheid en Milieu.

De metingen maken deel uit van het Nationaal Meetprogramma (NMP) in Nederland. Het betreft metingen die geacht worden essentieel te zijn voor een doelmatige controle van radioactieve besmetting in het milieu. De analyses worden uitgevoerd in monsters luchtstof, depositie, gras en melk. Monsters van gras en melk zijn genomen in de omgeving van Nederlandse nucleaire installaties en op Nederlands grondgebied in de omgeving van nucleaire installaties in het buitenland. Ook zijn melkmonsters van vier melkfabrieken, verspreid over het land, geanalyseerd. In dit rapport worden tevens de resultaten van het Landelijk Meetnet voor Radioactiviteit (LMR) besproken. Deze metingen zijn geen onderdeel van het NMP.

In 1995 is het jaargemiddelde van de totale α - en β -activiteitsconcentratie in luchtstof $0,077 \pm 0,001$ (SD 0,04) respectievelijk $0,471 \pm 0,002$ (SD 0,25) $\text{mBq}\cdot\text{m}^{-3}$, waarbij SD de variatie in wekelijkse en maandelijkse gemiddelden gedurende het jaar representeert.

Deze waarden zijn vergelijkbaar met die van 1992, 1993 en 1994. In 1995 zijn γ -spectrometrische analyses uitgevoerd aan luchtstof bemonsterd met een 'high volume sampler': jaargemiddelde activiteitsconcentraties van ^7Be , ^{137}Cs en ^{210}Pb zijn gevonden van respectievelijk 4100 ± 50 (SD 1200), $1,25 \pm 0,03$ (SD 0,8) en 470 ± 7 (SD 300) $\mu\text{Bq}\cdot\text{m}^{-3}$. De totale α - en β -activiteit in depositie in Bilthoven over 1995 bedragen 39 ± 4 en 95 ± 8 $\text{Bq}\cdot\text{m}^{-2}$. De totale activiteit van ^3H in depositie is 970 ± 40 $\text{Bq}\cdot\text{m}^{-2}$. De totale depositie van ^{137}Cs bedraagt $0,28 \pm 0,02$ $\text{Bq}\cdot\text{m}^{-2}$ en van ^{210}Pb $96,1 \pm 1,6$ $\text{Bq}\cdot\text{m}^{-2}$. Al de gemeten waarden zijn vergelijkbaar met de waarden die in de voorafgaande jaren zijn gemeten. De ^{210}Po -resultaten bepaald met α -spectroscopie zijn afgekeurd.

De jaargemiddelde activiteitsconcentraties van ^{137}Cs en ^{90}Sr in melk van een landelijk mengmonster zijn respectievelijk $0,07 \pm 0,02$ en $0,035 \pm 0,001$ $\text{Bq}\cdot\text{L}^{-1}$, hetgeen vrijwel hetzelfde is als vorig jaar.

De metingen met de aerosolmonitoren van het LMR, waarmee ook de activiteit van radon-dochters wordt gemeten, leveren zowel een waarde voor de totaal α -activiteitsconcentratie als ook voor de kunstmatige β -activiteitsconcentratie op. Voor totaal α -activiteitsconcentraties worden met de monitoren van het LMR waarden in een bereik van $0,2 - 14,5$ $\text{Bq}\cdot\text{m}^{-3}$ (5-percentiel - 95-percentiel waarden) gemeten, met een over het land en jaar gemiddelde waarde van $3,7$ $\text{Bq}\cdot\text{m}^{-3}$. Deze waarde is aanzienlijk hoger dan de waarden die in vorige jaren zijn gevonden en is het gevolg van de extreme weeromstandigheden in de zomer en het najaar van 1995. Er is geen kunstmatig β -activiteitsconcentratie in lucht gemeten met de LMR-monitoren. Het γ -stralingsniveau gemeten met de monitoren van de macro-stations van het LMR ligt in het bereik van $65,5 - 97$ $\text{nSv}\cdot\text{h}^{-1}$ (5-percentiel - 95-percentiel waarden). Het landelijk gemiddelde van $80,2$ $\text{nSv}\cdot\text{h}^{-1}$ komt goed overeen met de waarden van voorgaande jaren.

1 INTRODUCTION

Radioactive nuclides of natural origin, such as ^{40}K and daughters from the uranium and thorium series, are found in the environment. Human activities, such as factories processing ores, emit natural radionuclides into the environment and consequently may lead to enhanced levels. The presence of man-made radionuclides occur in the environment through, for instance, fallout from experiments with nuclear weapons or discharges from nuclear installations.

Under the authority of the State Health Inspectorate, the National Institute of Public Health and the Environment (RIVM) regularly monitors the concentration of a number of radionuclides in airdust and deposition. The results are part of the National Measurement Programme (NMP) of the Coordinating Committee for the Monitoring of Radioactive and Xenobiotic Substances (CCRX). The Veterinary Public Health Inspectorate (VHI) samples grass and milk to monitor the surroundings of Dutch nuclear installations and Dutch territory near foreign nuclear installations. Milk from four major dairies is also sampled by the VHI. All these samples are analysed by RIVM. The results are also part of the NMP-CCRX.

Table 2.1 gives an overview of the 1995 monitoring programme. Sampling, sample preparation and analysis methods are discussed in Chapter 2. In Chapter 3 results are given for the atmosphere compartment, consisting of both airdust and deposition. For grass and milk, both part of a food chain, the results are given in Chapter 4.

In the Netherlands RIVM takes part in the National Plan for Nuclear Emergency Planning and Response (NPK, [1]). One of the roles of RIVM in the NPK is the management of the National Radioactivity Monitoring Network (LMR), a fully automated early warning system operating on a 24-hour-a-day basis [2-6]. Chapter 5 of this report surveys the measurements of the LMR over 1995.

This report gives a data-presentation only. In the main report, the results will, in general, be presented visually with a minimum amount of text. More detailed tables will be shown in the Appendix and are referred to by means of the letter 'A' and the corresponding Chapter number, e.g. *Table A3.1* refers to the first Table in the Appendix of Chapter 3.

2 MONITORING PROGRAMME AND METHODS

Sampling, sample treatment and analytical methods used in the monitoring programme of 1995 (*Table 2.1*) will be described. Whenever possible the reader will be referred to Standard Operating Procedures (SOPs) for the detailed description of sampling, sample treatment and analytical methods (in Dutch).

2.1 ATMOSPHERE - AIRDUST AND DEPOSITION

Two types of samples are analysed: airdust and deposition. In 1995 the sampling of the airdust and deposition was done on the RIVM premises in Bilthoven. Samples that contain both wet and dry deposition are collected weekly (γ -emitters), monthly (γ -emitters, ^3H , gross- α , gross- β) or quarterly (^{210}Pb and ^{210}Po).

2.1.1 α - and β -activity in airdust

Sampling

On the RIVM premises in Bilthoven a High Volume Sampler (HVS) samples airdust continuously by drawing air through four filters placed two meters above ground level [7]. These filters have an efficiency of more than 99.97% for particles with a diameter larger than $0.3\ \mu\text{m}$. A mass-flow sensor, which gives a normalized flow independent of the temperature, monitors the flow. The flow through the filters is about $300\ \text{m}^3\cdot\text{h}^{-1}$, resulting in a sample volume of about $50,000\ \text{m}^3$ in seven days. After a sampling period of a week, the filters are replaced by clean filters and transferred to the laboratory.

Sample preparation

After arrival in the laboratory, the filters are dried in an oven at $25\ ^\circ\text{C}$ for 24 hours. From one airdust filter two samples with a diameter of 4.5 cm are taken, which is about 2% of the total surface area of the filters. Thus, the sampling volume of these samples is about $1000\ \text{m}^3$. The two samples are measured separately. The remaining filter surface area is being used for measurement of the γ -activity.

Analysis

Radiation measurements are carried out by means of a gas-flow proportional counter with a low background (Berthold LB 770-2). Directly after drying, LSO puts the filters in the counter for six days during which time the samples are analysed a number of times.

For further details see:

- SOP LSO/MMM/068 (Procedure for the determination of gross α - and gross β -activity in filters for RIVM samples of airdust).

Table 2.1 Monitoring programme in 1995 for the determination of radioactive nuclides in airdust, deposition, grass and milk samples.

Measurement	Location	Sample period	Sample volume	Analysis frequency	Analysis
Airdust	Bilthoven	week	$\pm 50,000 \text{ m}^3$	1 x/week	γ -em
	Bilthoven	week	$\pm 1000 \text{ m}^3$	1 x/week	gross α , gross β
Deposition	Bilthoven	week	variable	1 x/week	γ -em
	Bilthoven	month	variable	1 x/month	gross α , gross β , ^3H
	Bilthoven	quarter	variable	1x/quarter	$^{210}\text{Pb}/^{210}\text{Po}$
Milk	National sample		mix	1 x/quarter	Sr, γ -em
Milk (Nuclear instal.)	Borssele	3 x/year	3 x 5 L	mix 3 x/year	Sr, γ -em
	Dodewaard	3 x/year	4 x 5 L	mix 3 x/year	Sr, γ -em
	Petten	3 x/year	3 x 5 L	mix 3 x/year	Sr, γ -em
	Doel	3 x/year	2 x 5 L	mix 3 x/year	Sr, γ -em
	Mol	3 x/year	1 x 10 L	3 x/year	Sr, γ -em
	Jülich	3 x/year	1 x 10 L	3 x/year	Sr, γ -em
	Lingen	3 x/year	1 x 10 L	3 x/year	Sr, γ -em
	(Emsland)				
Grass (Nuclear instal.)	Borssele	2 x/year	3 x 1-2 kg	mix 2 x/year	γ -em
	Dodewaard	2 x/year	4 x 1-2 kg	mix 2 x/year	γ -em
	Petten	2 x/year	3 x 1-2 kg	mix 2 x/year	γ -em
	Doel	2 x/year	2 x 1-2 kg	mix 2 x/year	γ -em
	Mol	2 x/year	1 x 1-2 kg	2 x/year	γ -em
	Jülich	2 x/year	1 x 1-2 kg	2 x/year	γ -em
	Lingen	2 x/year	1 x 1-2 kg	2 x/year	γ -em
	(Emsland)				

γ -em : γ -spectroscopic analysis in which the contents of specific γ -emitting nuclides are determined,
 Sr : determination of both ^{89}Sr and ^{90}Sr ,

2.1.2 γ -activity in air-dust

Sampling

Airdust is continuously sampled using the HVS equipment as described in 2.1.1.

Sample preparation

After arrival in the laboratory, the filters are dried in an oven at 25 °C for 24 hours. The four filters from one sampling period are folded to fit in a counting box. The counting box with filters is placed on top of a high purity Ge semiconducting detector (coaxial-type) coupled to a Pulse Height Analyser, for screening on the presence of relatively short-lived or volatile nuclides, such as ^{131}I (iodine particulate only). To reach a detection limit of the order of $1 \mu\text{Bq.m}^{-3}$ a measurement on a well-type detector is required. For this measurement a reduction in volume of the sample material is obtained by chemical destruction of the four filters in HF (hydrogen fluoride). The remaining slurry is evaporated to dryness, dried at 400°C for one night and the residue is pressed into a small polyethene cylinder (diameter 12 mm, height 54 mm). The cylinder with the residue is put inside a well-type high purity Ge detector. The well of the detector has an internal diameter of 14.5 mm and a depth of 40 mm. The detector is coupled to a Pulse Height Analyser.

Analysis

For the measurement on the coaxial detector, a spectrum from 80 keV to 2 MeV over 8192 channels is recorded during 100,000 seconds using the emulation programme MAESTRO. For the well-type detector a spectrum is recorded from 10 keV to 2 MeV over about 8000 channels during 200,000 seconds. From these spectra the concentration of a number of nuclides is calculated using OMNIGAM software [7].

Parameters which influence the detection limit are the measuring time of the spectrum, the efficiency of the detector, the sample geometry and the total sample volume.

For further details see:

- SOP LSO/A/083 (Instrumentation for sampling of airdust with the HVS).
- SOP LSO/MMM/046 (Procedure for the determination of γ -emitters in airdust, sampled with the HVS).

2.1.3 α - and β -activity in deposition

Sampling

The deposition is measured with a standard rain gauge with an effective area of 0.02 m². Four separate collection flasks are used for the collection of deposition:

- 1: gross α -, gross β -activity and specific γ -nuclides;
- 2: ^3H ;
- 3: spare flask (for incidental Sr analyses) and
- 4: ^{210}Pb and ^{210}Po .

For further details on sampling and sample treatment:

- SOP LSO/MMM/007 (Procedure for sampling of deposition from the $^{210}\text{Pb}/^{210}\text{Po}$ container and the nuclide container),
- SOP LSO/MMM/008 (Procedure for sampling of deposition from the rainwater container (1 m^2), the rain gauge and the ^3H container).

Sample preparation

The analysis of gross α - and gross β -activity in deposition is carried out in a sulphate residue which remains after evaporation of the sample acidified with sulphuric acid.

Analysis

Gross α - and gross β -activity is measured using 100 mg of the residue between 28 and 31 days after the sampling period (sample mass of $20\text{ mg}\cdot\text{cm}^{-2}$).

For further details see:

- SOP LSO/MMM/029 (Procedure for the determination of gross α - and gross β - activity in deposition).

2.1.4 γ -activity in deposition

The *sampling* and *sample preparation* is carried out as described in 2.1.3 for α - and β -activity.

Analysis

The sulphate residue is used for γ -spectroscopy with a High Purity Ge well-type detector.

See for further details:

- SOP LSO/MMM/033 (Procedure for the determination of the activity of specific γ -emitting nuclides in deposition).

2.1.5 ^3H in deposition

Sampling as is described in section 2.1.3.

Sample preparation

The deposition samples are distilled and electrolytically concentrated from 100 ml to about 20 ml in a glass cell. The enriched liquid is neutralized and distilled.

Analysis

Ten (10.0) ml of the distillate are added to 10 ml scintillation liquid (Picofluor LLT, Packard). The homogenized mixture will be analysed at least 10 x 50 minutes.

For further details see: SOP LSO/MMM/035 (Procedure for the radiochemical determination of tritium in wet and dry deposition).

2.1.6 ^{210}Pb and ^{210}Po in deposition

Sampling as is described in section 2.1.3.

Sample preparation

The sample preparation is a two-step process:

- i) The sample, which is collected quarterly, is acidified and evaporated to dryness after addition of a known quantity of ^{208}Po as a tracer. The residue is dissolved in hydrochloric acid. From this solution ^{210}Po and ^{208}Po are precipitated selectively on to a silver disk; ^{210}Pb remains in solution.
- ii) The ^{210}Pb content of the solution is determined indirectly by allowing the ingrowth of ^{210}Po from ^{210}Pb . After a waiting period of some months the activity of the newly formed ^{210}Po is determined, and the original ^{210}Pb content of the sample is calculated.

Analysis

The determination of ^{210}Po in sample (i) and (ii) is carried out by α -spectroscopy.

See for further details:

- SOP LSO/MMM/001 (Procedure for the determination of polonium (^{210}Po) and lead (^{210}Pb) in wet and dry deposition).

2.2 FOOD CHAIN - GRASS AND MILK

2.2.1 Grass and milk from surroundings of nuclear installations

Grass and milk samples are taken from one or more sectors in the surroundings of nuclear installations in order to monitor the concentration of radionuclides in the environment of these installations (*Table 2.1*). The number of sectors depends on the geographical situation. At Dodewaard four, at Borssele and Petten three and at Doel two sectors are sampled; at Mol, Jülich and Lingen (Emsland) just one sector is sampled [8].

The milk samples are analysed by γ -spectroscopy in which the ^{134}Cs , ^{137}Cs and ^{131}I contents are determined. The samples are also analysed for their ^{89}Sr and ^{90}Sr content. For sample treatment see Section 2.2.3. Milk samples are not pretreated; if direct analysis is impossible, the milk samples are stored at -18°C .

For all sectors grass samples are analysed by γ -spectroscopy. The gross- β activity was not determined in 1995.

2.2.2 Overall country milk sample

Five-litre samples are taken from four milk factories which are situated as follows: De Ommelanden at Groningen (north); Coberco at Deventer (east); Campina at Bergeijk (south); De Graafstroom at Bleskensgraaf (west). The milk production of the factory at Groningen ended during 1995, therefore in the last quarter the northern milk sample is taken from Frico at Groningen. A mixture of these samples is supposed to be representative for milk in the Netherlands. The sampling is carried out at the beginning of the first week of every month. Analyses were performed on samples which were prepared by monthly mixing of the four factory samples into a one-month sample and mixing these monthly samples quarterly.

2.2.3 γ -spectroscopy in milk and grass

Sampling

Milk is sampled three times during the grazing season, May, July and September. The samples at Dodewaard, Petten and Lingen (Emsland) are taken at the beginning of the first week and the other samples at the beginning of the second week. This is due to the limited amount of time in which all the samples have to be analysed. At Dodewaard, Borssele, Petten and Doel the samples are a mixture of the sector samples.

Grass is sampled at the beginning and end of the grazing season, viz. the beginning of May and the end of September. A grass sample of about 1 to 2 kg is taken from each sector. Sampling is performed preferably on the same spot (pasture or flat banks, but not in the vicinity of a dike), where the grass should have not been recently mown or fertilized.

See *Table 2.1* for sample locations and sampling frequency.

Sample preparation

Milk samples (5 L) are made alkaline and subsequently incinerated at about 400 to 450 °C.

All grass samples are dried for at least 24 h at 150 °C. The calculated results are based on the dried-grass weight. Dried grass, which varies in weight from 0.1 to 0.9 kg, is also incinerated.

See the following SOPs for further information:

- LSO/MMM/016 (Procedure for the incineration of grass),
- LSO/MMM/021 (Procedure for the composition of mixed samples of milk and the incineration of the mixed samples).

Analysis

The ash samples are analysed by γ -spectroscopy with a High Purity Ge semi-conductor detector over an energy range of 80 keV to 2 MeV over 8192 channels (analysis time 60,000 s). The activities of the natural γ -nuclides ^7Be and ^{40}K and the man-made nuclides ^{131}I , ^{134}Cs and ^{137}Cs are determined.

See the following SOPs for further information:

- LSO/MMM/020 (Analytical Procedure for the determination of the activity of γ -nuclides in incinerated grass samples),
- LSO/MMM/023 (Analytical Procedure for the determination of the activity of γ -nuclides in incinerated milk samples).

2.2.4 ^{89}Sr and ^{90}Sr in milk

Sampling

See *Table 2.1* for sample locations and sampling frequency.

Sample preparation

For the determination of ^{89}Sr and ^{90}Sr in milk the sample is incinerated and dissolved in nitric acid.

Analysis

The radiochemical analysis consists in principle of a precipitation of calcium and strontium as an oxalate and a calcium/strontium separation in 70% nitric acid. The ^{90}Sr content is determined indirectly via ^{90}Y , which has grown into the sample and is separated as an oxalate.

See for further details:

- SOP LSO/MMM/006 (Analytical procedure for the radiochemical determination of strontium (^{89}Sr , ^{90}Sr) in milk).

2.3 NATIONAL RADIOACTIVITY MONITORING NETWORK (LMR)

Sampling

Fifty-eight stations, evenly distributed over the country (*Figure 2.1*), are equipped with a proportional γ -radiation counter to monitor external radiation ($\text{nSv}\cdot\text{h}^{-1}$); 14 of these stations, the so-called 'macro-stations,' are equipped with an aerosol monitor with which the aerosolbound α - and 'man-made' β -activity concentration in air ($\text{Bq}\cdot\text{m}^{-3}$) is determined.

The natural background γ -radiation, measured by the proportional γ -counter, is composed of contributions due to terrestrial and cosmic radiation, and due to the decay of airborne and deposited radionuclides (for instance, ^{214}Pb and ^{214}Bi , daughters of the natural occurring radioactive ^{222}Rn -gas). The natural background gross α - and β -activity concentration, as measured by the aerosol monitor, is primarily due to the decay of short-lived daughters of ^{222}Rn gas. The man-made β -activity concentration is calculated from the measured gross α -activity and gross β -activity concentration. Due to uncertainties in this calculation the 'man-made' β -activity may have a negative or positive value, instead of being zero.

The LMR network is integrated with another radiation monitoring network into the NMR, which is officially operational since December 1995. This network contains 280 γ -monitors and the 14 LMR stations equipped with both an aerosol monitor and a proportional γ -radiation counter. Consequently, the results of the LMR presented in this report will be the last one in this format.

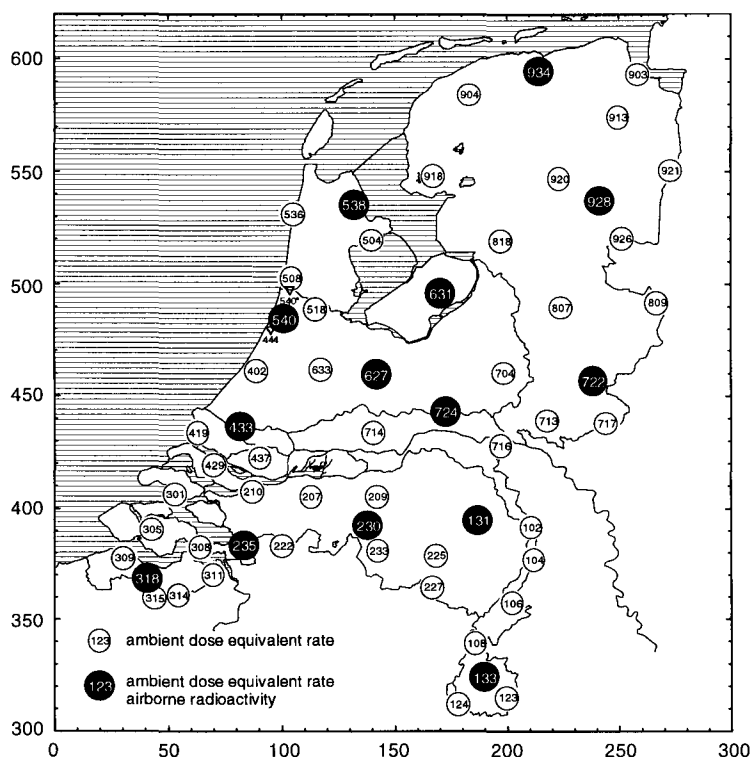


Figure 2.1 Overview of the locations of the LMR-stations

Analysis

The data from the LMR monitors consists of values measured every ten minutes. To present the data, a reduction of this set of ten-minute values ('raw data') is applied by determining the arithmetic mean over periods of an hour, a day, a week, a month and a year. The hourly averages are calculated from ten-minute values, daily averages from hourly averages and weekly, monthly and yearly averages from daily averages. Restrictions are placed on the 'data range'. For the construction of the hourly, and weekly averages, as an additional validation criterium, at least 80% of the data in the period has to be valid. A description of the procedure of data validation is given in the references [5], [6] and [25].

Information on technical aspects regarding monitors, data acquisition and communication, management of the network is given in the first and second progress reports of the LMR [2,3]. The results of the LMR in the period 1990-1994 are presented in the references [5], [6], [9], [10] and [24]. For the last three years of the operational LMR (1993-1995) a final data report is in preparation [25].

2.4 THE PRESENTATION OF DATA

2.4.1 Correction for radioactive decay

The activities of specific nuclides, in general, are corrected for radioactive decay. The measured activities in the sample are divided by a decay factor containing the time from the middle of the sampling period to the time of analysis, and the half-life of the nuclide. However, when the activity of a nuclide is equal to or lower than the detection limit, the activity is calculated for the day of analysis (instead of the middle of the sampling period). In cases where the nuclides are unknown, as with gross α and gross β , no correction for radioactive decay is made.

2.4.2 Calculation of sums, averages and errors

In the calculation of weekly, monthly and yearly averages or sums the original results before rounding off are used. If a measured value is below the detection limit, this detection limit is not used in the calculation of averages and sums. However, in calculating the average values for ^{90}Sr and ^{137}Cs in grass and milk, reported in Table 4.1, the detection limits were used.

The error given in the analyses is in all cases the 1σ interval consisting of a counting error and an experimental error as described in SOP LSO/KD/0259, which is based on NEN 3114 [27] and NEN 1047 [28]. Depending on the analysis calibration errors, errors in the nuclide libraries and cascade errors are taken into account too.

In yearly sums the errors reported are the square root of the sum of the squared 52 weekly or 12 monthly errors (s_i):

$$\sqrt{\sum s_i^2}$$

In yearly averages the errors reported are the square root of the sum of the squared 52 weekly or 12 monthly errors (s_i) divided by N , being the number of weeks or months, respectively:

$$\frac{1}{N} \sqrt{\sum s_i^2}$$

Moreover for yearly averages, the standard deviations, SD, in the 52 weekly or 12 monthly data are calculated according to:

$$SD = \sqrt{\sum \frac{(x_i - \bar{x})^2}{(N-1)}}$$

where x_i is the individual measurement, $\bar{x}$ is the yearly average and N is the number of measurements. In the presentation of averages, SD is indicated between parentheses. Moreover, SD is presented in the last rows of the tables in the appendix. The standard deviation (SD) illustrates the variation in weekly and monthly averages during the year.

For the yearly averages of ^{90}Sr and ^{137}Cs in milk and grass, reported in *Table 4.1*, total errors are calculated by the square root of the sum of the squared individual errors divided by the number of observations (N).

2.4.3 Calculation of detection limits

For the detection of peaks in the γ -spectra the standard criterion of the analysis program is used (so called MDA 1 EG & G ORTEC; see reference manual OMNIGAM [11]). In all other analyses the detection limit is a simple approximation of 3 times the standard deviation by:

$$D_L = 3\sqrt{\left(\frac{B}{T}\right)}$$

where D_L is the detection limit (in counts per minute), B is the background (in counts per minute) and T is the detection time (in minutes). In general, the time for recording the background spectrum is taken the same as that for recording the real spectrum. The resulting detection limit depends on a number of parameters, for instance counting time and sample density. If a measured value is below the detection limit this is indicated in the tables by '<' followed by the detection limit.

2.4.4 Interlaboratory studies

The Laboratory of Radiation Research of the RIVM takes part in several intercomparison studies in order to compare the analytical results with those from other laboratories. These studies are published in separate reports [e.g. 12].

3 RESULTS IN THE ATMOSPHERE - airdust and deposition.

3.1 AIRDUST

The weekly averages of gross α - and β -activity concentrations in airdust are given in *Figure 3.1* and *Table A3.1*. The period between sampling and analysis is five to ten days, which is long compared to the decay time of the short lived decay products of ^{222}Rn and ^{220}Rn . Therefore, these naturally occurring decay-products do not contribute to the α - and β -activity concentrations. The yearly averages of the gross α - and β -activity concentrations are of the same order as in 1992, 1993 and 1994, but are significantly higher than those of the period 1987 to 1991 as is shown in *Figure 3.2* [6,13-17]. This enhancement is due to a change in the sample preparation procedure [9].

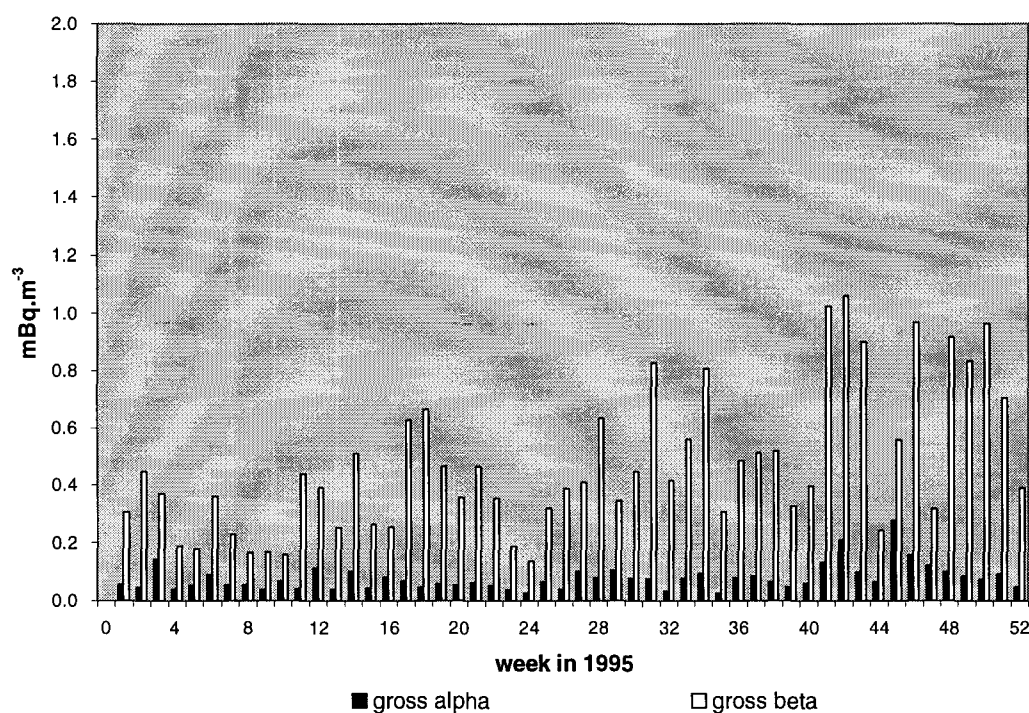


Figure 3.1 Weekly averages in 1995 of long-lived gross α - and gross β -activity concentrations in airdust sampled at the RIVM premises in Bilthoven (The Netherlands).

The frequency distributions of gross α -activity and gross β -activity concentrations in airdust are given in *Figures 3.3 and 3.4*, respectively. The variation of the gross β -activity concentration in 1995 corresponds well to the variation of the ^{210}Pb concentration in airdust as found using the HVS-equipment (see *Table A3.2* and *Figures 3.1 and 3.7*). In *Table A3.3* the detection limits for the nuclides considered in the analysis of the HVS-samples are given [7].

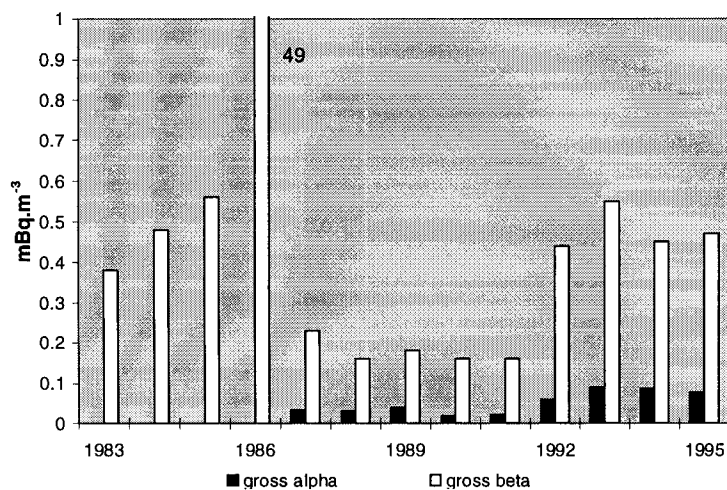


Figure 3.2 Yearly averages of long-lived gross β -activity concentration in air dust for 1983 to 1995. For the long-lived gross α -activity data are only available from 1987. For the long-lived gross β -activity a different method was used since 1987 [13]. The 49 mBq·m⁻³ level in 1986 was caused by the accident at the Chernobyl nuclear power plant.

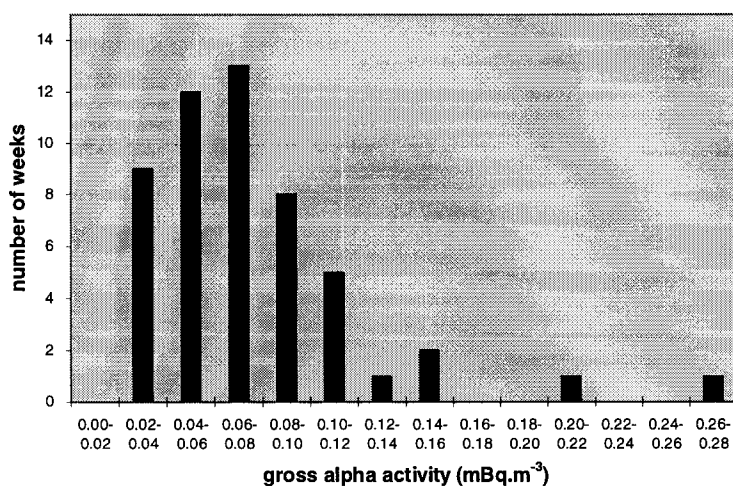


Figure 3.3 Frequency distribution of long-lived gross α -activity concentration in air dust collected weekly at RIVM, Bilthoven (The Netherlands) in 1995. Mean value: 0.077 ± 0.001 (SD 0.04) mBq·m⁻³.

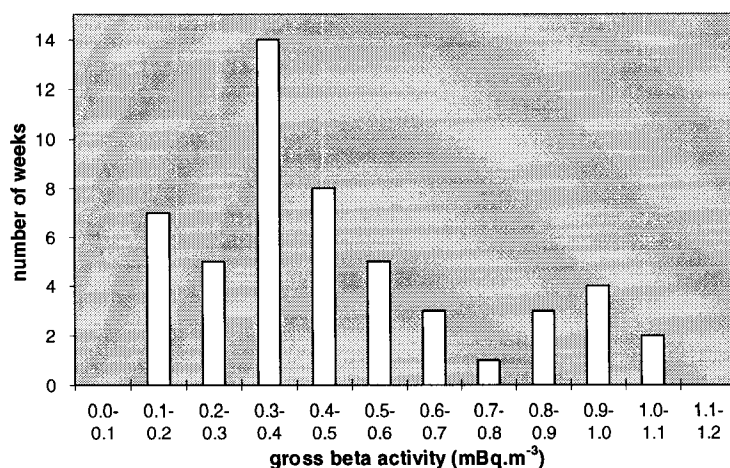


Figure 3.4 Frequency distribution of long-lived gross β -activity concentration in air dust collected weekly at RIVM, Bilthoven (The Netherlands) in 1995. Mean value: 0.471 ± 0.002 (SD 0.25) mBq·m⁻³.

The nuclides ^7Be , ^{137}Cs and ^{210}Pb were found with values above the detection limit (Figure 3.5, 3.6 and 3.7). However, for ^{137}Cs no results above the detection limit were obtained in week 4 and 23. The nuclides ^{22}Na , ^{40}K were frequently found with values above the detection limit. Occasionally, ^{95}Nb , ^{125}Sb and ^{202}Tl were found: about $1 \mu\text{Bq}\cdot\text{m}^{-3}$ for ^{95}Nb (week 28), ^{125}Sb (week 23 and 40) and 2 to $4 \mu\text{Bq}\cdot\text{m}^{-3}$ for ^{202}Tl (weeks 24 and 39). The values found in 1995 were comparable with the values found in the period 1991-1994 [6,9,10,24]. The weekly averages did not reach the maximum values of 1993 and were in the same order of magnitude as the values of 1994. Compared with 1994, the yearly averages were higher for ^7Be and ^{210}Pb and lower for ^{40}K . For ^{137}Cs the average was nearly equal to the average of 1994.

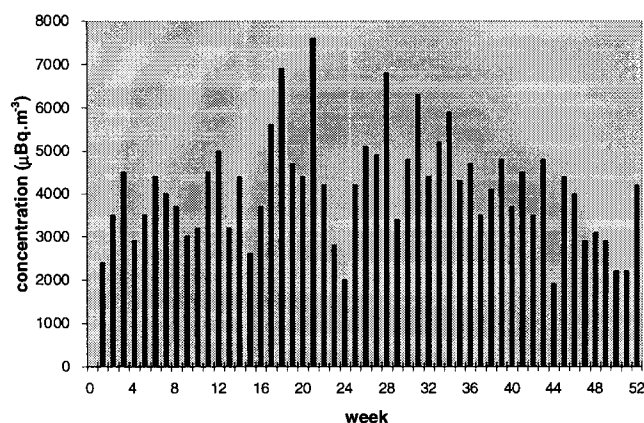


Figure 3.5 Activity concentration of ^7Be in air in Bilthoven in 1995.

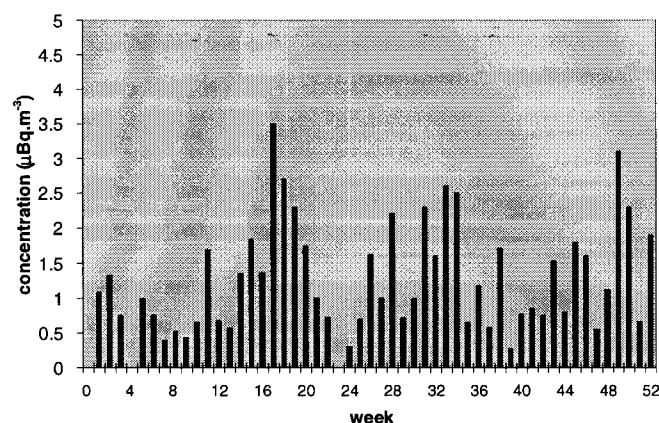


Figure 3.6 Activity concentration of ^{137}Cs in air in Bilthoven in 1995. In week 4 and 23 no validated results above the detection limit were obtained.

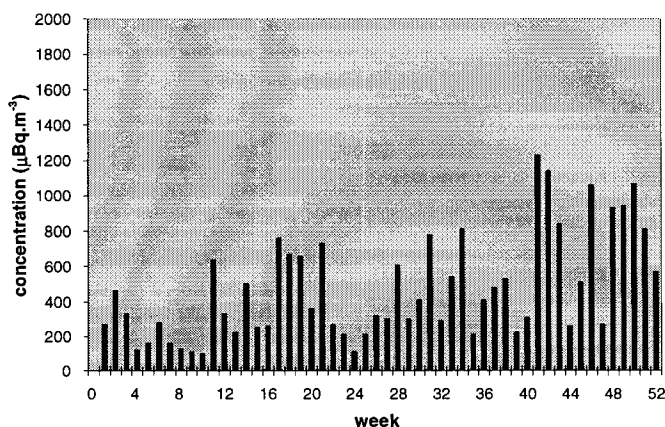


Figure 3.7 Activity concentration of ^{210}Pb in air in Bilthoven in 1995.

3.2 DEPOSITION

The monthly values of deposited long-lived gross α - and gross β -activity are given in *Figure 3.8* and in *Table A3.4*. The yearly total depositions were 39 ± 4 and 95 ± 8 Bq·m⁻², respectively. These values are not significantly different from those since 1987, as is illustrated in *Figure 3.9* and *Table 3.1*.

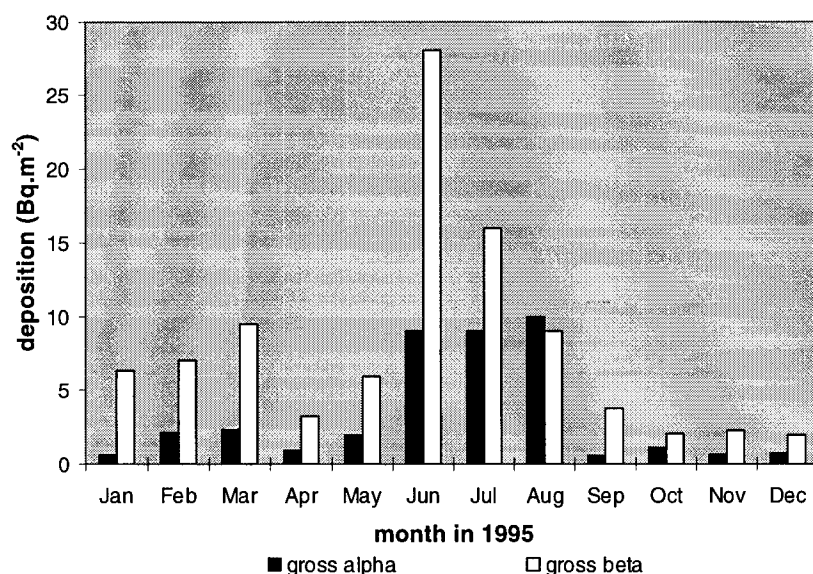


Figure 3.8 Monthly data of long-lived gross α - and gross β -activity in deposition in 1995.

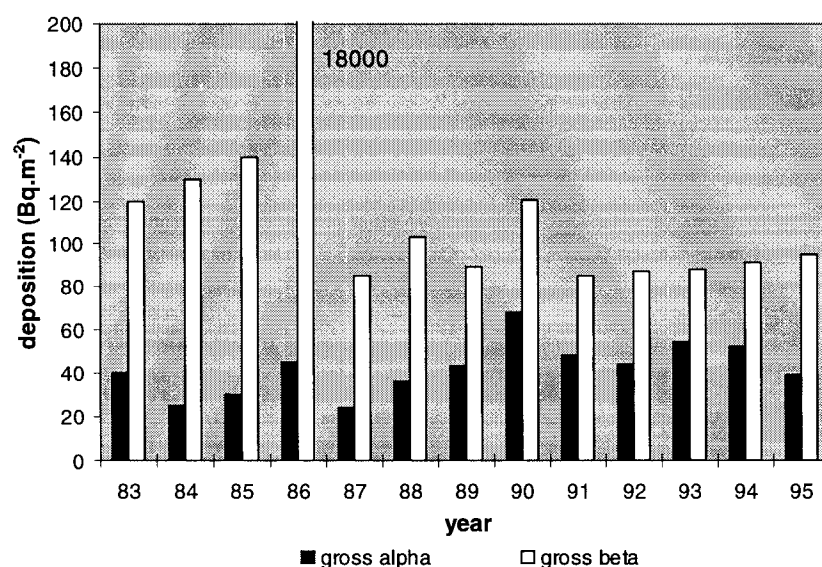


Figure 3.9 Total deposition of long-lived gross α - and gross β -activity from 1983 to 1995. See also Table 3.1. The 18,000 Bq·m⁻² level in 1986 was caused by the accident at the Chernobyl nuclear power plant.

Table 3.1 Yearly totals for long-lived gross α - and gross β -activity, ^3H , ^{210}Pb and ^{210}Po in deposition from 1983 to 1995 (see also [18 - 21]).

Year	Precipitation mm	Gross α $\text{Bq}\cdot\text{m}^{-2}$	Gross β $\text{Bq}\cdot\text{m}^{-2}$	^3H $\text{Bq}\cdot\text{m}^{-2}$	$^{210}\text{Pb}^\#$ $\text{Bq}\cdot\text{m}^{-2}$	$^{210}\text{Po}^\#$ $\text{Bq}\cdot\text{m}^{-2}$
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	85 ± 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	$(-)^1$	$(-)^1$

(*) Different method starting from 1987.

- No analysis.

Data from α -spectroscopy.

$(-)^1$ No validated results obtained.

The monthly values of ^3H , ^7Be , ^{137}Cs and ^{210}Pb are given in *Tables A3.4 and A3.5*. The yearly total deposition of ^3H is $970 \pm 40 \text{ Bq}\cdot\text{m}^{-2}$, which is the lowest value since 1983 (see *Table 3.1*). *Figure 3.10* presents the relationship between the monthly deposition of ^3H and the amount of precipitation. In *Figure 3.11* the same graph is presented for ^7Be and in *Figure 3.12* for ^{210}Pb . *Figures 3.10 and 3.11* indicate a correlation between the amount of rainfall and the deposition of ^3H and ^7Be , respectively. For ^{210}Po , as indicated in *Figure 3.12*, such a correlation is less obvious.

Using γ -spectroscopy significant activities of the naturally occurring nuclide ^7Be were found. For ^{134}Cs no activity was found higher than the detection limit of about $0.2 \text{ Bq}\cdot\text{m}^{-2}$, while for ^{137}Cs monthly depositions with a maximum of $0.107 \text{ Bq}\cdot\text{m}^{-2}$ (detection limit is about $0.02 \text{ Bq}\cdot\text{m}^{-2}$) were found.

All results for the ^{210}Po -analysis by α -spectrometry were rejected. Acidic fumes from the HCL carrier in the steel collection flask has lead to progressive rust formation over the years. Iron has a negative influence on the polonium plating efficiency leading to erroneous results. Consequently, no results for ^{210}Pb will be reported (see section 2.1.6). Starting from 1996, the collection flask has

been replaced by a polyethylene flask. The results obtained in 1996 will be compared with the results of 1995, aiming to determine the cause of the rejected results.

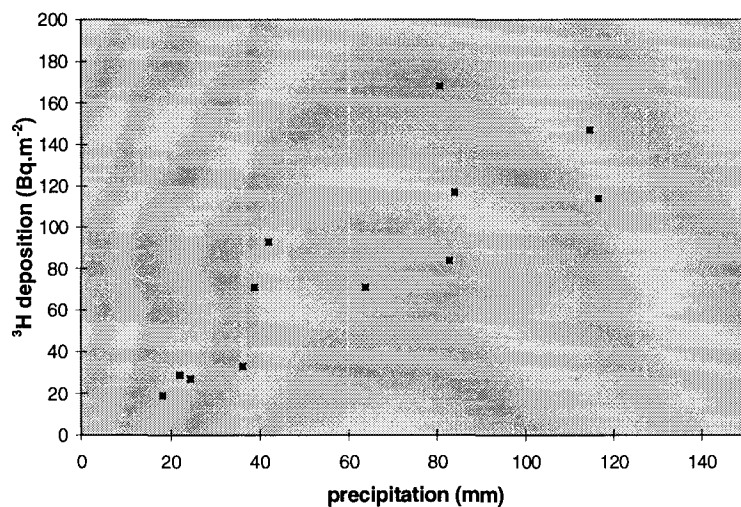


Figure 3.10 The monthly deposition of ^3H in 1995 versus precipitation.

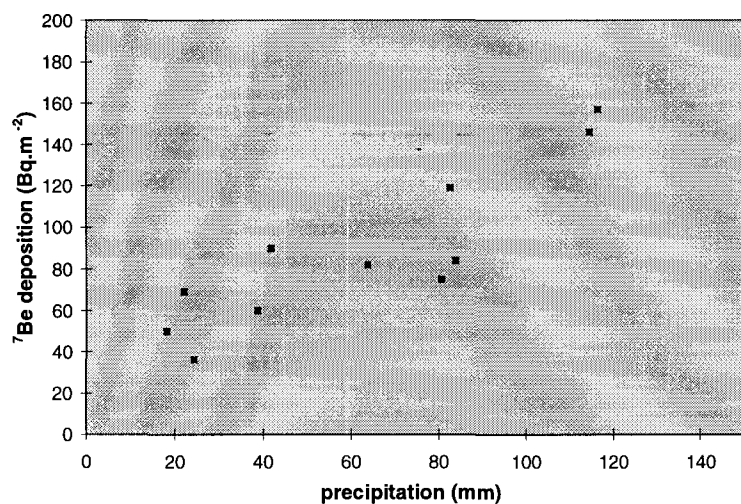


Figure 3.11 The monthly deposition of ^7Be in 1995 versus precipitation.

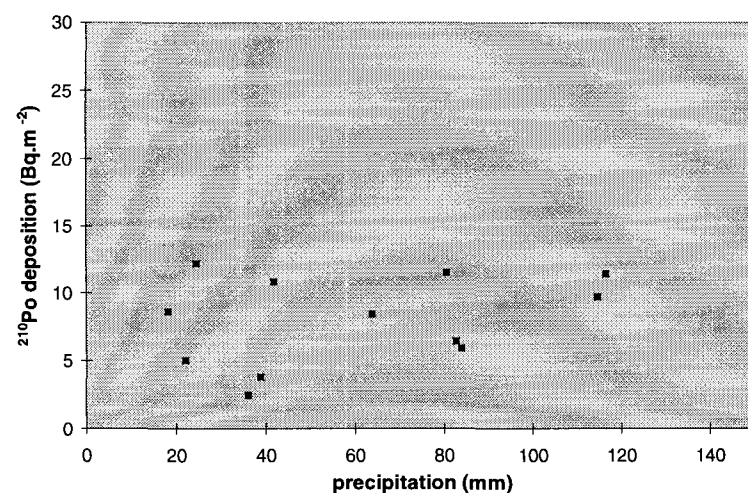


Figure 3.12 The monthly deposition of ^{210}Po in 1995 versus precipitation.

3.3 CONCLUSIONS

The yearly averages in airdust and the yearly totals in deposition are summarized in *Table 3.2*. More detailed data are given in *Table A3.1* and *Table A3.2* for airdust, and *Table A3.4* and *A3.5* for deposition.

The conclusion is that no unexpected activities have been observed for long-lived nuclides in airdust. The data for α - and β -emitting nuclides in airdust for 1995 are comparable with the values for 1992, 1993 and 1994. The results of the γ -emitting nuclides in airdust as sampled by the HVS-equipment were comparable to the values found in 1991-1994. Also no unexpected activities of α -, β - and γ -emitting, long-lived, nuclides in deposition have been observed.

Table 3.2 Results summarized for 1995: yearly average activities in airdust and yearly total activity in deposition; see section 2.4 for the reported errors.

Type of activity	Average airdust Activity concentration $\text{mBq}\cdot\text{m}^{-3}$ (SD)		Total Deposition $\text{Bq}\cdot\text{m}^{-2}$	
Gross α	0.077	± 0.001 (0.04)	39	± 4
Gross β	0.471	± 0.002 (0.25)	95	± 8
^{137}Cs	0.00125	± 0.00003 (0.0008)	0.28	± 0.02
^7Be	4.100	± 0.050 (1.200)	993	± 16
^3H	-		970	± 40
^{210}Pb	0.470	± 0.007 (0.300)	(-) ¹	
^{210}Po	-		(-) ¹	

- no analysis

(-)¹ no validated results for α -spectroscopy

4 RESULTS IN A FOOD CHAIN - grass and milk

4.1 OVERALL COUNTRY MILK SAMPLE

The yearly results for ^{90}Sr and ^{137}Cs in a mixed milk sample, which is composed of four regional milk samples from the north, south, east and west of the Netherlands, show that the activity of both nuclides is down to the level just before the Chernobyl accident. This is illustrated in *Figure 4.1* below (see also *Table A4.1* and refs. [8,22-23]). The activity concentrations of ^{89}Sr , ^{134}Cs and ^7Be were below the detection limit.

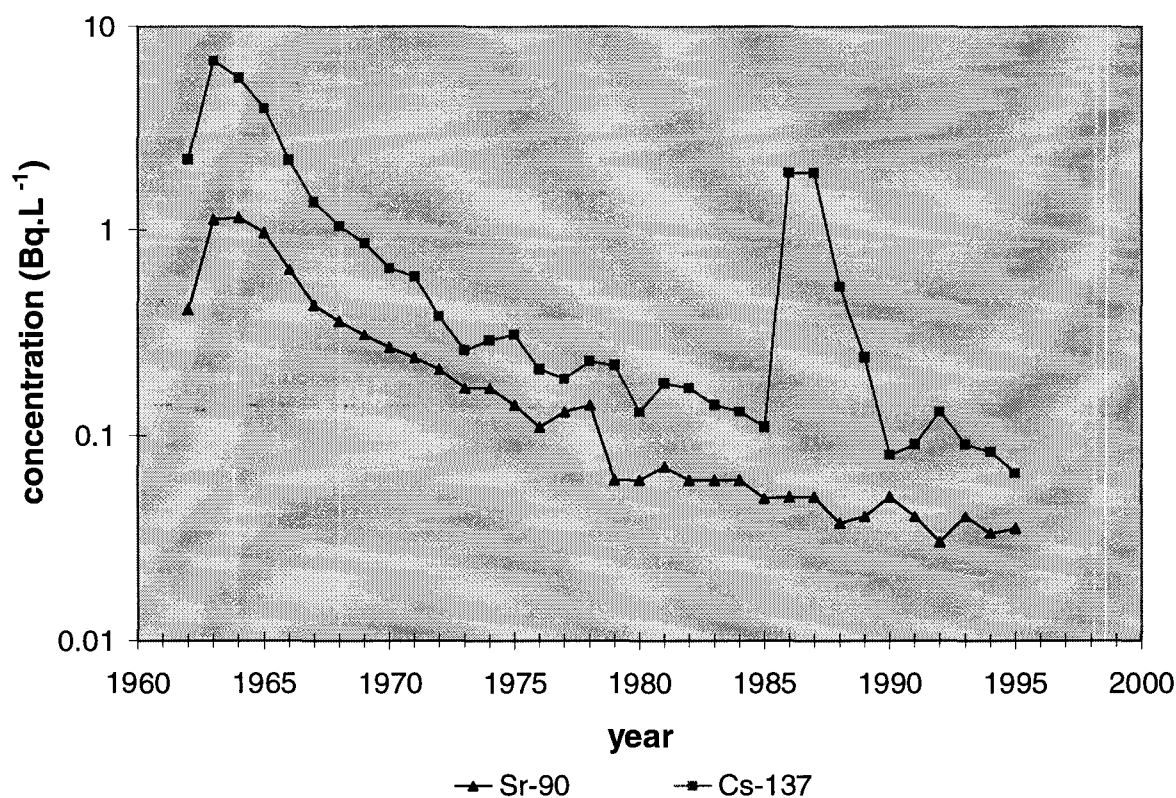


Figure 4.1 The yearly average concentrations of ^{90}Sr and ^{137}Cs in milk in the Netherlands since 1962. Note the logarithmic scale.

4.2 MILK SAMPLES FROM NUCLEAR INSTALLATION SURROUNDINGS

The yearly averages of ^{90}Sr and ^{137}Cs in milk samples taken from the surroundings of three Dutch nuclear installations are shown in *Figure 4.2*. Compared with the measurements of the period 1988-1994 no significant different activities were measured in 1995. *Table A4.2* gives the measured activity concentrations in the milk samples of 1995.

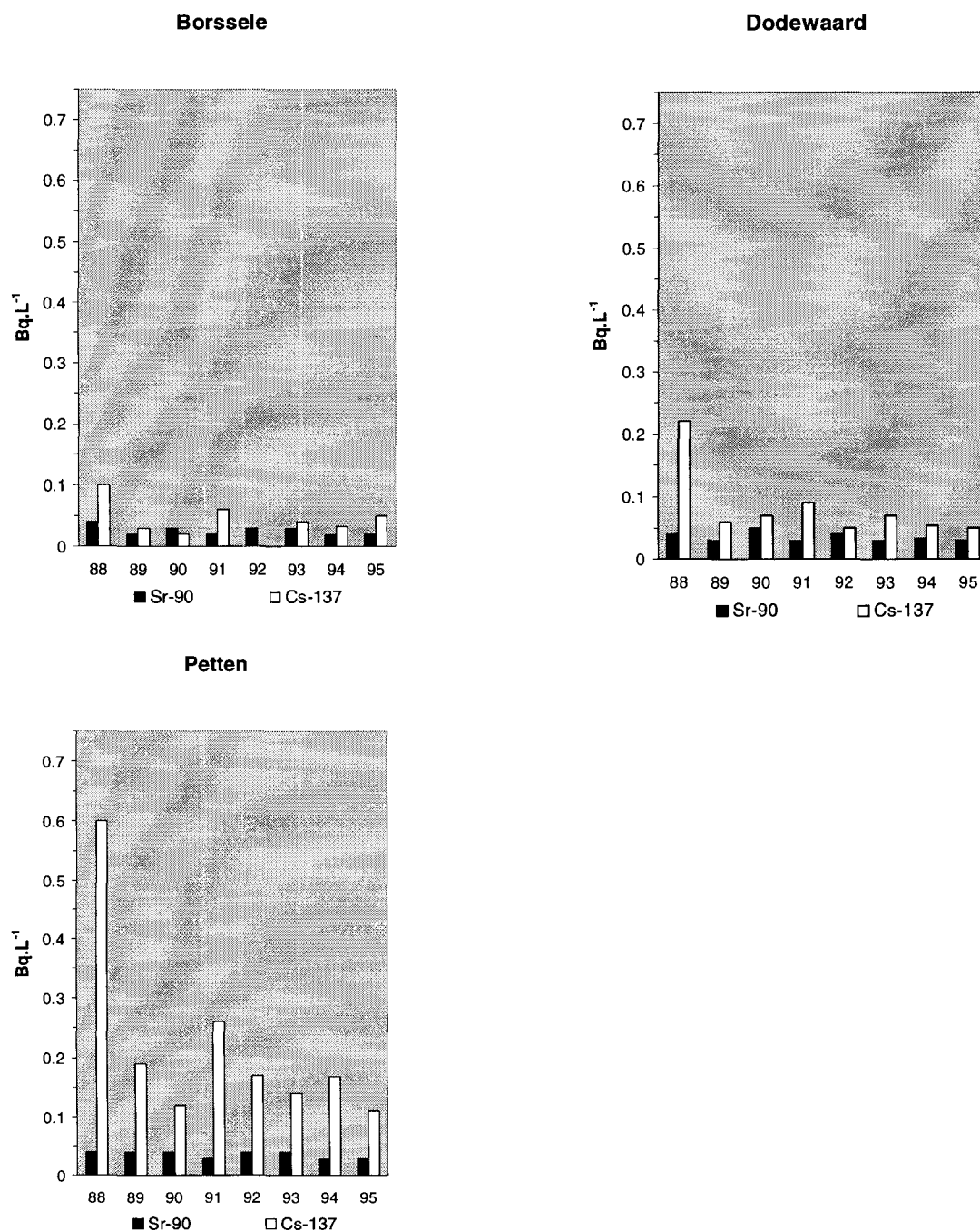


Figure 4.2 ^{90}Sr and ^{137}Cs concentrations in milk sampled between 1988 and 1995 from cows fed with grass from surroundings of three nuclear installations in the Netherlands.

The yearly averages of ^{90}Sr and ^{137}Cs in milk samples from Dutch territory in the vicinity of two Belgian (Doel and Mol) and two German (Lingen and Jülich) nuclear installations are shown in *Figure 4.3*. Compared with the period 1988-1994 no significant different activities were measured in the milk samples in 1995.

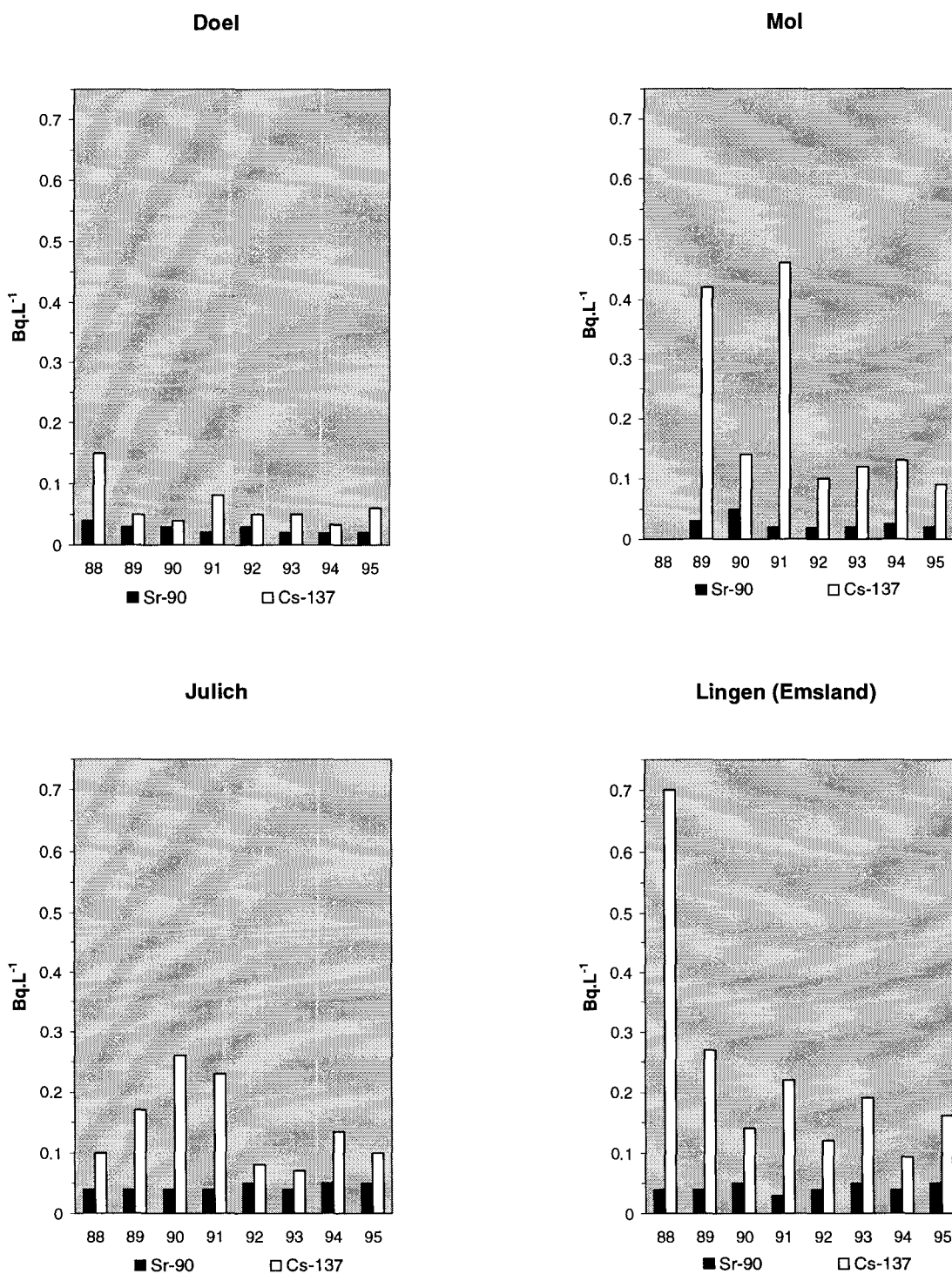


Figure 4.3 ^{90}Sr and ^{137}Cs concentrations in milk sampled between 1988 and 1995 from cows fed with grass from Dutch surroundings of four foreign nuclear installations.

4.3 GRASS SAMPLES FROM NUCLEAR INSTALLATION SURROUNDINGS

The average concentration of ^{90}Sr and ^{137}Cs in grass samples taken at the beginning (May) and end (September) of the grazing season, from the surroundings of three Dutch nuclear installations (Borssele, Dodewaard en Petten) between 1988 and 1995 are shown in *Figure 4.4*. ^{90}Sr was not measured in grass samples in 1994 and 1995. Measured activity concentrations for 1995 are shown in *Table A4.2*.

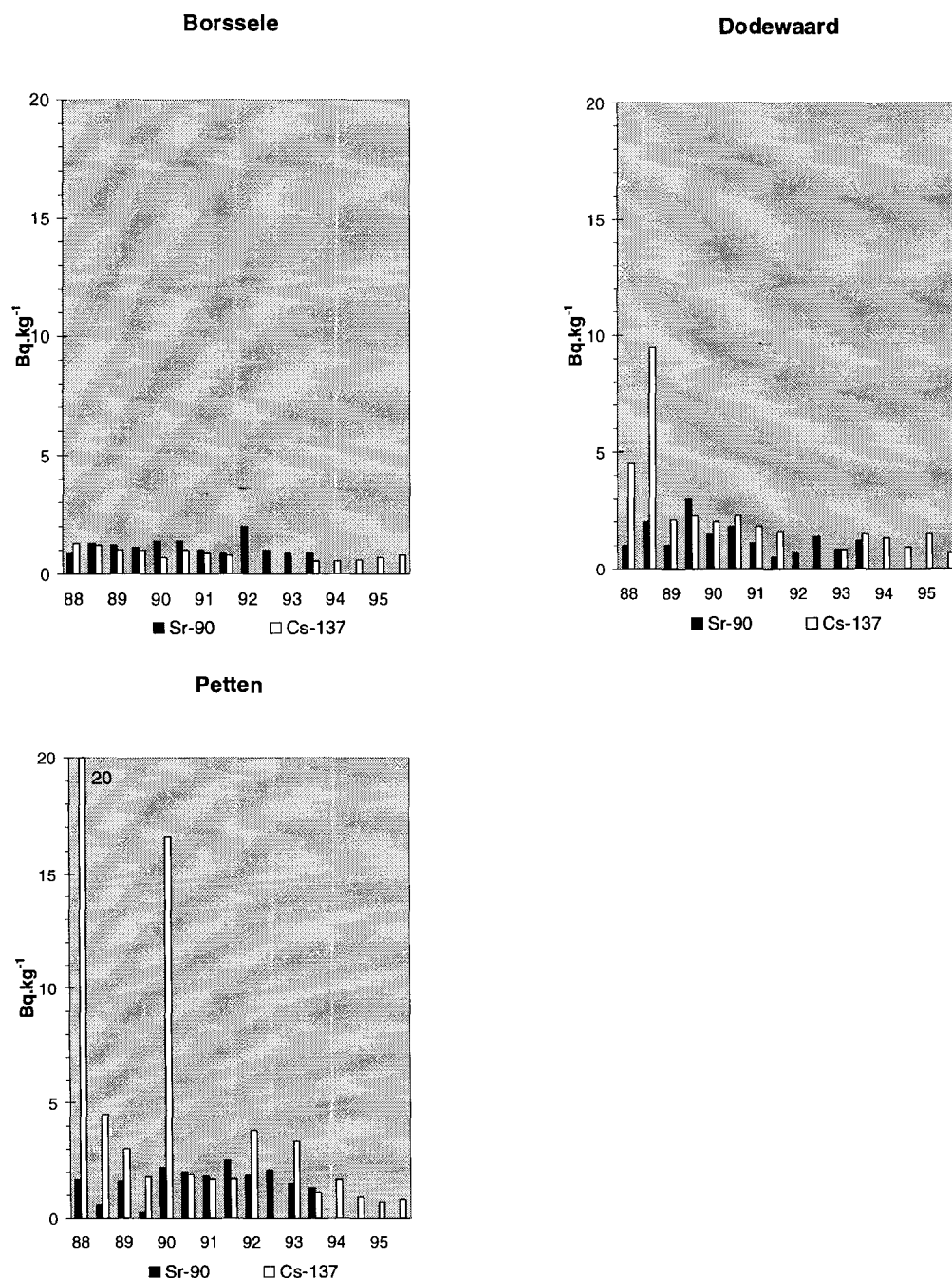


Figure 4.4 ^{90}Sr and ^{137}Cs concentrations in grass from the surroundings of three nuclear installations in the Netherlands between 1988 and 1995.

The average concentrations of ^{90}Sr and ^{137}Cs in grass samples taken at the beginning (May) and end (September) of the grazing season, taken from Dutch territory in the vicinity of two Belgian (Doel and Mol) and two German (Lingen and Jülich) nuclear installations between 1988 and 1995 are shown in *Figure 4.5*.

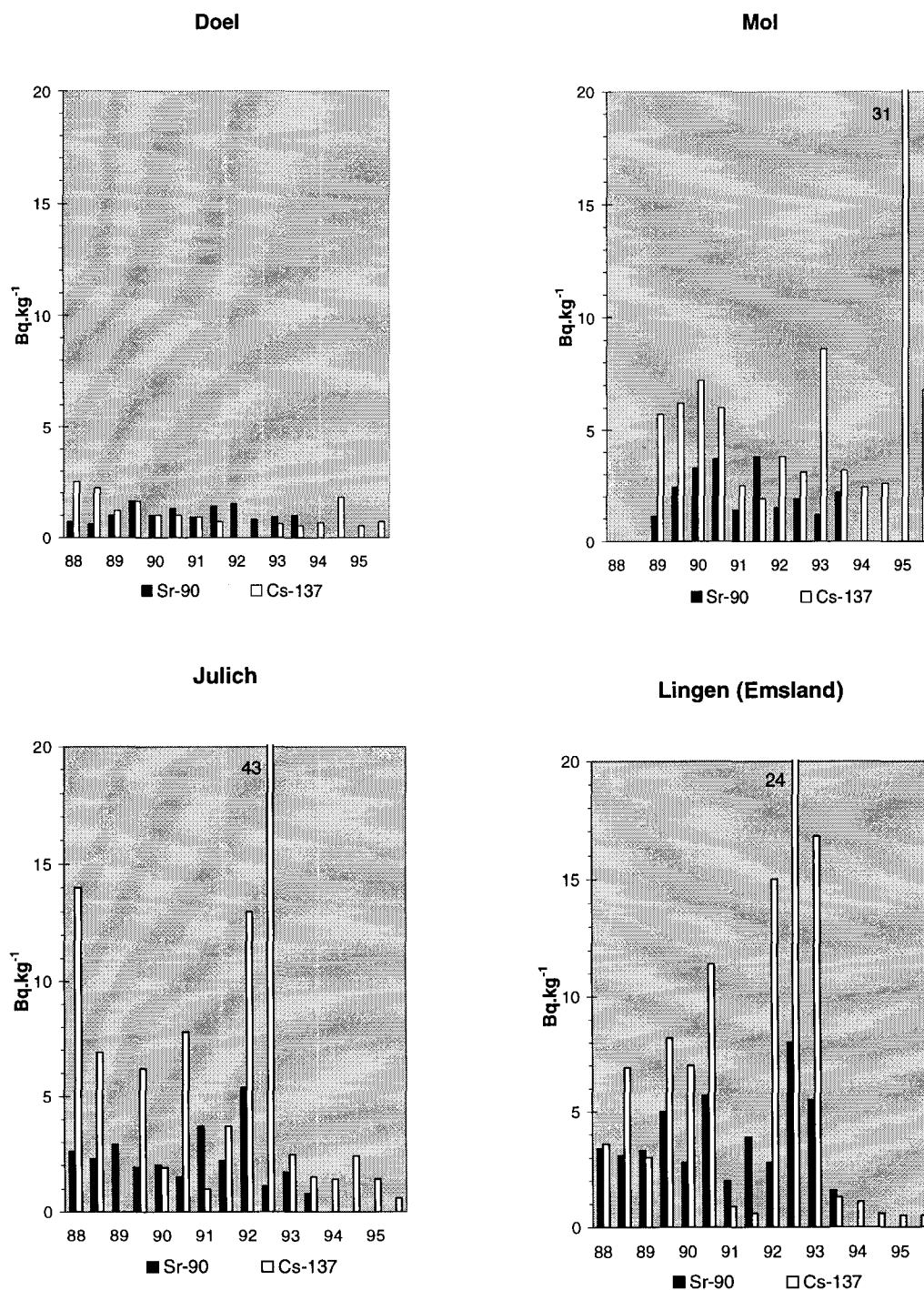


Figure 4.5 ^{90}Sr and ^{137}Cs concentrations in grass sampled from Dutch surroundings of four foreign nuclear installations.

Compared with previous years, the activity concentrations of ^{137}Cs in the vicinity of Jülich and Lingen (Emsland) are at normal values. The ^{137}Cs activity concentration in the vicinity of Mol, however, was relatively high in 1995. This is probably caused by the attachment of some soil material to the grass sample.

4.4 CONCLUSIONS

The concentrations of ^{89}Sr , ^{134}Cs and ^{131}I in milk and grass are generally below the detection limit. In an overall country milk sample both the ^{90}Sr and ^{137}Cs concentrations are comparable with values recorded just before Chernobyl.

The ^{137}Cs activity concentration in a grass sample in the vicinity of Mol was relatively high in 1995. This is probably caused by the attachment of some soil material to the grass sample.

The 1995 averages of ^{137}Cs in grass and of ^{90}Sr and ^{137}Cs in milk sampled around three nuclear installations in the Netherlands and in Dutch territory in the vicinity of such installations in Belgium (Doel, Mol) and Germany (Jülich, Lingen) are presented in *Table 4.1*. The concentrations of ^{90}Sr range from 0.19 to 0.50 $\text{Bq}\cdot\text{L}^{-1}$ in milk. For ^{137}Cs concentrations range from 0.6 to 19 $\text{Bq}\cdot\text{kg}^{-1}$ in grass and from 0.05 to 0.16 $\text{Bq}\cdot\text{L}^{-1}$ in milk..

Table 4.1 Average results in 1995 for ^{90}Sr and ^{137}Cs in grass and milk sampled around three nuclear installations in the Netherlands and in Dutch territory in the vicinity of nuclear installations in Belgium (Doel, Mol) and Germany (Jülich, Lingen).

	GRASS ^{137}Cs $\text{Bq}\cdot\text{kg}^{-1}$	MILK ^{90}Sr $\text{Bq}\cdot\text{L}^{-1}$	^{137}Cs $\text{Bq}\cdot\text{L}^{-1}$
Borssele	< 0.7	0.019 ± 0.004	0.05 ± 0.01
Dodewaard	1.1 ± 1.2	0.027 ± 0.007	0.05 ± 0.01
Petten	0.8 ± 0.3	0.031 ± 0.008	0.11 ± 0.03
Doel	0.6 ± 0.2	0.021 ± 0.003	0.06 ± 0.03
Mol	19 ± 12	0.020 ± 0.001	0.09 ± 0.05
Jülich	1.0 ± 0.6	0.047 ± 0.018	0.10 ± 0.04
Lingen (Emsland)	< 0.5	0.050 ± 0.017	0.16 ± 0.08
Country milk sample	n.a.	0.035 ± 0.001	0.07 ± 0.02

n.a. non-applicable

5 NATIONAL RADIOACTIVITY MONITORING NETWORK (LMR)

5.1 RESULTS

The data presented in this report are based on the set of values measured every ten-minutes (see Section 2.3). In *Table A5.1* the average results and 5-percentile and 95-percentile values of α -activity concentration, man-made β -activity concentrations and ambient dose-equivalent rate are given for the 14 macro-stations in 1995. Per monitor the percentile values are calculated for each month on the basis of the daily averages. The average over the year of these monthly values is given in *Table A5.1*. To indicate the lower level of the data of a monitor this 5-percentile value averaged over the year is used, the upper level is indicated by the 95-percentile value averaged over a year. To indicate a collective data range the minimum of the 5-percentile values averaged over the year and the maximum of the 95-percentile values averaged over the year, as determined for the 14 monitors in the macro-stations, are used.

The spatial distribution of the yearly averages of the LMR data is constructed with the Geographical Information System (GIS) of the RIVM. To calculate values in between the LMR stations an interpolation algorithm was applied. The algorithm does not generate valid values for the Dutch 'Wadden' islands.

A comprehensive analysis on the LMR data has recently been completed and is given in [25] and [26].

5.1.1 Gross α -activity concentration

Figure 5.1 gives the averaged gross α -activity concentration over the year 1995 in relation to the topographical position. In 1995 the average value over all stations of the gross α -activity concentration is $3.7 \text{ Bq}\cdot\text{m}^{-3}$. This is the highest yearly average compared with the values of the previous years: averages of 2.4, 3.3, 2.4, 2.6 and $2.4 \text{ Bq}\cdot\text{m}^{-3}$ were measured in 1990, 1991, 1992, 1993 and 1994, respectively [24]. This high value for the gross α -activity concentration is caused by the extreme weather conditions in the summer and in the last months of 1995 [26]. Highest monthly averages were observed in July and August and in October and December. The highest ten-minute value was $81 \text{ Bq}\cdot\text{m}^{-3}$ measured in August at the station in Wageningen (724). The minimum of the 5-percentile and the maximum of the 95-percentile values are used to indicate the range of the gross α -activity concentration over all stations for 1995: 0.2 - $14.5 \text{ Bq}\cdot\text{m}^{-3}$.

5.1.2 'Man-made' gross β -activity concentration

For the 'man-made' gross β -activity concentration the year averages do not significant deviate from zero.

5.1.3 γ -radiation level

Figure 5.2 gives the γ -radiation level as a function of the topographical position. The overall picture of the LMR measurements corresponds relatively well with the results of 1990-1994 [5,6,9,10,24].

For the γ -radiation level measured by the LMR proportional counters, the arithmetic mean over the year and across the country is $80.2 \text{ nSv}\cdot\text{h}^{-1}$ which is in good agreement with the averages of 1992, 1993 and 1994. For the dose-equivalent rate measured at the macrostations the data range between the 5-p and 95-p values is $65.5 - 97 \text{ nSv}\cdot\text{h}^{-1}$. The highest validated 10-minute value was $152.3 \text{ nSv}\cdot\text{h}^{-1}$, observed at the station in Heijningen (210).

5.2 CONCLUSIONS

As a result of the extreme weather conditions in 1995 the average gross α -activity concentration level is about 1.5 times higher than in previous years. The average gross γ -radiation level measured by the LMR monitors are in agreement with the results of previous years.

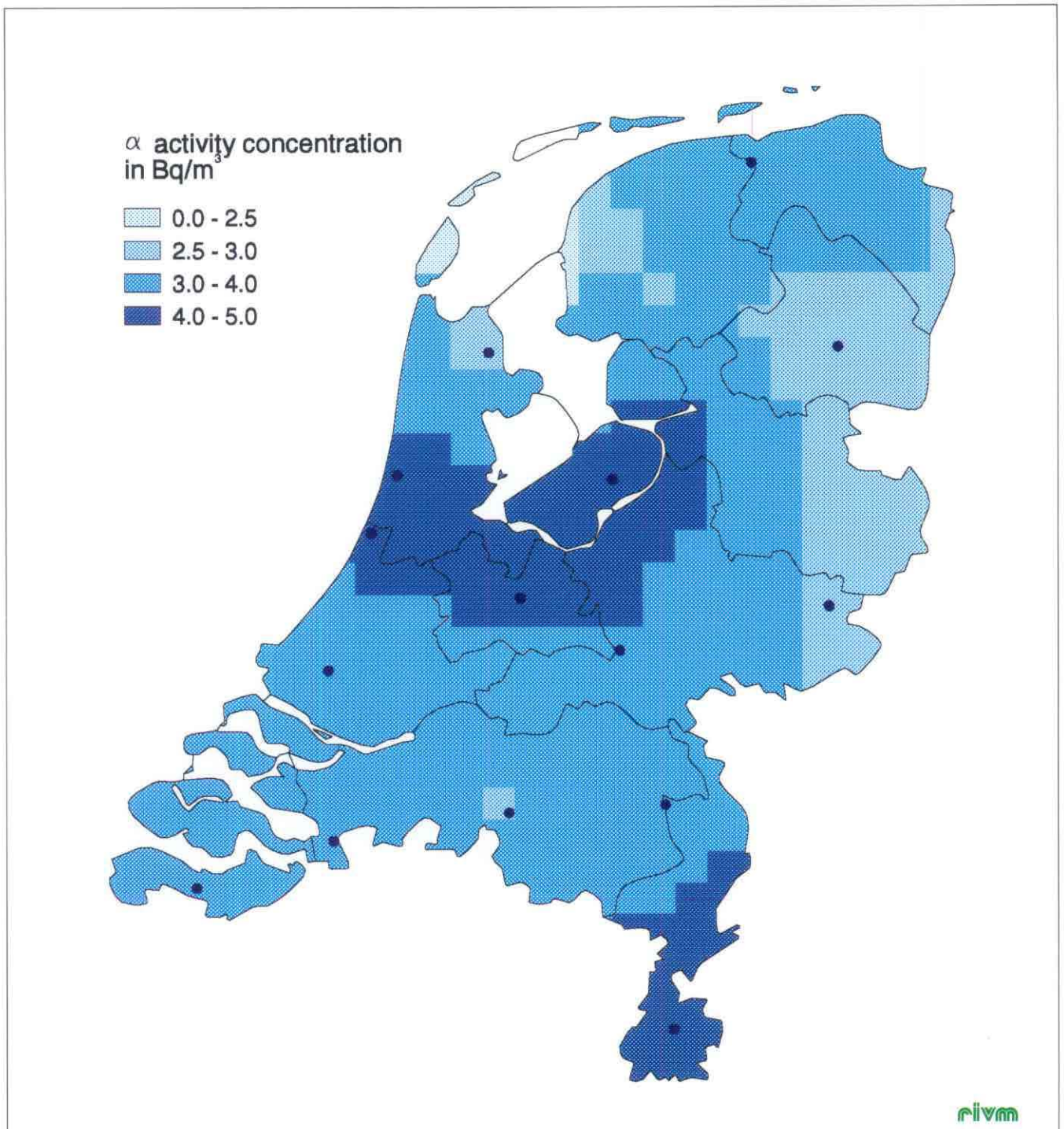


Figure 5.1 The gross short-lived α -activity concentration averaged over the year 1995

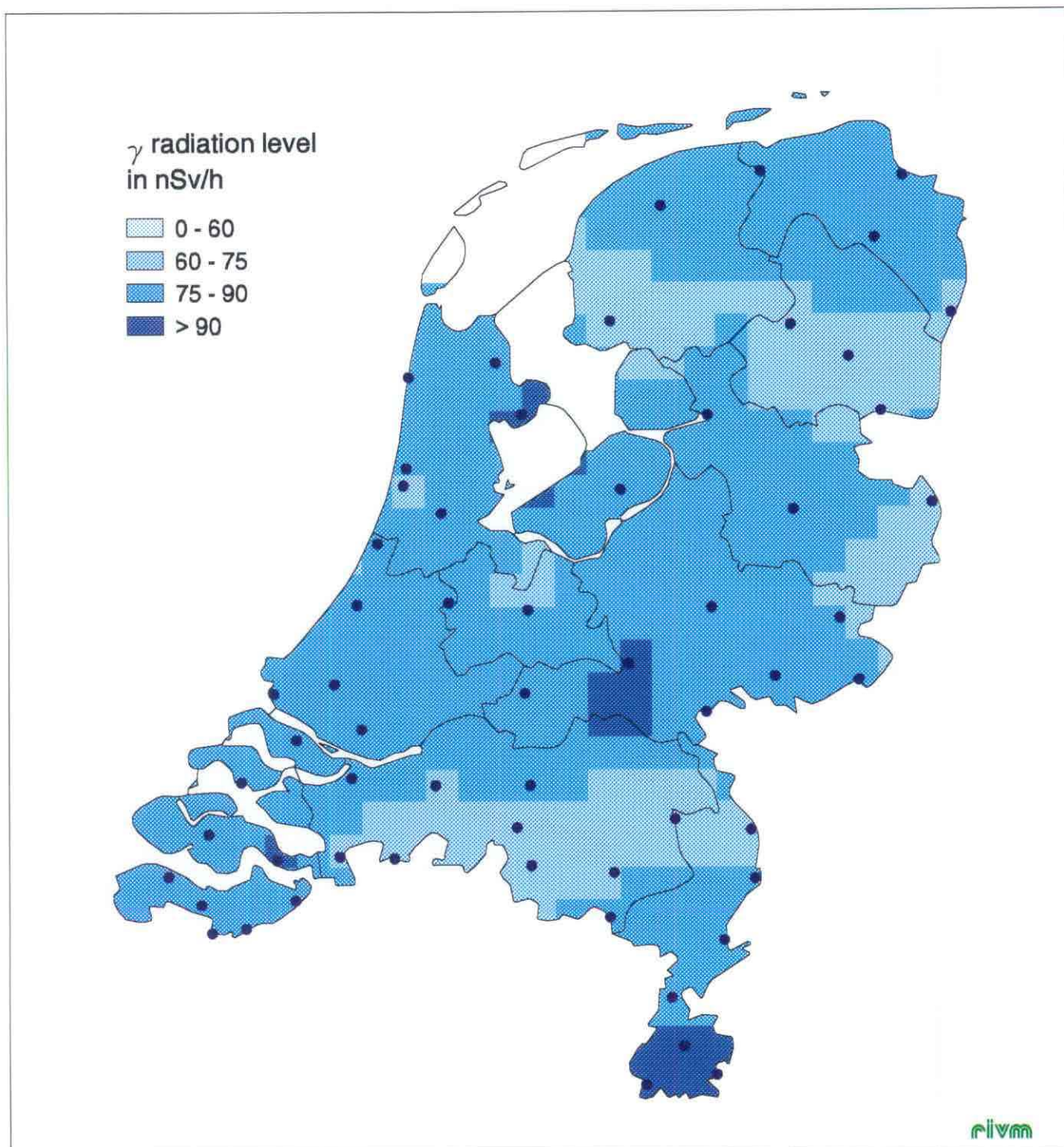


Figure 5.2 The ambient dose equivalent rate averaged over the year 1995

6 GENERAL CONCLUSIONS

It can be concluded that for all monitoring measurements no significant deviations from values in previous years were observed in the Netherlands in 1995. In all cases the activity concentrations are back to or even lower than the levels of just before the Chernobyl accident.

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8 APPENDIX

In all Tables the first number refers to the corresponding Chapter.

Table A3.1 Weekly averages of gross α - and gross β -activities in airdust sampled in 1995 at the RIVM premises in Bilthoven (The Netherlands); SD in the last row indicates the standard deviation (see section 2.4 for the error reported).

number week	gross- α mBq·m ⁻³	gross- β mBq·m ⁻³	week number	gross- α mBq·m ⁻³	gross- β mBq·m ⁻³
1	0.055 ± 0.006	0.306 ± 0.011	27	0.101 ± 0.008	0.409 ± 0.014
2	0.047 ± 0.005	0.446 ± 0.014	28	0.079 ± 0.007	0.631 ± 0.019
3	0.142 ± 0.010	0.368 ± 0.013	29	0.105 ± 0.008	0.343 ± 0.012
4	0.040 ± 0.005	0.187 ± 0.008	30	0.077 ± 0.007	0.447 ± 0.014
5	0.053 ± 0.006	0.180 ± 0.008	31	0.076 ± 0.007	0.83 ± 0.02
6	0.089 ± 0.008	0.361 ± 0.012	32	0.033 ± 0.005	0.416 ± 0.014
7	0.053 ± 0.006	0.231 ± 0.009	33	0.077 ± 0.007	0.557 ± 0.017
8	0.054 ± 0.006	0.166 ± 0.008	34	0.093 ± 0.008	0.81 ± 0.02
9	0.039 ± 0.005	0.167 ± 0.008	35	0.027 ± 0.004	0.305 ± 0.011
10	0.068 ± 0.006	0.157 ± 0.008	36	0.077 ± 0.007	0.485 ± 0.015
11	0.039 ± 0.005	0.438 ± 0.014	37	0.086 ± 0.007	0.512 ± 0.016
12	0.113 ± 0.009	0.391 ± 0.013	38	0.065 ± 0.006	0.519 ± 0.016
13	0.040 ± 0.005	0.252 ± 0.010	39	0.046 ± 0.005	0.327 ± 0.012
14	0.100 ± 0.008	0.509 ± 0.016	40	0.060 ± 0.006	0.397 ± 0.013
15	0.044 ± 0.006	0.264 ± 0.011	41	0.131 ± 0.010	1.02 ± 0.03
16	0.082 ± 0.007	0.255 ± 0.009	42	0.210 ± 0.013	1.06 ± 0.03
17	0.066 ± 0.006	0.625 ± 0.019	43	0.098 ± 0.008	0.90 ± 0.03
18	0.045 ± 0.006	0.66 ± 0.02	44	0.064 ± 0.006	0.243 ± 0.010
19	0.059 ± 0.006	0.465 ± 0.014	45	0.278 ± 0.017	0.557 ± 0.018
20	0.053 ± 0.006	0.355 ± 0.012	46	0.156 ± 0.011	0.97 ± 0.03
21	0.062 ± 0.007	0.464 ± 0.016	47	0.120 ± 0.008	0.316 ± 0.011
22	0.052 ± 0.005	0.352 ± 0.011	48	0.098 ± 0.008	0.92 ± 0.03
23	0.038 ± 0.005	0.187 ± 0.008	49	0.084 ± 0.007	0.83 ± 0.02
24	0.027 ± 0.005	0.137 ± 0.008	50	0.074 ± 0.007	0.96 ± 0.02
25	0.065 ± 0.006	0.319 ± 0.011	51	0.091 ± 0.008	0.703 ± 0.019
26	0.040 ± 0.005	0.386 ± 0.013	52	0.047 ± 0.005	0.390 ± 0.013
			Avg.	0.077 ± 0.001	0.471 ± 0.002
			SD	0.04	0.25

Table A3.2. Weekly averages of ^7Be , ^{22}Na , ^{40}K , ^{134}Cs , ^{137}Cs and ^{210}Pb concentrations in air dust sampled by HVS in 1995 at the RIVM premises in Bilthoven (The Netherlands). Well-type detector. Empty fields indicate that the value was below the detection limit (Table A3.3).

number week	^7Be $\mu\text{Bq}\cdot\text{m}^{-3}$	^{22}Na $\mu\text{Bq}\cdot\text{m}^{-3}$	^{40}K $\mu\text{Bq}\cdot\text{m}^{-3}$	^{137}Cs $\mu\text{Bq}\cdot\text{m}^{-3}$	^{210}Pb $\mu\text{Bq}\cdot\text{m}^{-3}$
1	2400 $\pm$ 210			1.09 $\pm$ 0.17	270 $\pm$ 20
2	3500 $\pm$ 310			1.33 $\pm$ 0.15	460 $\pm$ 40
3	4500 $\pm$ 390			0.75 $\pm$ 0.13	330 $\pm$ 30
4	2900 $\pm$ 250				120 $\pm$ 10
5	3500 $\pm$ 310			0.99 $\pm$ 0.14	160 $\pm$ 10
6	4400 $\pm$ 390			0.76 $\pm$ 0.17	280 $\pm$ 30
7	4000 $\pm$ 350			0.39 $\pm$ 0.14	160 $\pm$ 10
8	3700 $\pm$ 330			0.52 $\pm$ 0.18	130 $\pm$ 10
9	3000 $\pm$ 260			0.43 $\pm$ 0.11	110 $\pm$ 10
10	3200 $\pm$ 280			0.65 $\pm$ 0.16	100 $\pm$ 10
11	4500 $\pm$ 390		15 $\pm$ 4	1.7 $\pm$ 0.2	640 $\pm$ 60
12	5000 $\pm$ 430	1.0 $\pm$ 0.3		0.68 $\pm$ 0.15	330 $\pm$ 30
13	3200 $\pm$ 280	1.0 $\pm$ 0.3		0.57 $\pm$ 0.12	220 $\pm$ 20
14	4400 $\pm$ 390			1.35 $\pm$ 0.19	500 $\pm$ 40
15	2600 $\pm$ 230			1.84 $\pm$ 0.18	250 $\pm$ 20
16	3700 $\pm$ 320			1.36 $\pm$ 0.17	260 $\pm$ 20
17	5600 $\pm$ 490			3.5 $\pm$ 0.3	760 $\pm$ 70
18	6900 $\pm$ 600			2.7 $\pm$ 0.3	670 $\pm$ 60
19	4700 $\pm$ 410		20 $\pm$ 4	2.3 $\pm$ 0.3	660 $\pm$ 60
20	4400 $\pm$ 380			1.75 $\pm$ 0.19	360 $\pm$ 30
21	7600 $\pm$ 660	1.1 $\pm$ 0.3	25 $\pm$ 7	1.00 $\pm$ 0.17	730 $\pm$ 60
22	4200 $\pm$ 360			0.73 $\pm$ 0.15	270 $\pm$ 20
23	2800 $\pm$ 250				210 $\pm$ 20
24	2000 $\pm$ 170		47 $\pm$ 6	0.30 $\pm$ 0.14	110 $\pm$ 10
25	4200 $\pm$ 360	1.4 $\pm$ 0.3	16 $\pm$ 5	0.70 $\pm$ 0.10	210 $\pm$ 20
26	5100 $\pm$ 440		21 $\pm$ 5	1.62 $\pm$ 0.17	320 $\pm$ 30

Table A3.2. Continued.

number week	^7Be $\mu\text{Bq}\cdot\text{m}^{-3}$	^{22}Na $\mu\text{Bq}\cdot\text{m}^{-3}$	^{40}K $\mu\text{Bq}\cdot\text{m}^{-3}$	^{137}Cs $\mu\text{Bq}\cdot\text{m}^{-3}$	^{210}Pb $\mu\text{Bq}\cdot\text{m}^{-3}$
27	4900 $\pm$ 420	1.1 $\pm$ 0.3		1.0 $\pm$ 0.3	300 $\pm$ 30
28	6800 $\pm$ 590	0.9 $\pm$ 0.3	37 $\pm$ 6	2.2 $\pm$ 0.3	610 $\pm$ 50
29	3400 $\pm$ 300			0.72 $\pm$ 0.13	300 $\pm$ 30
30	4800 $\pm$ 420	0.6 $\pm$ 0.2		0.99 $\pm$ 0.15	410 $\pm$ 40
31	6300 $\pm$ 550	0.9 $\pm$ 0.2		2.3 $\pm$ 0.3	780 $\pm$ 70
32	4400 $\pm$ 380			1.6 $\pm$ 0.2	290 $\pm$ 30
33	5200 $\pm$ 450			2.6 $\pm$ 0.3	540 $\pm$ 50
34	5900 $\pm$ 510		19 $\pm$ 6	2.5 $\pm$ 0.3	810 $\pm$ 70
35	4300 $\pm$ 380	1.2 $\pm$ 0.3		0.65 $\pm$ 0.15	210 $\pm$ 20
36	4700 $\pm$ 410	0.7 $\pm$ 0.2	12 $\pm$ 4	1.18 $\pm$ 0.18	410 $\pm$ 40
37	3500 $\pm$ 300			0.58 $\pm$ 0.09	480 $\pm$ 40
38	4100 $\pm$ 360		16 $\pm$ 5	1.71 $\pm$ 0.3	530 $\pm$ 50
39	4800 $\pm$ 410			0.27 $\pm$ 0.07	220 $\pm$ 20
40	3700 $\pm$ 320		19 $\pm$ 5	0.77 $\pm$ 0.16	310 $\pm$ 30
41	4500 $\pm$ 390		39 $\pm$ 6	0.85 $\pm$ 0.10	1230 $\pm$ 110
42	3500 $\pm$ 310			0.75 $\pm$ 0.18	1140 $\pm$ 100
43	4800 $\pm$ 420		30 $\pm$ 5	1.53 $\pm$ 0.19	840 $\pm$ 70
44	1900 $\pm$ 170			0.8 $\pm$ 0.2	260 $\pm$ 20
45	4400 $\pm$ 380		16 $\pm$ 6	1.8 $\pm$ 0.2	510 $\pm$ 50
46	4000 $\pm$ 350		28 $\pm$ 6	1.6 $\pm$ 0.2	1060 $\pm$ 90
47	2900 $\pm$ 250		31 $\pm$ 5	0.55 $\pm$ 0.08	270 $\pm$ 20
48	3100 $\pm$ 270		22 $\pm$ 5	1.12 $\pm$ 0.12	930 $\pm$ 80
49	2900 $\pm$ 260		40 $\pm$ 6	3.1 $\pm$ 0.3	940 $\pm$ 80
50	2200 $\pm$ 140		48 $\pm$ 7	2.3 $\pm$ 0.2	1070 $\pm$ 80
51	2200 $\pm$ 150		51 $\pm$ 8	0.66 $\pm$ 0.14	810 $\pm$ 60
52	4200 $\pm$ 260		24 $\pm$ 4	1.9 $\pm$ 0.2	570 $\pm$ 40
Avg.	4100 $\pm$ 50	1.0 $\pm$ 0.1	27.4 $\pm$ 1.2	1.25 $\pm$ 0.03	470 $\pm$ 7
SD	1200	0.2	12	0.8	300

Table A3.3 Detection limits in $\mu\text{Bq}\cdot\text{m}^{-3}$ of the well-type detectors for a seven day sampling period and a sample volume of about $50,000\text{ m}^3$.

Nuclide	Detection limit	Nuclide	Detection limit
^7Be	1.4	^{113}Sn	0.1
^{22}Na	0.2	$^{115\text{m}}\text{Cd}$	8
^{24}Na	*	$^{123\text{m}}\text{Te}$	0.1
^{40}K	7	^{124}Sb	0.4
^{51}Cr	1.6	^{125}Sb	0.4
^{54}Mn	0.1	$^{129\text{m}}\text{Te}$	5
^{57}Co	0.1	^{131}I	**
^{58}Co	0.1	^{132}Te	3
^{59}Fe	0.3	^{134}Cs	0.2
^{60}Co	0.2	^{136}Cs	0.2
^{65}Zn	0.3	^{137}Cs	0.1
^{75}Se	0.2	^{140}Ba	0.6
^{95}Nb	0.2	^{140}La	22
^{95}Zr	0.4	^{141}Ce	0.2
^{99}Mo	20	^{144}Ce	0.7
^{103}Ru	0.1	^{202}Tl	0.3
^{106}Ru	0.9	^{210}Pb	5
^{109}Cd	3	^{237}U	2
$^{110\text{m}}\text{Ag}$	0.2		

* OMNIGAM software reports the message "> 12 half-lives"

** Due to the sample preparation procedure the volatile nuclide ^{131}I cannot be determined on the well-type detector, see 2.1.2

Table A3.4. Monthly values of precipitation and of ^3H , long-lived gross α - and gross β -activity in deposition sampled in 1995 at the RIVM premises in Bilthoven (The Netherlands).

Month 1995	Precipitation mm	^3H $\text{Bq}\cdot\text{m}^{-2}$	gross- α $\text{Bq}\cdot\text{m}^{-2}$	gross- β $\text{Bq}\cdot\text{m}^{-2}$
January	117	114 $\pm$ 18	0.6 $\pm$ 0.8	6.3 $\pm$ 1.4
February	83	84 $\pm$ 12	2.1 $\pm$ 0.5	7.0 $\pm$ 1.6
March	84	117 $\pm$ 10	2.3 $\pm$ 0.5	9.5 $\pm$ 2.2
April	22	29 $\pm$ 4	0.9 $\pm$ 0.4	3.2 $\pm$ 0.7
May	81	168 $\pm$ 14	1.9 $\pm$ 0.5	5.9 $\pm$ 1.3
June	64	71 $\pm$ 9	9 $\pm$ 2	28 $\pm$ 6
July	42	93 $\pm$ 8	9 $\pm$ 2	16 $\pm$ 4
August	25	27 $\pm$ 5	10 $\pm$ 2	9 $\pm$ 2
September	115	147 $\pm$ 23	0.59 $\pm$ 0.16	3.7 $\pm$ 0.8
October	18	19 $\pm$ 5	1.1 $\pm$ 0.3	2.0 $\pm$ 0.5
November	39	71 $\pm$ 10	0.66 $\pm$ 0.09	2.2 $\pm$ 0.2
December	36	33 $\pm$ 9	0.72 $\pm$ 0.09	1.9 $\pm$ 0.2
Sum	724	970 $\pm$ 40	39 $\pm$ 4	95 $\pm$ 8

Table A3.5. Monthly values of ^7Be , ^{137}Cs and ^{210}Pb deposition sampled in 1995 at the RIVM premises in Bilthoven (The Netherlands). Measurements are carried out using γ -spectroscopy.

Month	^7Be $\text{Bq}\cdot\text{m}^{-2}$	^{137}Cs $\text{Bq}\cdot\text{m}^{-2}$	^{210}Pb $\text{Bq}\cdot\text{m}^{-2}$
1995			
January	157 ± 7	< 0.02	11.4 ± 0.7
February	119 ± 5	< 0.02	6.4 ± 0.3
March	84 ± 5	0.030 ± 0.006	5.9 ± 0.3
April	69 ± 4	0.052 ± 0.008	5.0 ± 0.3
May	75 ± 4	0.107 ± 0.010	11.5 ± 0.6
June	82 ± 4	< 0.02	8.4 ± 0.4
July	90 ± 4	0.040 ± 0.005	10.8 ± 0.5
August	36.3 ± 1.7	< 0.02	12.2 ± 0.6
September	146 ± 9	0.047 ± 0.007	9.7 ± 0.6
October	50 ± 3	< 0.02	8.6 ± 0.6
November	60 ± 3	< 0.02	3.8 ± 0.3
December	25.7 ± 1.5	< 0.02	2.4 ± 0.2
Sum	993 ± 16	0.28 ± 0.02	96.1 ± 1.6

Table A4.1 ^{90}Sr and ^{137}Cs activity concentrations in 1995 in a mixed sample of four regional milk samples from the north, south, east and west of the Netherlands. See section 2.4 for the error reported.

date 1995	^{89}Sr Bq/L	^{90}Sr Bq/L	^7Be Bq/L	^{134}Cs Bq/L	^{137}Cs Bq/L
1/1-31/3	< 0.03	0.035 ± 0.006	< 0.23	< 0.02	0.08 ± 0.01
1/4-30/6	< 1.74 ¹	0.036 ± 0.006	< 0.29	< 0.02	0.04 ± 0.01
1/7-30/9	< 0.44	0.035 ± 0.006	< 0.21	< 0.03	0.09 ± 0.01
1/10-31/12	< 0.12	0.034 ± 0.006	< 0.40	< 0.02	0.05 ± 0.01

¹ The sample has been analysed with delay. Because of the large correction for decay the detection limit is considerably larger than for the other samples.

Table A4.2 Measured activity concentrations in grass (in $\text{Bq}\cdot\text{kg}^{-1}$ dry weight) and milk (in $\text{Bq}\cdot\text{L}^{-1}$) taken from the surroundings of three Dutch nuclear installations (Borssele, Dodewaard and Petten), and on Dutch territory in the vicinity of such installations in Belgium (Doel and Mol) and Germany (Jülich and Lingen/Emsland). If a value is below the detection limit this is indicated in the Tables by "<" followed by the detection limit; see section 2.4 for the reported error.

Borssele

Grass results in Bq/kg dry weight

sector	date	^{40}K	^7Be	^{134}Cs	^{137}Cs
1	May	1240 ± 100	60 ± 10	< 0.6	< 0.6
2	May	1920 ± 150	60 ± 10	< 0.4	< 0.7
3	May	1260 ± 100	120 ± 10	< 0.6	< 0.7
1	Sept	990 ± 80	360 ± 30	< 0.5	< 0.7
2	Sept	1270 ± 100	310 ± 30	< 1.0	< 1.0
3	Sept	1380 ± 110	250 ± 20	< 0.7	< 0.6

Milk results in Bq/L

date	^{89}Sr	^{90}Sr	^7Be	^{134}Cs	^{137}Cs
May	<0.05	0.020 ± 0.004	< 0.3	< 0.02	< 0.05
July	<0.15	0.018 ± 0.003	< 0.1	< 0.05	< 0.04
Sept	<0.07	0.019 ± 0.004	< 0.6	< 0.03	0.05 ± 0.01

Dodewaard

Grass results in Bq/kg dry weight

sector	date	^{40}K	^7Be	^{134}Cs	^{137}Cs
1	May	1260 ± 100	110 ± 10	< 0.6	4.0 ± 0.6
2	May	1210 ± 100	40 ± 10	< 0.5	< 0.7
3	May	1310 ± 110	100 ± 20	< 0.7	< 0.4
4	May	1110 ± 90	70 ± 10	< 0.7	< 0.7
1	Sept	1090 ± 90	100 ± 10	< 0.5	< 0.7
2	Sept	1200 ± 100	110 ± 10	< 0.8	< 0.8
3	Sept	920 ± 70	100 ± 10	< 0.6	< 0.6
4	Sept	1020 ± 80	100 ± 10	< 0.8	< 0.8

Milk results in Bq/L

date	^{89}Sr	^{90}Sr	^7Be	^{134}Cs	^{137}Cs
May	< 0.05	0.027 ± 0.005	< 0.3	< 0.03	0.04 ± 0.01
July	< 0.26	0.034 ± 0.007	< 0.2	< 0.02	0.04 ± 0.03
Sept	< 0.01	0.021 ± 0.004	< 0.3	< 0.03	0.06 ± 0.02

Petten

Grass results in Bq/kg dry weight

sector	date	^{40}K	^7Be	^{134}Cs	^{137}Cs
1	May	860 ± 70	70 ± 10	< 0.3	1.2 ± 0.3
2	May	1200 ± 100	30 ± 10	< 0.2	< 0.4
3	May	990 ± 80	60 ± 10	< 0.5	< 0.6
1	Sept	1080 ± 90	390 ± 40	< 0.4	< 0.7
2	Sept	1280 ± 100	440 ± 40	< 0.8	< 0.9
3	Sept	1370 ± 110	390 ± 40	< 0.8	< 0.7

Milk results in Bq/L

date	⁸⁹ Sr	⁹⁰ Sr	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
May	< 0.05	0.025 ± 0.005	< 1.9	< 0.01	0.09 ± 0.02
July	< 0.23	0.040 ± 0.007	< 0.8	< 0.02	0.14 ± 0.02
Sept	< 0.08	0.028 ± 0.005	< 0.2	< 0.02	0.10 ± 0.02

Doel

Grass results in Bq/kg dry weight

sector	date	⁴⁰ K	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
1	May	1080 ± 90	130 ± 10	< 0.6	< 0.5
2	May	940 ± 80	150 ± 10	< 0.6	< 0.5
1	Sept	1120 ± 90	280 ± 30	< 0.9	< 0.9
2	Sept	640 ± 50	230 ± 20	< 0.5	< 0.4

Milk results in Bq/L

date	⁸⁹ Sr	⁹⁰ Sr	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
May	< 0.07	0.018 ± 0.004	< 0.4	< 0.03	< 0.04
July	< 0.18	0.021 ± 0.004	< 0.3	< 0.03	< 0.05
Sept	< 0.09	0.024 ± 0.004	< 0.3	< 0.03	0.10 ± 0.03

Mol

Grass results in Bq/kg dry weight

sector	date	⁴⁰ K	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
1	May	590 ± 50	120 ± 10	1.3 ± 0.3	31 ± 3
1	Sept	810 ± 70	200 ± 20	< 0.5	6.8 ± 0.7

Milk results in Bq/L

date	⁸⁹ Sr	⁹⁰ Sr	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
May	< 0.06	0.019 ± 0.004	< 0.2	< 0.02	0.13 ± 0.03
July	< 0.13	0.021 ± 0.004	< 0.3	< 0.03	0.06 ± 0.02
Sept	< 0.10	0.021 ± 0.004	< 0.3	< 0.04	0.09 ± 0.01

Jülich

Grass results in Bq/kg dry weight

sector	date	⁴⁰ K	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
1	May	1210 ± 100	120 ± 10	< 0.4	1.4 ± 0.3
1	Sept	970 ± 80	220 ± 20	< 1.0	< 0.6

Milk results in Bq/L

date	⁸⁹ Sr	⁹⁰ Sr	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
May	< 0.10	0.028 ± 0.006	< 0.2	< 0.07	0.11 ± 0.02
July	< 0.28	0.063 ± 0.011	< 0.1	< 0.04	0.13 ± 0.04
Sept	< 0.13	0.051 ± 0.009	< 0.3	< 0.04	< 0.05

Lingen (Emsland)

Grass results in Bq/kg dry weight

sector	date	⁴⁰ K	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
1	May	1090 ± 90	100 ± 10	< 0.5	< 0.5
1	Sept	920 ± 70	120 ± 10	< 0.5	< 0.5

Milk results in Bq/L

date	⁸⁹ Sr	⁹⁰ Sr	⁷ Be	¹³⁴ Cs	¹³⁷ Cs
May	< 0.07	0.033 ± 0.006	< 0.3	< 0.03	0.07 ± 0.02
July	< 0.24	0.066 ± 0.012	< 0.2	< 0.04	0.22 ± 0.03
Sept	< 0.15	0.052 ± 0.009	< 0.2	< 0.12	0.19 ± 0.04

Table A5.1 Average results and 5- and 95-percentile values in 1995 for α -activity concentration, man-made β -activity concentrations and ambient dose-equivalent rate, as measured by the LMR-monitors (see section 2.3).

Station (nr.)	α -activity concentration			man-made β -activity concentration			ambient dose-equivalent rate		
	Bq·m ⁻³			Bq·m ⁻³			nSv·h ⁻¹		
	5-p	year average	95-p	5-p	year average	95-p	5-p	year average	95-p
Vredepeel (131)	0.6	4.0	11.2	-0.3	-0.0	0.1	67.0	69.8	74.4
Wijnandsrade (133)	0.7	4.9	14.4	-0.1	0.1	0.4	84.2	87.4	91.0
Houtakker (230)	0.4	2.8	8.1	-0.1	0.0	0.1	70.4	73.0	75.8
Huijbergen (235)	0.5	3.7	11.5	-0.1	0.0	0.1	65.5	68.0	71.1
Braakman (318)	0.5	3.8	11.5	-0.5	-0.1	0.0	74.3	77.0	80.7
Vlaardingen (433)	0.4	3.3	10.4	-0.3	-0.1	0.0	78.8	81.4	84.5
De Zilk (444)	0.3	4.8	14.5	-0.2	-0.0	0.1	74.2	76.7	79.7
Wieringerwerf (538)	0.2	2.3	6.7	-0.1	0.0	0.2	80.7	83.4	86.7
Bilthoven (627)	0.5	4.0	13.0	0.0	0.1	0.3	72.3	74.7	78.1
Biddinghuizen (631)	0.8	4.8	12.5	-0.2	0.0	0.2	82.6	87.3	90.4
Eibergen (722)	0.5	2.9	8.1	-0.1	0.0	0.1	70.1	72.6	75.8
Wageningen (724)	0.5	3.9	11.2	-0.1	0.1	0.4	89.8	93.3	97.0
Witteveen (928)	0.4	2.7	8.3	-0.1	0.0	0.2	65.9	68.5	71.7
Kollumerwaard (934)	0.4	3.5	9.9	-0.1	0.0	0.2	74.3	80.1	84.2

Erratum

Monitoring of radiation in the atmosphere and a food chain: Results in the Netherlands in 1995

Bilthoven: 20 January 2026

Subject: Erratum report 610056029

An error was made in RIVM report 610056029 entitled *Monitoring of radiation in the atmosphere and a food chain: Results in the Netherlands in 1995*. The decay correction on the activities of ^{210}Po in deposition was calculated incorrectly. Unfortunately, due to the absence of necessary data, a revision is not possible. For the years 2009 till 2019, a recalculation was possible. For these years the yearly totals did not change significantly or became lower than reported before. On average, the yearly totals were 13 % lower. Probably, this will also be the case for the measurements of ^{210}Po in deposition from before 2009. To be able to see the long term trends of ^{210}Po in deposition the results are not retracted. Instead, the results should be seen as approximation.

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