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PART I

ENVIRONMENTAL RADIATION MONITORING ON THE CERN SITES AND IN THE CERN ENVIRONMENT DURING 1997

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1 INTRODUCTION

As a consequence of changes in the administrative structure of TIS Division in 1996 and 1997, the Environmental Section was integrated into the TIS Technical Services and Environment Group that also looks after the non-radiation parameters in the CERN releases and environment. However, it remains the duty of the Radiation Protection Group to define the environmental programme for radiation and radioactivity, and to report its results both inside and outside CERN.

In 1997, the environmental programme was slightly modified after discussions with the Sektion zur Überwachung der Radioaktivität (SÜR) in Fribourg. Gamma spectroscopy analyses of moss and water plants collected once per year in the rivers l'Allondon, Le Lion, Le Nant d'Avril and La Versoix were added. Moss and water plants were chosen as they are sensitive indicators of the presence of natural and man-made radioactivity in the environment.

Part I of this Annual Report describes the results of measurements which are relevant for assessing the radiological impact of CERN's activities on the environment and the population living in the vicinity of the CERN sites. Measurements of radioactivity released into the atmosphere and into water, as well as measurements of stray radiation at or near the CERN site boundaries, are reported. Radiation and radioactivity measurements performed on the CERN sites are described in Part II.

2 DESCRIPTION OF THE ENVIRONMENTAL PROGRAMME

The CERN environmental monitoring programme covers the Meyrin and Prévessin sites, the six isolated islands (BA1, BA2, BA3, BA4, BA5, BA6) along the SPS Main Ring, the neutrino cave (BA7), and the seven surface areas PA2–PA8 specific to LEP. An outline of the CERN environmental monitoring programme listing the instruments and methods used for measuring radiation and radioactivity is presented in Table 1a and Table 1b. The main objectives of the programme are:

- The measurement of the quantities of radioactivity released into the atmosphere and into water from the various accelerator installations and other CERN facilities (the source term).

- The monitoring of the radiological impact of the operation of the CERN accelerators and experimental areas. This is achieved by measuring radiation fields at or outside the CERN boundaries, and by measuring radioactivity in environmental samples of air (aerosols), tap and well water, precipitation, river sediments, river vegetation, soil, and grass, taken on the CERN sites and in their vicinity (the environmental impact).

The distribution of the environmental monitors on the Meyrin and Prévessin sites is shown in Figs. 1 and 2, respectively. Effluent monitors are situated at the points of potential release of radioactive material into the atmosphere and into water. Stray radiation monitors are located at the site boundaries or inside the Meyrin and Prévessin sites where they are used for assessing the on-site radiological conditions and where in the past radiation surveys have indicated measurable radiation levels caused by the operation of the various CERN accelerator installations, experimental areas, auxiliary and service buildings, etc. A few of these monitors and aerosol samplers are installed some distance from the CERN premises and far from expected sources of radiation. They provide a continuous record of natural background radiation and radioactivity. Their location and the places for taking environmental samples are shown in Fig. 3. These measurements are reported in the quarterly reports of the CERN environmental radiation monitoring programme [1]–[4] and are summarized in this report. During 1997, 13 air (ventilation) monitors, 23 aerosol samplers, 7 water monitors, and 43 stray radiation monitors were in operation. The system of active stray radiation monitors is complemented by an array of 94 ^{6}LiF/^{7}LiF thermoluminescence dosimeters (TLDs) installed near the CERN fences (47 at the Meyrin site, 32 at the Prévessin site, and 13 at the LEP islands).

Table 1a: Programme of environmental monitoring on the CERN sites – Emission control

Monitored subject	Radioactivity	Type and frequency of sampling and measurements	Number of points	Locations
1.1 Air/aerosol	Total beta Gamma	*Glass-fibre filters changed 2×/month;* large-area proportional counter HPGe gamma spectrometry	15	PMV11, 31, 51, 61, 70, 72, 73, 74, 170, 801, 819, 901, 903, 905, 907 (70 and 819: closed circuit systems)
1.2 Air/gas	Total beta	*Continuous;* differential ionization chamber	14	At ventilation shafts in TT10, BA3, 5, 85, Bldg.26, TT20, 60, 70, BA7, PS, ISOLDE, LEP
2. Release (surface) water	Total gamma	*Continuous;* NaI(Tl) cryst. immersed in water tank	6	Near BA2, BA6, Meyrin site, LEP Point 1
	Dissolved total beta Gamma Tritium	*Sampling 2ml/173 sec or 5ml/288 sec for whole month;* large-area proportional counter if beta is > 0.37 Bq/l, HPGe g. spectr. liquid scintillation counting	7	Meyrin site - Le Lion Prévessin site - Le Lion Meyrin site - Le Nant d'Avril Prévessin site - Le Nant d'Avril LEP Point 1 - Le Nant d'Avril Pit DP62 Bldg. 193

Table 1b: Programme of environmental monitoring on the CERN sites and in the CERN environment – Immission control

Monitored subject	Radiation, radioactivity	Type and frequency of sampling and mesurements	Number of points	Locations
1. Stray radiation	Total gamma dose rate Total neutron dose rate	*Continuous;* argon-air filled ionization chamber moderated BF_3 counter	43	30 near fences or outside 13 on the sites
2. Air/aerosol	Total beta Gamma	*Glass-fibre filters changed 2×/month;* large-area proportional counter HPGe gamma spectrometry	8	PMA32, 71, 100,126, 805, 821, 911, 951
3. Tap and well water	Total gamma Dissolved total beta Gamma Tritium	*Continuous;* NaI(Tl) cryst. immersed in water tank *once per year;* large-area proportional counter if beta is > 0.37 Bq/l, HPGe g. spectr. liquid scintillation counting	1 5	Near BA6 (PMW61) Meyrin site - Peney (FWPE) Prévessin site - Le Vengeron (FWVE) Prévessin (UWPR), St. Genis (UWSG) Versonnex (UWVX)
4. Precipitation	Dissolved total beta Gamma Tritium	*Sampling for one month into a funnel;* large-area proportional counter if beta is > 0.37 Bq/l, HPGe g. spectr. liquid scintillation counting	2	Roof of RP Bldg. 24 (RWSS) Roof of Bldg. 865 SPS (RWSF)
5. Rivers/ water sediment, moss	Total beta in w. and s. Gamma in s. and m. Tritium in water	*Once per year;* large-area proportional counter HPGe gamma spectrometry liquid scintillation counting	11	Allondon (SWA1, MUA1, MOA1) Le Lion (SWL4, MUL4, MOL4) La Versoix (SWV1, MUV1, MOV1) Le Nant d'Avril (SWN4, MUN4, MON4) LEP Points 2-8 (SWLP2-8, MUL2-8, MOLP2-8)
6. Grass, soil	Total beta in soil Gamma in g. and s.	*Once per year;* large-area proportional counter HPGe gamma spectrometry	9	NE of BA7 (GRB4), ISOLDE (GRB3), PS (GRB1), North Area (GRN1), Cessy LEP Point 5 (GRC1), LEP Pit 7 GRCB, EACB), SW and NE of Meyrin site (GRSW, GRNE, EASW, EANE), Le Vengeron (GRVE, EAVE)
7. Agricultural products	Gamma	*Once per year at harvest time;* HPGe gamma spectrometry		Surrounding fields

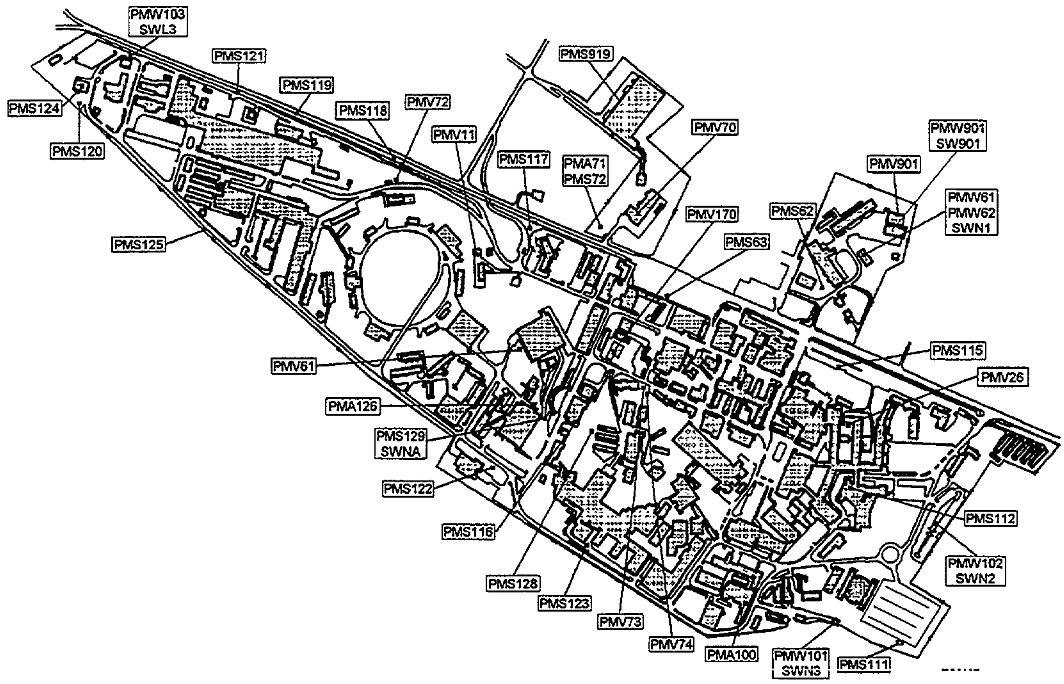

Figure 1: Location of monitor stations on the Meyrin site.

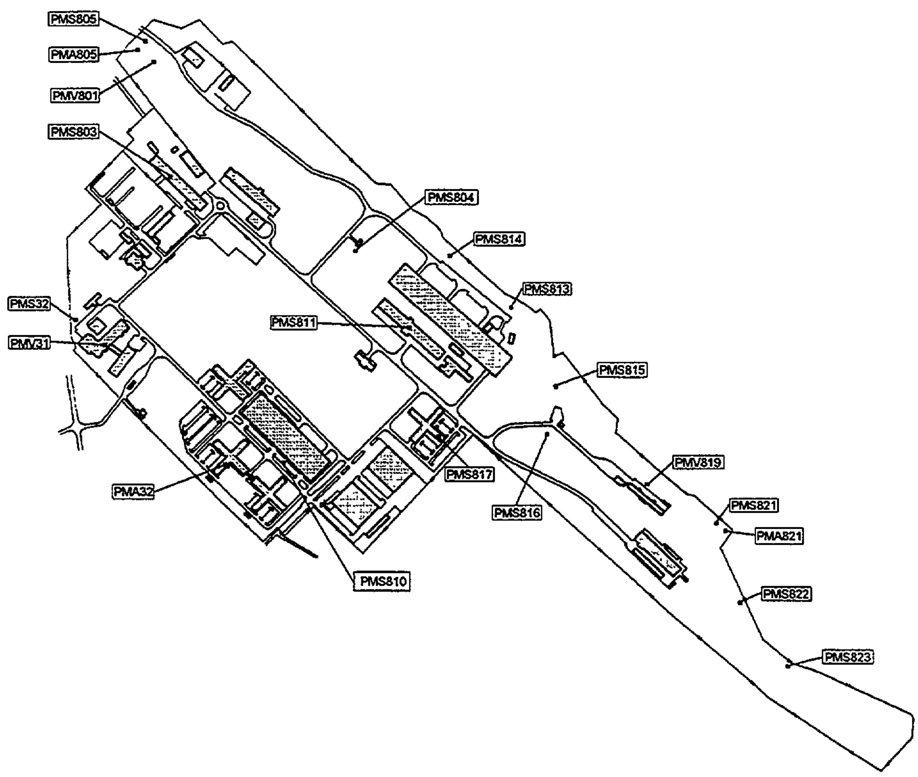

Figure 2: Location of monitor stations on the Prévessin site

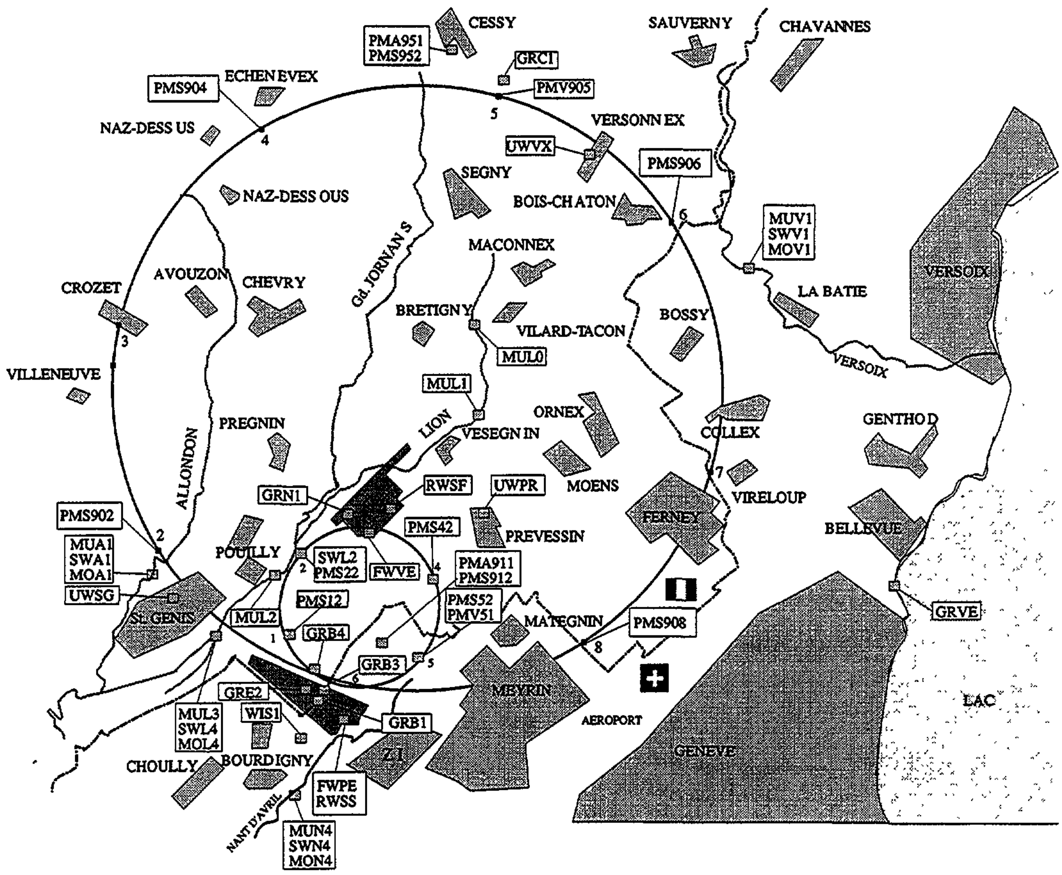

Figure 3: Location of site stations and of sampling points for water, river sediments, and vegetation in the CERN surroundings

3 MONITOR STATUS

The fire in the RF power supply in surface building BA3 of the SPS on 13 May caused not only a long-term interruption of SPS operation during the summer, but also affected several environmental monitors which were either located in BA3 or depended on the BA3 installations.

3.1 Stray radiation monitors

3.1.1 Calibrations

During the year, the following monitors underwent their routine calibration: PMS 12, 32, 52, 62, 72, 111G, 118N, 123N, 125, 120, 805, 817, 821, 822, 902, and 952.

3.1.2 Repairs and replacements

Monitors PMS32 and PMS810 were stopped on 19 May because of the fire in the RF power supply in BA3. They were put back into operation on 5 July and 25 June, respectively. Monitor PMS805, which is supplied from the electric cupboard of ventilation monitor PMV805, was switched off from 22 May to 15 August because of work on the ventilation system.

During July and August the huts of several monitors were painted, but the monitors remained operational during the work. In 1997, some minor technical problems with monitors PMS123G, PMS816, PMS111N, PMS121, PMS120, and PMS115 occurred, and were solved promptly.

In November, monitor PMS919 had to be moved temporarily. It was moved a short distance to allow construction work at SM18, and was disconnected from the ARCON for five days.

During the year, a thorough investigation of gamma dose rates measured by monitor PMS118G installed in Bldg. 295 was carried out. It was found that this monitor measures the dose rate in the vicinity of the V_0 installation rather than the dose rate at the fence. It was therefore relocated outside Bldg. 295, close to the fence in a hut, and connected to ARCON at the beginning of 1998.

3.2 Ventilation monitors

From the end of May to the end of July, work was performed by ST division on the ventilation system of the SPS and some transfer tunnels. A number of control boards were replaced affecting the following monitors: PMV/PMVG31 (BA3), PMV/PMVG51 (BA5), PMV/PMVG11 (TT10), PMV/PMVG801 (TT20), PMV/PMVG72 (TT60), and PMV/PMVG73 (TT70). Owing to this work, the flow rate indication for the air released was missing for some time. The systems were reconnected and signals for ARCON were provided at the end of September, but the signals for ARCON did not match the existing ARCON interfaces which had to be adapted. Eventually in November the ARCON connections for the flow-rate measurements of monitors PMV/PMVG11 and PMV/PMVG72 were again fully operational. The remaining ventilation stations were equipped with modified ARCON interfaces at the beginning of 1998. The release flow rates of the ventilation points concerned (during the period of missing flow rate data) were estimated from those of previous years which have been fairly stable in the past. The period when the data were estimated partially overlapped with the unplanned SPS shutdown caused by the fire at BA3. Therefore, the calculated results of the annual release of gaseous and aerosol activity are considered to be correct despite the aforementioned problems.

Since the middle of March, work on the Antiproton Collector (ACOL) started, to transform the complex into an Antiproton Decelerator (AD). The corresponding ventilation system and its monitor PMV/PMVG61 were stopped as there was no release of radioactivity in 1997. After the LEP shutdown in November monitors PMV905 and PMVG905 (LEP PA5) were disconnected and taken out of Bldg. 2850 where civil engineering work related to the LHC has begun. A new location for the monitors will be defined with the assistance of ST Division.

3.2.1 Repairs and replacements

During the period of reduced power consumption in March, monitors PMVG72 in TT60, and PMVG73 in TT70, including the whole station, were stopped for maintenance.

In May, a hole in the rubber hose supplying the differential chamber PMVG70 with sampled air was detected when investigating low read-out values from this monitor when the Neutrino Experiment was running. However, no radioactive air was released as this system works in a closed circuit. The hose was replaced and the other gas monitors were checked for similar problems.

In May, the blocked pump of PMV73 was replaced. At the end of July, the digitizer of monitor PMVG901 broke down. It was repaired and the monitor was put back into operation at the end of August. In November, the digitizer had to be repaired again and monitor PMVG901 was not operational for one week. The pump of monitor PMV170 did not work during the second half of July.

3.3 Aerosol monitors

During the year, the Environmental Section continued changing the filters from the high-volume sampler installed behind the new building 40, on the far side of the car park close to the fence, and sent them to the Sektion für die Überwachung der Radioaktivität (SÜR) in Fribourg. The air sampler is operated by CERN.

In May, a location for a planned second, but transportable, high-volume sampler was investigated in the vicinity of LEP point PA7. Taking into consideration the prevailing wind direction and noise propagation criteria, a suitable place was found in the northern corner of the LEP island.

3.3.1 Repairs

In May, the blocked counter of aerosol monitor PMA911 was replaced. The pump of monitor PMA805 did not work during the second half of November.

3.4 Water monitors

In July, the output of PMW103I to ARCON broke during a thunderstorm. It was repaired immediately. At the end of August, the scintillation probe of monitor PMW21 was replaced as it had deformed encapsulation. It was probably damaged when the water tank was cleaned. The monitor showed elevated count rates, but no excessive radioactivity was found in the water in an analysis using an HPGe detector.

The automatic water sampler SWL2, blocked during November, collected only a little amount of water. It was replaced with a new CERN-design sampler. Owing to a long-term power cut in the underground area of the cooling towers as a consequence of the civil engineering work for the LHC, the automatic water sampler SWN1 did not collect any water during December.

4 DEVELOPMENTS AND NON-ROUTINE ACTIVITIES OF THE ENVIRONMENTAL SECTION

4.1 General

Improvements and technical upgrading of the Environmental Section continued in 1997. Major developments were carried out or prepared in the environmental laboratory. The section participated in many intercomparison exercises and the special programme 'Sediments in Rivers' continued. The operating system of the ARCON servers was upgraded during the summer.

4.2 Data handling

After the upgrading of the Oracle program in January, numerous problems appeared in the preparation of reports from the environmental database. The problems were always solved, but often only with the assistance of an expert from the Software Support Section.

ARCONs at LEP and SPS no longer booted from their servers after their operating system was upgraded in summer, and they had to be booted from a portable computer. As the information on the portables had not been kept up-to-date automatically, old calibration factors were sometimes entered. The intervention of the section staff and software experts was frequently required during the second half of the year.

4.3 Instrumentation

A new HPGe gamma detector was purchased to cope with the expected sample increase caused by the LHC project. It has considerably higher efficiency (50%) and significantly lower background (1.3 counts per minute integral) compared with the older detectors. Combined with a superior resolution, this device will allow very sensitive gamma spectroscopic analyses.

Hardware problems with the aged data acquisition and evaluation system for the HPGe detectors occurred frequently, and since the middle of the year only two of three detectors could be used reliably. However, all the analyses were finished according to schedule thanks to the efficient organization of the measurements and despite the increase of the sample load. Nevertheless, the troubles stressed the need for a new system. A lot of effort was expended to select the most suitable, flexible and reliable system for the whole TIS Division. It will be installed at the beginning of 1998.

Some improvements were also made to the liquid scintillation counting of tritium. After problems with chemiluminescence in spring, a procedure for the thermal treatment of vials was developed. This ensured an excellent stability of the measurements when using the liquid scintillation counter, even during summer. The counting protocols were modified and an Excel work sheet was prepared for calculating specific activities and detection limits. An instrument for sampling tritium in both water vapour and gaseous form in air was purchased.

4.4 Special measurements

The study of the influence of CERN's accelerator operation on the ^{7}Be content in the surrounding rivers, which started in 1996, continued in 1997. Sediment samples were taken from four sampling points along the river Le Lion on a monthly basis. Two points (MUL0 and MUL1) were located upstream and two points (MUL2 and MUL3) downstream of the CERN water release points. By the end of the year, 44 sediment samples had been analysed in addition to the routine programme. The results for ^{7}Be are presented in Fig. 4. It was shown with multiple sampling that the measured specific activities of ^{7}Be taken from the same place at the same time may vary by a factor of almost two, whilst the specific activities of the long-lived primordial nuclides and ^{137}Cs are almost constant. The reason for this is the short half-life of ^{7}Be (53.3 days) and time stratification in the sediment perturbed by sampling. The specific activity of each nuclide depends on the type and composition of the sediment. As expected, sediment containing more mud in detriment to sand grains shows higher specific activities. The omnipresent ^{137}Cs is a good indicator of the mud content. Its concentration is about an order of magnitude higher in MUL1 than in other sediments, indicating a high degree of natural radionuclide concentration in the sediments from MUL1. Despite the large scattering of the measured values, some general features of the ^{7}Be concentrations can be observed in the sediment. The annual mean concentration of ^{7}Be has a tendency to increase downstream, with the exception of MUL1 in which, however, the radioactivity is more concentrated than at the other sampling points. It is about two times higher in MUL3 than in MUL0. Up to now, the possible CERN contribution to the ^{7}Be content in the sediments of Le Lion could not be assessed easily because the natural seasonal variation of the ^{7}Be fall-out coincided with the operation of CERN's accelerators. Owing to the fire at BA3, the 1997 peak of the CERN ^{7}Be releases into air moved to August, September, and October (Fig. 5). On the other hand, the maximum ^{7}Be concentrations in the Le Lion sediments occurred in the early summer (May, June, July) which is typical for natural seasonal variations. This implies that the relatively high ^{7}Be concentration found in the river Le Lion is predominantly of natural origin. A contamination of Le Lion with ^{7}Be caused by CERN water releases is excluded. The river receives discharge water from the North Area and West Experimental Hall, but no proton beam was delivered to the corresponding targets during June and July. In addition, no ^{7}Be was identified in the water releases (Table 2). The wash-out activity rinsed off from the basin of Le Lion, which covers a large part of the Pays de Gex, concentrates in the sediments. This does not occur to such an extent in the rivers l'Allondon and La Versoix which is also confirmed by the lower ^{137}Cs concentrations found in these rivers. Finally, the low ^{7}Be concentrations in the sediments of Le Nant d'Avril compared to those of Le Lion can be explained by the artificial origin of this river. The flow of Le Nant d'Avril is formed mostly by the discharged used SPS cooling water that is originally supplied from the water treatment plant Le Vengeron, and which is free of wash-out activity. Again, the comparatively low ^{137}Cs concentrations in the sediments of Le Nant d'Avril confirm this.

Some measurements of farm products were performed. The asparagus from a farm near CERN only showed: ^{40}K (86 Bq/kg of fresh weight). Fountain water from the farm was also analysed, but no artificial radioactivity was found.

In September, a soil sample was taken at Choully (vineyards, 100 m south-west of the water tower) and analysed in parallel with the SÜR in Fribourg. Besides the natural members of the uranium and thorium decay series and ^{40}K, only omnipresent artificial ^{134}Cs and ^{137}Cs and natural and man-made ^{7}Be were identified (^{134}Cs: 0.8 Bq/kg, ^{137}Cs: 47.5 Bq/kg, ^{7}Be: 19 Bq/kg).

Table 2: The release of aqueous activity from the CERN sites during 1997

Release point	Water released	Total beta activity		^{3}H		^{22}Na		Released into :
	$10^6 \cdot m^3$	Bq/l	MBq	Bq/l a)	MBq	Bq/l	MBq	
SWL2	2.3	0.14 b)	–	29	66700	–	–	Le Lion
SWL3	0.05	0.10 b)	–	< 15	–	–	–	Le Lion
SWN1	7.85	0.09 b)	–	< 15	–	–	–	Le Nant d'Avril
SWN2	1.25	0.13 b)	–	< 15	–	–	–	Le Nant d'Avril
SWN3	4.7	0.11 b)	–	< 15	–	–	–	Le Nant d'Avril
SW901	2.0	0.10 b)	–	< 15	–	–	–	Le Nant d'Avril
SWNA	0.000448	17	7.6	150	67	18	8.1	Sewage treatment plant, Peney
Total	18.2		7.6		66800		8.1	

a) Detection limit: 15 Bq/l.

b) Activity corresponds to natural background for these release points.

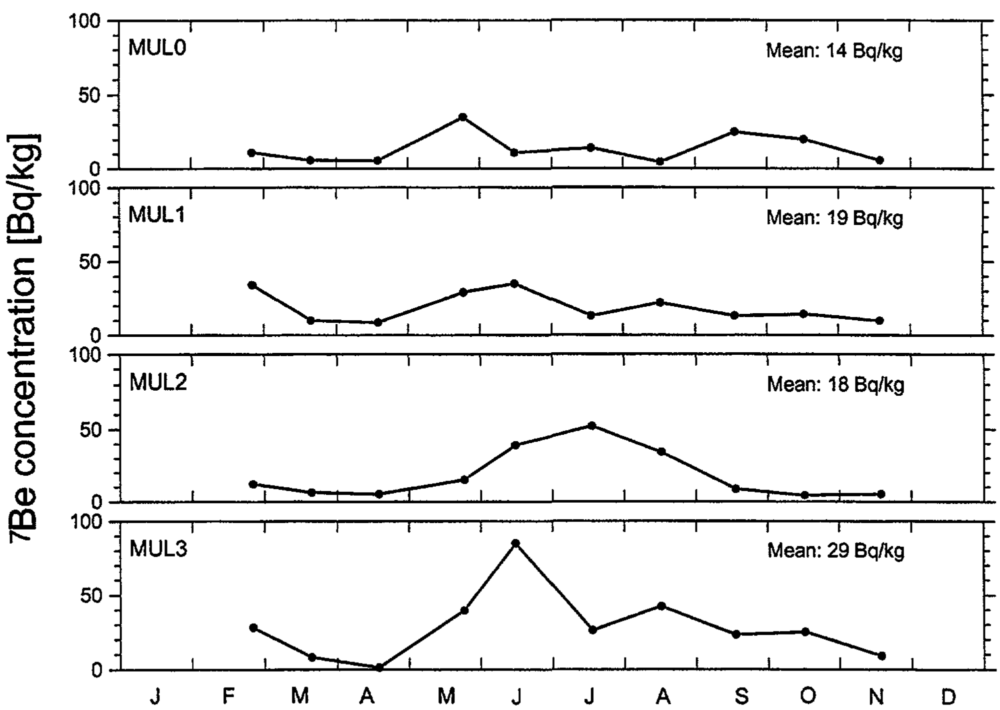

Figure 4: Activity of ^{7}Be in river sediment samples in 1997 for four sampling points in the river Le Lion (MUL0 - MUL3)

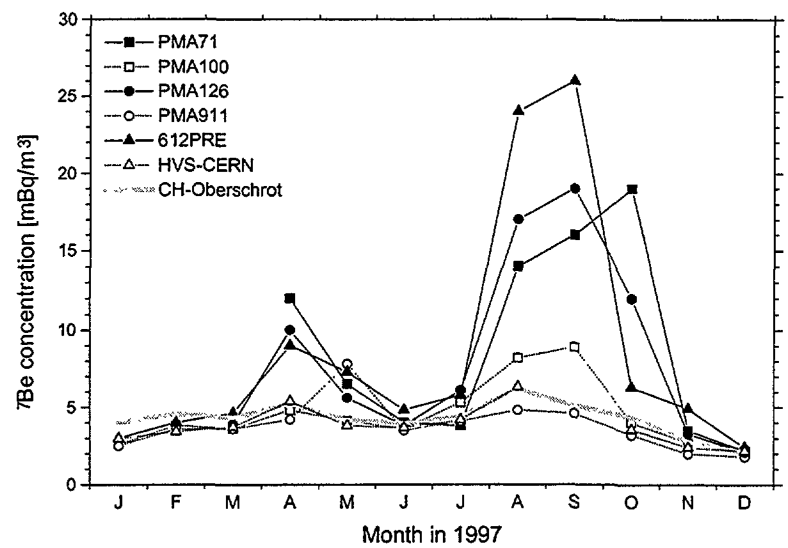

Figure 5: Monthly concentrations of ^{7}Be in aerosol measured at CERN and Oberschrot in 1997

4.4.1 Intercomparisons

The Section participated in four intercomparison exercises in 1997. The first exercise organized by the 'Intitut de radiophysique appliquée' in Lausanne, simulated a situation during a nuclear accident. A sample of wet grass had to be analysed for gamma activity in the shortest possible time. A prompt reporting of the results rather than their accuracy was important. The second intercomparison, arranged by the 'Office de Protection contre les Rayonnements Ionisants' (O.P.R.I.), Le Vésinet, France, required the analysis of a water sample for tritium and gamma activity. The remaining two exercises, 'Abluft 1997' and 'Wasser 1997', were co-ordinated by 'Bundesamt für Strahlenschutz' in Berlin. In the former, a polyethylene disc contaminated with radionuclides had to be analysed in the same way as an aerosol filter for gamma activity, whilst in the latter, tritium and gamma nuclides had to be measured in a water sample.

Table 3 summarizes the types of the samples, the identified nuclides, their reference activities, and the ratios of the measured over the reference values. In general, quite good results were obtained, especially for the water samples because the counting geometry is defined and preserved. The excellent tritium analysis rewarded the efforts expended for improving the liquid scintillation counting method. The values for the IRA grass sample were significantly overestimated as the available amount of grass was not sufficient to fill up the used 1 l Marinelli beaker, and the counting geometry did not correspond to the calibration conditions. However, the overestimation kept the results on the safe side. The short-lived daughter product ^{99m}Tc in equilibrium with its parent ^{99}Mo was not reported separately because the used nuclide library had assigned the ^{99m}Tc lines to ^{99}Mo. Owing to the lack of time the possible ^{99}Mo progenies were overlooked. The nuclide tables in the counting equipment were modified to prevent such a mistake happening in the future.

The results of numerous intercomparison exercises in 1997 proved the quality of the data provided by the Section, and placed its environmental laboratory amongst the best laboratories in the region.

Table 3: CERN results in the 1997 intercomparisons presented as ratios of the measured over the reference activities

Intercomp.	Sample type	Nuclide	Reference activity	Ratio	Method
IRA	Wet grass	^{131}I	1.85 kBq	1.38	HPGe
		^{99}Mo	1.10 kBq	1.20	HPGe
O.P.R.I.	Water	^{3}H	48.6 Bq/l	1.00	LSC
		^{40}K	57.0 Bq/l	0.91	HPGe
		^{137}Cs	50.2 Bq/l	0.96	HPGe
BfS "Abluft"	PE disc	^{57}Co	6.48 Bq	1.24	HPGe
		^{60}Co	2.61 Bq	1.05	HPGe
		^{65}Zn	6.56 Bq	1.12	HPGe
		^{152}Eu	13.1 Bq	1.03	HPGe
BfS "Wasser"	Water	^{60}Co	4.70 Bq/l	0.94	HPGe
		^{75}Se	9.86 Bq/l	1.01	HPGe
		^{85}Sr	2.80 Bq/l	1.13	HPGe
		^{137}Cs	6.96 Bq/l	1.07	HPGe
		^{3}H	50.8 Bq/l	0.98	LSC

5 OPERATION OF THE CERN ACCELERATORS DURING 1997

Figure 6 gives the time schedule of the CERN accelerators for 1997 and their different modes of operation. The PS mainly provided protons for the SPS, electrons and positrons for LEP, and protons for experiments at the East Hall. The fire at BA3 caused an interruption of SPS operation from 13 May until 27 July, a delay in the start-up of LEP by about 35 days, and the cancellation of the traditional Pb ion run at the end of the year. The total number of protons delivered to fixed targets by the SPS was almost the same as in 1996 despite the stop caused by the fire at BA3. For LEP a record integrated luminosity was reached in 1997, running mostly at energies higher than 90 GeV. The total number of all particles accelerated at CERN is given in Table 4 [5], [6].

Table 4: Integrated number of accelerated particles (for PS and SPS in 10^{16})

Year	PS			SPS			LEP
	p	Heavy ions	e^-, e^+	$p^{1)}$	Heavy ions	$e^-, e^{+\,2)}$	Integrated luminosity$^{3)}$
1987	$2.6 \cdot 10^3$	$1.1 \cdot 10^{-3}$	0.74	$8.0 \cdot 10^2$	$1.3 \cdot 10^{-3}$	–	–
1988	$6.1 \cdot 10^3$	–	2.2	$1.3 \cdot 10^3$	–	–	–
1989	$6.3 \cdot 10^3$	–	30	$1.5 \cdot 10^3$	–	22	11.7
1990	$5.5 \cdot 10^3$	$1.0 \cdot 10^{-3}$	23	$1.1 \cdot 10^3$	$3.0 \cdot 10^{-4}$	17	7.6
1991	$4.7 \cdot 10^3$	$1.0 \cdot 10^{-2}$	39	$1.3 \cdot 10^3$	$1.0 \cdot 10^{-3}$	30	17.3
1992	$4.2 \cdot 10^3$	$3.6 \cdot 10^{-2}$	44	$1.1 \cdot 10^3$	$6.5 \cdot 10^{-3}$	34	28.6
1993	$5.6 \cdot 10^3$	–	45	$1.3 \cdot 10^3$	–	35	40.0
1994	$5.5 \cdot 10^3$	0.91	51	$1.1 \cdot 10^3$	$7.4 \cdot 10^{-2}$	40	64.5
1995	$5.7 \cdot 10^3$	0.91	79	$2.0 \cdot 10^3$	0.15	62	46.1
1996	$5.8 \cdot 10^3$	1.30	19	$2.3 \cdot 10^3$	0.49	15	24.7
1997	$3.6 \cdot 10^3$	–	20	$2.2 \cdot 10^3$	–	16	73.4

1) Protons on targets

2) Estimated, 78% of the PS figure

3) in pb^{-1}

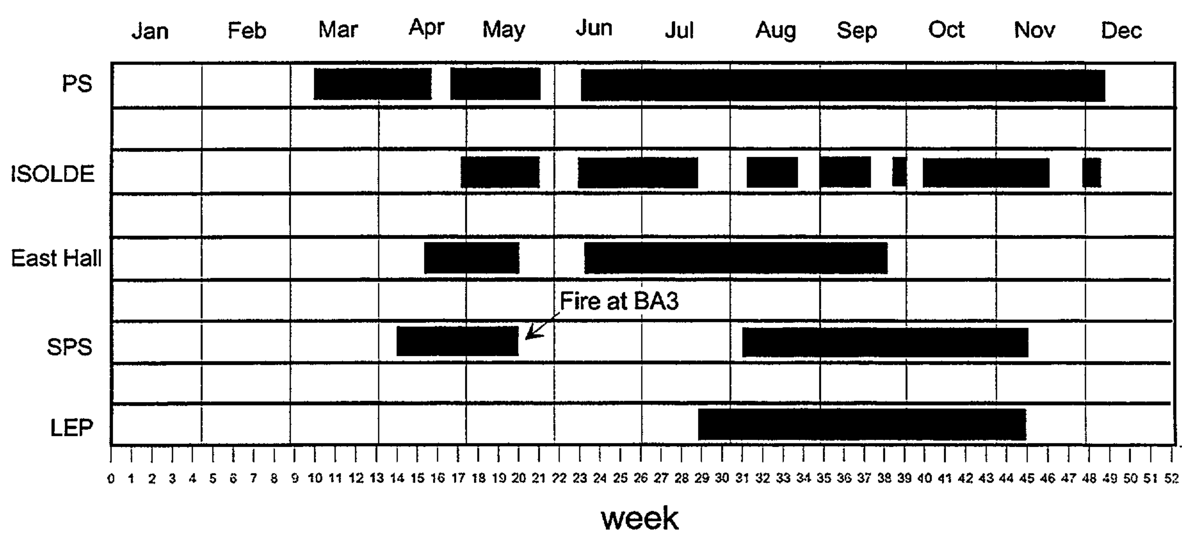

Figure 6: Schedule of the CERN accelerator operation in 1997

6 RESULTS OF MEASUREMENTS

6.1 Summary of releases

6.1.1 Radioactivity released into the atmosphere

Aerosol and gaseous radioactivity released from the PS, SPS and LEP accelerator complex and beam-transfer tunnels is continuously sampled at the air extraction points of their respective ventilation systems. The beta radioactivity concentration is measured by passing the sampling stream through an ionization chamber. The fraction of the radioactivity attached to aerosols is collected on an aerosol sampling filter which is replaced bimonthly and analysed for beta and gamma radioactivity. The sampling points are downstream of coarse filters which are part of the ventilation systems. The exhaust rate of the ventilation systems is recorded continuously. Based on the measurements of beta radioactivity on the aerosol filters and the record of the exhaust rate, the total release of long-lived beta activity attached to aerosol is estimated to have been 14 MBq (19 MBq in 1996). The detailed breakdown per exhaust is given in Table 5. These values represent the radioactivity released when CERN's accelerators are operating corrected for the background measured by each individual station. It should be noted that the operation of LEP, at times with an energy higher than 90 GeV, did not produce any aerosol activity. The only significant gamma-emitting radionuclide identified on aerosol filters at the PS and SPS air exhaust points was, as during previous years, ^{7}Be. It is estimated that 25 MBq of ^{7}Be (121 MBq in 1996) radioactivity was released from the SPS installation and 417 MBq (496 MBq in 1996) from the PS complex. Other gamma-emitting nuclides (^{22}Na, ^{46}Sc, ^{48}V, ^{56}Co, ^{58}Co, ^{52}Mn, ^{54}Mn, ^{121}Te, ^{133}Ba and ^{233}Pa) were detected on the aerosol filters at the air exhaust points of the SPS, at its transfer tunnels TT20, 60, and 70, and at the PS. However, their concentrations were at least two to three orders of magnitude lower than those of ^{7}Be found on the same filters.

Table 5: The release of gaseous and aerosol activity during 1997

Release point (PMV)	Air release	Beta activity (aerosol)		^{7}Be activity (aerosol)		Gaseous activity ^{11}C, ^{13}N, ^{15}O, ^{41}Ar		Remarks
	$10^6 \cdot m^3$	mBq/m^3	MBq	mBq/m^3	MBq	mBq/m^3	TBq	
11	41	26	1.1	590	24	18	0.7	TT10 injection SPS
31	73	< 0.9	–	< 1	–	6	0.4	Main ring SPS
51	65	< 0.5	–	11	0.72	–	–	Main ring SPS
801	26	1.6	0.04	5.5	0.14		1.6	TT20 extr. North
Total			1.14		24.9		2.7	SPS
74	190	40	7.6	1300	247	17	3.2	Main ring PS
72	46	13	0.60	440	20	50	2.3	TT60 extr. West, PS
73	43	3.1	0.13	67	2.9	14	0.6	TT70 transfer p,PS
170	105	40	4.2	1400	147	127	13.3	ISOLDE
Total			12.5		417		19.4	PS/ISOLDE
901	241	< 0.15	–	< 1.0	–	–	–	LEP point 1
903	241	< 0.03	–	< 1.0	–	–	–	LEP point 3
905	241	< 0.12	–	<1.2	–	–	–	LEP point 5
907	241	< 0.11	–	<1.0	–	–	–	LEP point 7
TOTAL		14		442		22		SPS/PS/ ISOLDE/LEP

Note: PMV 70 and PMV 819 are closed circuits and are therefore not given in the table. PMV 26 monitors the air of the hot chemistry. No activity was released during 1997.

Gaseous radioactivity produced in air by the operation of high-energy accelerators is mainly in the form of short-lived positron-emitting radioisotopes such as ^{11}C, ^{13}N, ^{14}O, and ^{15}O. Their radioactivity concentrations are measured continuously by the flow-through ionization chambers on the exhaust sampling lines. During 1997, 2.7 TBq of gaseous beta activity (4.9 TBq in 1996) were released through the air extraction shafts of the SPS installation, 19.4 TBq from the PS and ISOLDE (13.2 TBq in 1996). No measurable activity was released from the LEP tunnel (Table 5).

A total of 29 m^3 of water collected from the pit V_0 was evaporated retaining the ^{22}Na as a deposit. The highest tritium concentration in the V_0 water determined during the year was 270 MBq/m^3, resulting in the upper estimate of the tritium release of 7.8 GBq in the form of HTO vapour. This figure is comparable to that of the previous year. Finally, the release of tritium by the ventilation systems of accelerator tunnels must be considered. This tritium is not directly measured, but its amount can be estimated using the ^{7}Be activities released, as both nuclides are spallation products with a similar behaviour in their formation. In 1996, measurements on the release of tritiated water vapour and tritium gas were performed at CERN for various installations [7]. The results showed that most of the tritium is released in the form of water vapour and that the ratio between the concentrations of ^{3}H and ^{7}Be is not greater than ten. Hence, an upper limit for the total amount of tritium released via the ventilation systems is estimated as 3.9 GBq.

In the course of the year, five uranium carbide targets and one thorium carbide target were changed in ISOLDE. For these operations, the releases of gaseous radioactivity were monitored and they amounted to 60 MBq of ^{220}Rn and 140 kBq of ^{131}I for the entire year (255 MBq of ^{220}Rn and 82 kBq of ^{131}I in 1996). The balloons which collect the exhaust air from the vacuum pumps of ISOLDE were emptied three times after periods allowing decay of the radionuclides. Analyses showed that the air contained a total of 2.5 GBq of ^{3}H (6.6 GBq in 1996), 6.6 MBq of ^{127}Xe (186 MBq in 1996), and 18 MBq of ^{85}Kr. The releases of radioactivity from ISOLDE decreased significantly in 1997 compared with 1996 as a new system of plugging the flanges of heavy targets was installed in the target area. Taking into account the tritium release from ISOLDE, the total amount of gaseous tritium releases from CERN can be estimated as 14 GBq, a value well below the reference level of 10 000 TBq.

In conclusion, it can be said that airborne activity with a longer half-life released from CERN in 1997 decreased compared with 1996, and approached the level of 1995 due to the much smaller release of ^{7}Be from the SPS complex.

6.1.2 Radioactivity released into water

The quantities of cooling and drainage water released from the two CERN sites into the rivers Le Lion and Le Nant d'Avril during 1997 are shown schematically in Fig. 7. Table 2 gives the mean concentration of long-lived beta and tritium activities in water released from the CERN sites during 1997. The total amount of water released into these rivers was 2.35×10^{6} m^{3} and 15.8×10^{6} m^{3}, respectively. The release of radioactivity into Le Lion consisted of 66.7 GBq of tritium. The releases into Le Nant d'Avril were consistent with natural background levels. Water samples were also taken close to the ACOL installation, at sample point SWNA (pit DP62 in Bldg. 193). The water collected in pit DP62 percolates through the ground around ACOL where it leaches out radioactivity produced by secondaries in the earth shield around the target. The radioactivity measured for 1997 averaged over the monthly samples was about the same as in 1996: 17 Bq/l of total beta activity, 18 Bq/l of ^{22}Na, and 150 Bq/l of tritium. However, considerably less water was released in 1997 than in previous years with no increase of the long-lived specific activity in the pit water as there was no beam in 1997. The total radioactivity in the water released from SWNA into the general sewage system connected to the Peney water treatment plant was estimated from the measured samples. A total of 67 MBq of tritium activity and 7.6 MBq of other beta activity was released in 1997, one order of magnitude less than in 1996. In 1997, no water was released from the retaining vessel in the Nuclear Chemistry Group Laboratory.

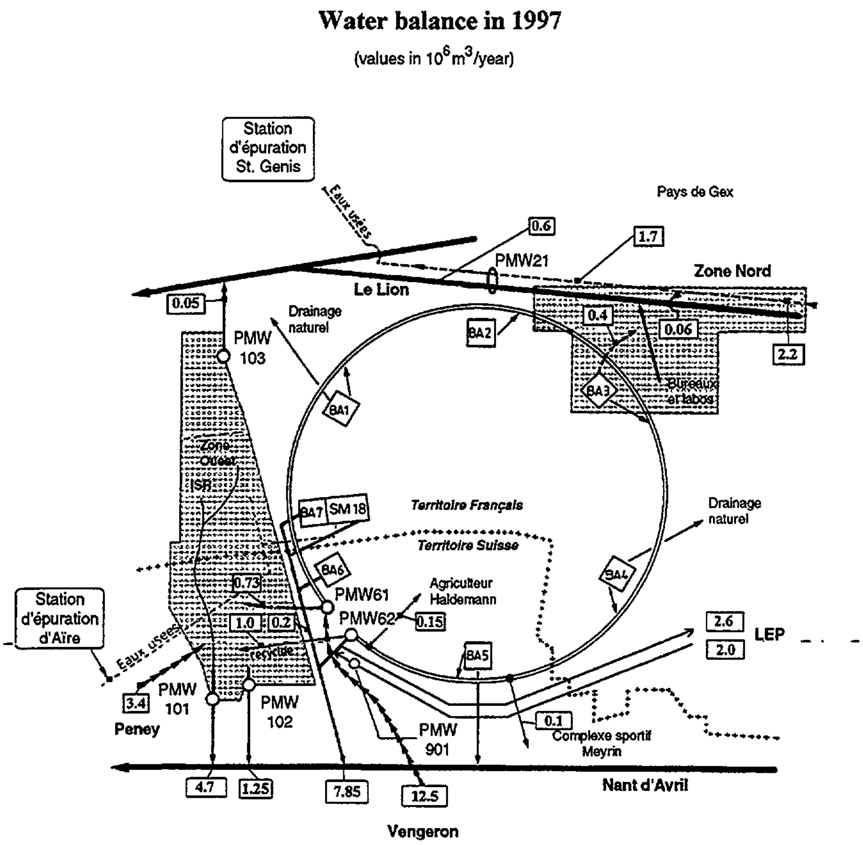

Figure 7: Distribution and consumption of water for the two CERN sites in 1997

Except for tritium, the mean long-lived beta activities measured in water samples taken continuously at the CERN water release points were comparable with those found in the incoming water. The concentration of gamma-emitting isotopes produced by CERN in all water samples was below the detection limit of the measuring equipment.

6.2 Environmental Impact

6.2.1 Natural environmental radiation

The total mean annual dose due to natural environmental radiation around the CERN sites for 1997 was established from the readings of the stray radiation monitors during the shutdown periods of the accelerators. This figure has been stable over the years and in 1997 the average of the 28 gamma monitors was 730 ± 65 μSv compared to a 10-year average of 724 ± 21 μSv. The average reading of the 28 neutron monitors during 1997 was 66 ± 7 μSv compared to a 10-year average of 61 ± 7 μSv. A constant annual background of 724 μSv gamma and 61 μSv neutron was deducted from the readings of the site gamma and neutron monitoring stations, respectively.

6.2.2 Dose measurements at the CERN boundaries

The total annual doses for 1997, measured at the Meyrin, Prévessin, SPS, and LEP site boundaries by neutron and gamma radiation monitors, are shown in Fig. 8. The mean contributions from gamma radiation and neutrons of natural origin are indicated at the lower parts of the graph bars. The higher readings of some monitors, exceeding the indicated natural background, are due to an inherent higher background reading of this type of monitor (Harwell). This concerns, for example, PMS120 and PMS912. The relatively high gamma dose measured by PMS118 (located close to pit V_0) occurred again in 1997. However, as shown in a special investigation, the monitor, which is placed in Bldg. 295, cannot be considered as a fence-post monitor. The high gamma dose measured by PMS817 is due to the high background of this monitor which is situated in a building with some radioactive concrete nearby (Bldg. 892). Quarterly dose values for four representative radiation monitoring stations are shown in Fig. 9. As the accelerators were shut down during the first quarter, the readings for this quarter are representative of the background radiation levels. PMS72 is located near the neutrino access pit BA7 and shows no significant readings above background for the entire year, although the neutrino experiment continued to receive beam of high intensity in 1997. Station PMS119 monitors radiation from the operation of the West Experimental Hall (EHW). Increased neutron doses are clearly visible during the second, third and fourth quarter of the year. PMS122 reflects the operation of LINAC and the PS and showed slightly elevated neutron doses during the last three quarters. PMS813 usually measures radiation (neutrons) escaping in a sideways direction from the Experimental Hall EHN1 during experiments with lead ions. There were no increased neutron doses in 1997 as the run with lead ions was cancelled. The neutron and gamma doses (background subtracted) as measured by all fence post stations are summarized and compared with the results of previous years in Table 6. The measured net values of the monitoring stations installed near the LEP access pits can be explained by variations of the natural backgrounds of the installed monitors. There were no doses near the LEP access pits caused by LEP operation in 1997. Figure 10 illustrates the history of the readings of four representative monitoring stations over the past ten years. No significant changes occurred in 1997.

To obtain a more detailed spatial distribution of the annual doses along the perimeter of the CERN premises, a network of dose-integrating ^{6}LiF/^{7}LiF TLDs, placed inside 12.5 cm diameter by 12.5 cm long polyethylene cylinders, are mounted at the fences around the Meyrin and Prévessin sites. The results of these measurements are presented in detail in Part II of this Annual Report. They show that the net annual dose at the boundary of the Meyrin site due to gamma, charged-particle, and neutron radiation, was less than 300 μSv everywhere. The highest value is located near the West Experimental Area with a maximum neutron contribution of 280 μSv. The annual net dose averaged over all the integrating detectors around the Meyrin site was 90 μSv, compared to 112 μSv in 1996. At the boundaries of the Prévessin site, net doses were always smaller than 370 μSv, with a mean net dose at the fence of 117 μSv. The neutron dose alongside EHN1 was negligible due to the absence of the heavy ion run in 1997. Finally, the mean net dose at the fence of the LEP islands was below the threshold of detection, showing that the operation of LEP has no influence on the ambient radiation level around the access pits. The net fence-post dose limit of 1500 μSv set by CERN's Radiation Protection Policy was not exceeded anywhere.

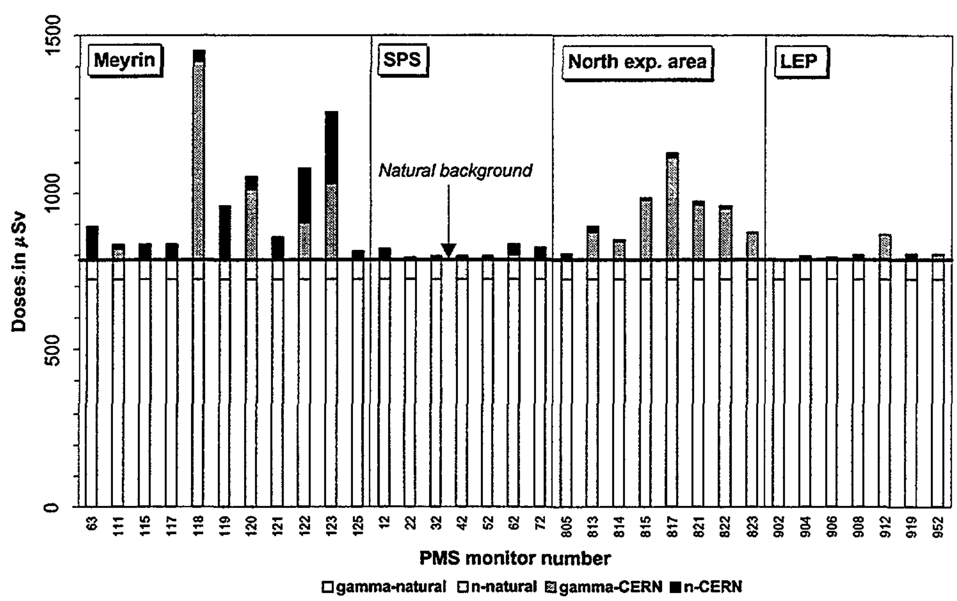

Figure 8: Results of dose measurements by the CERN monitor stations for the year 1997.The mean natural gamma and neutron backgrounds of 724 μSv and 61 μSv are assumed, respectively.

Table 6: Annual total doses (in μSv) at the fence post site stations (natural background of 785 μSv subtracted) from 1988 to 1997

Sites	Monitors PMS	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Meyrin	63	11	32	12	0	0	137	28	54	64	107
	111	0	32	38	20	130	145	115	153	95	47
	115	15	17	0	0	0	7	0	65	127	41
	117	48	57	14	44	77	80	11	63	61	29
	118	15	130	14	0	92	112	583	500	609	667
	119	330	190	140	200	200	427	268	293	187	170
	120	0	0	130	140	43	54	75	126	163	266
	121	–	–	140	75	150	263	177	174	95	13
	122	160	270	150	160	160	424	102	305	220	295
	123	110	210	150	200	210	272	180	299	198	473
	125	–	–	0	0	64	62	94	37	69	10
SPS	12	0	0	0	110	0	249	103	136	107	9
	22	39	60	0	0	57	38	13	0	0	0
	32	0	0	0	0	0	0	0	0	0	0
	42	0	0	0	47	34	0	0	37	1	0
	52	20	51	0	100	0	133	0	19	0	0
	62	1	5	0	0	0	27	11	55	41	48
	72	16	0	0	0	68	45	0	14	12	20
North experimental area	805	170	98	5	79	36	167	41	86	84	0
	813	110	160	0	96	280	544	80	192	216	107
	814	–	400	70	180	190	362	236	293	213	65
	815	53	22	29	36	96	228	111	97	257	200
	817	450	480	330	390	337	373	349	404	368	345
	821	19	76	0	0	55	126	11	98	94	188
	822	150	190	91	210	0	255	145	190	168	172
	823	240	280	81	130	170	205	115	174	146	87
LEP	902								0	0	0
	904								0	0	0
	906								0	0	0
	908								36	36	14
	912	0	0	0	0	0	62	0	15	4	81
	919								146	114	0
	952	0	0	0	0	0	58	48	93	21	19

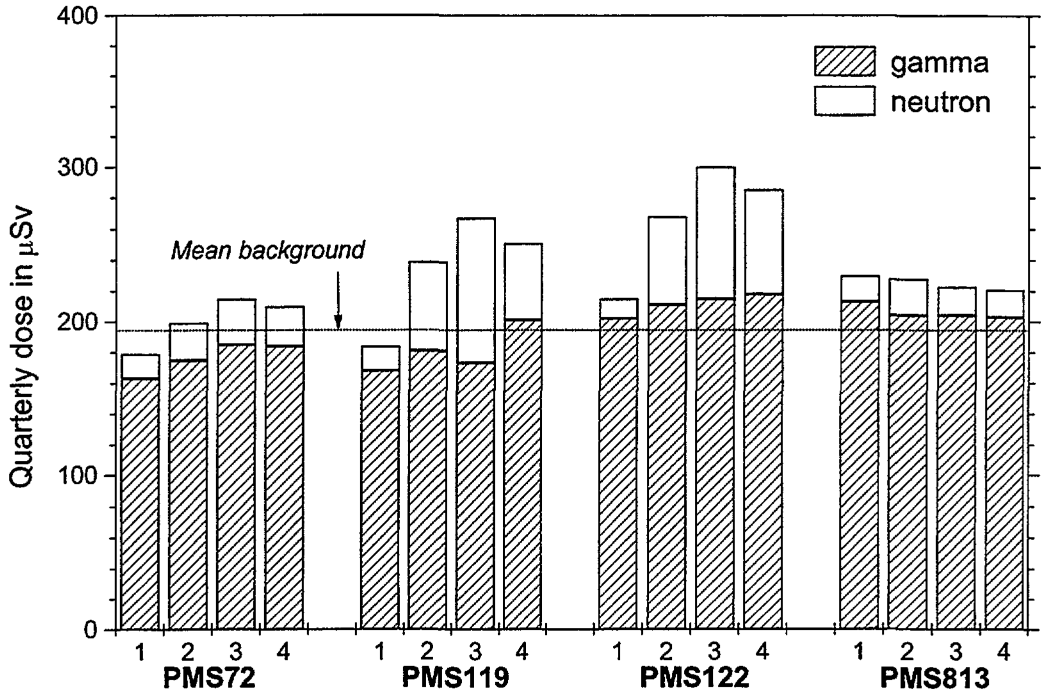

Figure 9: Quarterly doses at some selected and representative site monitor stations in 1997

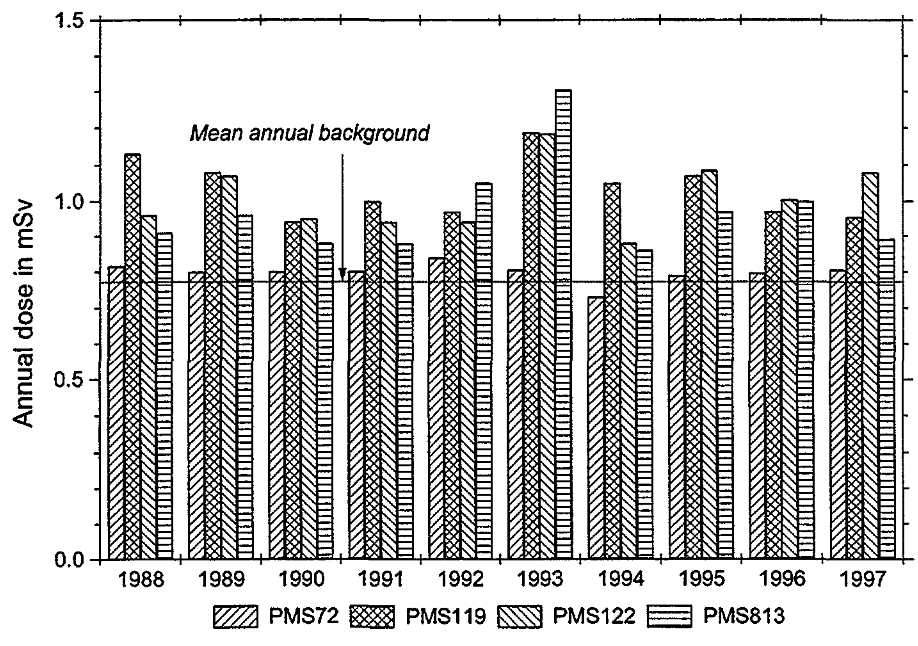

Figure 10: Annual doses for four representative fence post monitor stations, from 1988 to 1997

6.2.3 Measurements of samples from the environment

The number of samples measured in the laboratory in 1997 is given in Table 7. The samples were measured for their content of beta and gamma radioactivity as part of the routine CERN environmental monitoring programme (sampling points, see Fig. 3). The water samples were also measured for tritium. The number of special measurements is also presented. This category comprises additional samples, samples analysed as part of intercomparison measurements, samples analysed at the request of other RP sections, and samples for special survey programmes.

Table 7: Summary of samples analysed in the environmental laboratory in 1997

	Sample	Type of analysis				Total
		Alpha	Beta	Gamma	Tritium	
Routine	Aerosol filters	72	378	203	–	653
	Water		111	25	111	247
	Rainwater		24	2	24	50
	River sediments		4	4	–	8
	Water plants/moss		–	6	–	6
	Grass		–	7	–	7
	Wine		–	1	1	2
Special	Others		150	43	80	273
	River sediments		40	40		80
	Earth/vegetation		–	4	–	4
	Water		11	24	25	60
	Total	72	718	359	241	**1390**

6.2.3.1 Aerosol activity

The measurement of the high-energy spallation product ^{7}Be in air, collected on aerosol filters is a relevant parameter for the operation of CERN's proton accelerators and experimental areas. The results from four site stations for 1997 are presented in Fig. 5, together with results from the French monitoring station 612PRE at CERN [8], the Swiss high-volume sampler HVS-CERN at CERN [9], [10], and the Swiss monitoring station at Oberschrot [11]. As usual, only PMA71, PMA126 and 612PRE measure levels that are significantly different from natural background. All other stations show the well-known seasonal variation, although only three CERN stations were operated during all months of the year. As usual, the remaining stations were switched off during the first three months of the general CERN shutdown. PMA71 is aligned with one of the main wind directions from the neutrino target area and PMA126 is downwind from ISOLDE and the exhausts from the PS extraction region and tunnel. All these are known sources of ^{7}Be releases (Table 5). The influence of the unplanned SPS stop from 13 May to 27 July can be clearly seen in the annual variations of the ^{7}Be concentrations measured by the three affected stations. The ^{7}Be concentrations increased above the natural background in April, when the SPS started, then they decreased to the background level for June and July, but culminated during August, September and October. Slightly higher maximum concentrations than in 1996 were observed, probably due to the dry weather during August, September and October, causing limited wash-out of the aerosols from the air. For comparison, the average precipitation rate during these three months of only 41 mm/month was three times smaller than that during May, June and July (125 mm/month). The wash-out effect explains the annual variation of the total beta activity measured for the same stations (Fig. 11). The curves of all the monitors follow the same pattern, suggesting that the total beta activity consists mostly of the naturally present activity from U, Th decay series, and ^{40}K. The variations occur due to changes of the aerosol content of the ground-level atmosphere. The observations from previous years confirm this conclusion. The time coincidence of the ^{7}Be peaks and the beta activity peaks in August, September and October is only of a random nature, and the annual variations of the total beta activity reflect a cold and wet early summer followed by a warm and dry autumn. Exactly the opposite was observed for the washed-out beta activity in the precipitation expressed in Bq/m^2 which is shown in Fig. 12. Finally, the average annual ^{7}Be concentration measured at all PMA sampling stations, except PMA805, over the year was 5.0 mBq/m^3, compared with 4.3 mBq/m^3 in 1996. The results of the mean concentration of ^{7}Be in air for four selected sampling points for the last 10 years are shown in Fig. 13. No significant changes occurred in 1997.

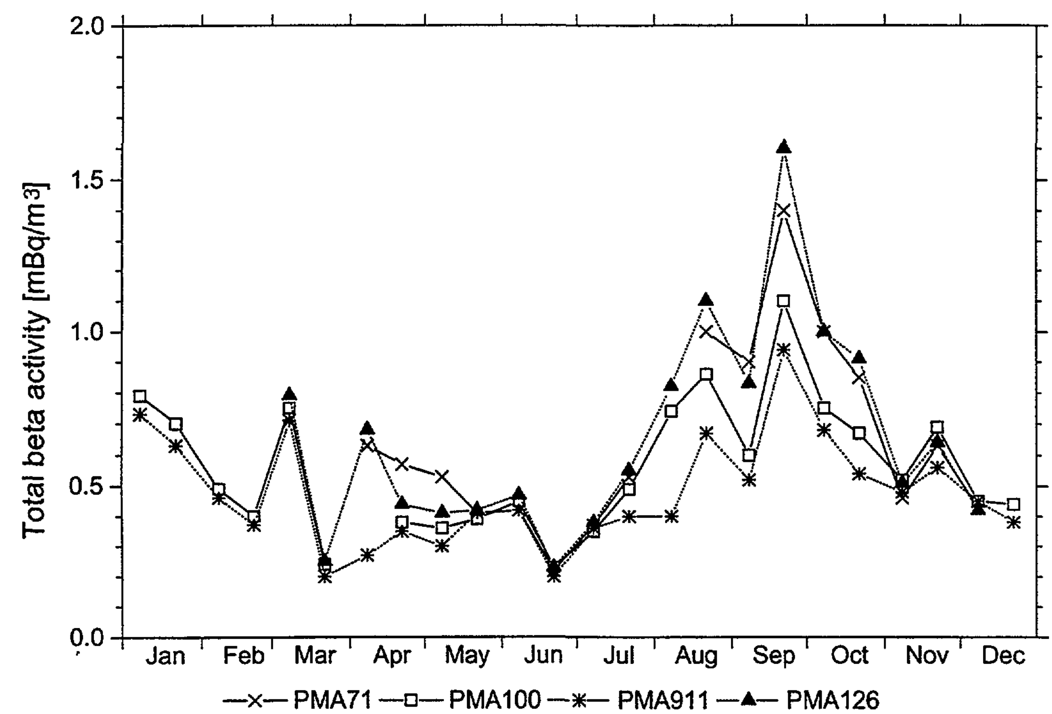

Figure 11: Total beta activity in aerosol measured at CERN in 1997 in a two weeks interval

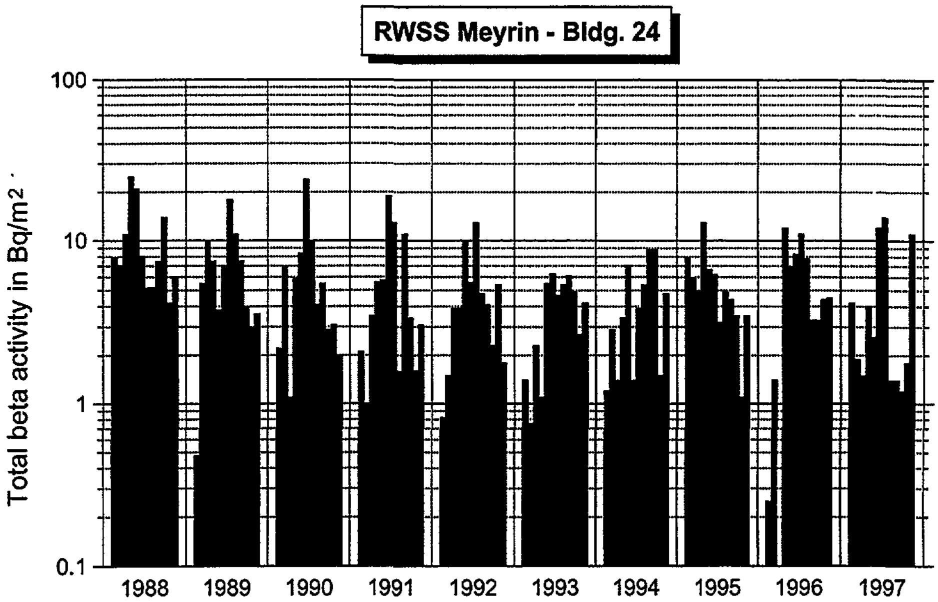

Figure 12: Total long-lived beta activity in precipitation at the Meyrin station RWSS since 1988

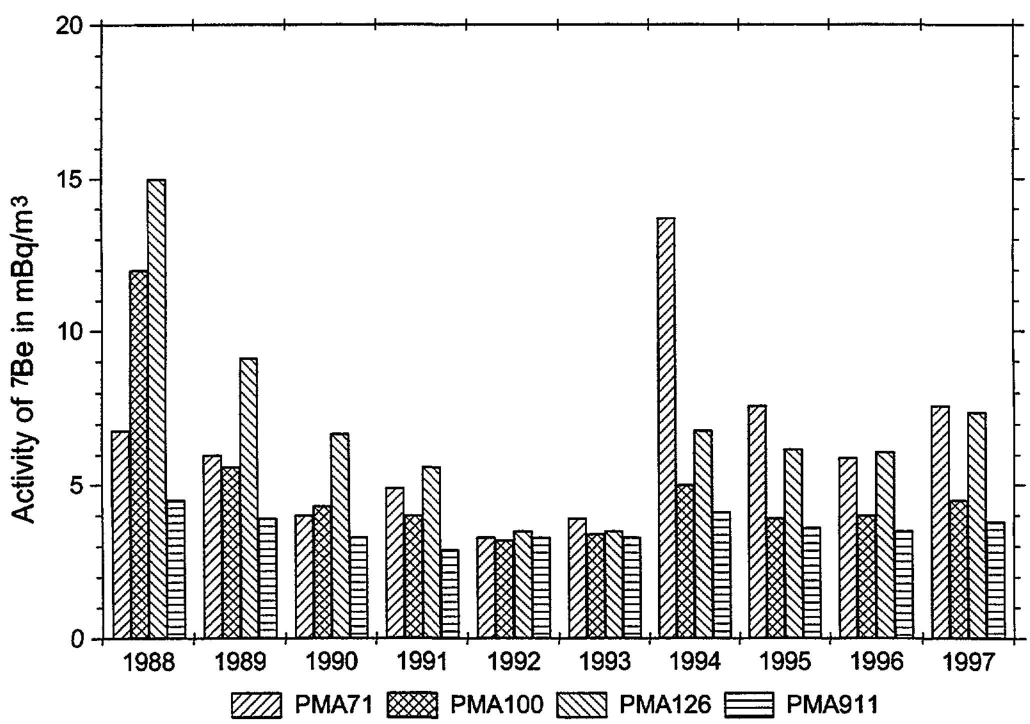

Figure 13: Average annual concentrations of ^{7}Be in aerosol measured at CERN for four selected sampling points since 1988

6.2.3.2 Water samples

a) Precipitation

The mean beta activity measured in rainwater samples for stations RWSS and RWSF during 1997 was 0.089 and 0.077 Bq/l, respectively. The total amount of precipitation collected for the entire year was 849 mm for station RWSS and 966 mm for station RWSF. The ^{7}Be and tritium concentrations in rainwater were always below the detection limit of the measuring equipment. For the years 1988 to 1997 the monthly variations of the total beta activity measured in rainwater and expressed as the quantity of radioactivity washed out of the atmosphere in Bq/m^2 at the stations RWSS in Meyrin and RWSF in Prévessin are shown in Figs. 12 and 14, respectively. The steady decrease noticed over the years following the reactor incident in Chernobyl in 1986 is barely visible as only the evolution over the last ten years is presented in the figures.

b) River water

Samples of river water were taken in June and September in L'Allondon, Le Lion, Le Nant d'Avril, La Versoix and around the LEP islands (Table 8). The values of the total beta activity concentration were low and in the range 0.055 to 0.14 Bq/l. The results of all tritium measurements remained below the detection limit of 15 Bq/l.

Table 8: Results of measurements of river and surface waters

1997 Date	Sampling site		Activity in Bq/l	
			Total beta	Tritium
20.06	SWA1	L'Allondon	0.055	< 15
20.06	SWL4	Le Lion	0.110	< 15
20.06	SWN4	Le Nant d'Avril	0.110	< 15
20.06	SWV1	La Versoix	0.092	< 15
24.09	SWLP2 (LEP)	Sergy	0.077	< 15
24.09	SWLP3 (LEP)	Crozet	0.120	< 15
24.09	SWLP4 (LEP)	Echenevex	0.094	< 15
24.09	SWLP5 (LEP)	Cessy	0.097	< 15
24.09	SWLP6 (LEP)	Versonnex	0.083	< 15
24.09	SWLP7 (LEP)	Collex/Ferney	0.130	< 15
24.09	SWLP8 (LEP)	Ferney/Mategnin	0.140	< 15

c) Well water and tap water

Samples of well water and tap water were taken in July on both sites and in their vicinity (Table 9). The values of the total beta activity concentration were low and in the range 0.032 to 0.15 Bq/l. The mean value for the total beta activity was 0.087 Bq/l. No tritium was measured above the detection limit of 15 Bq/l.

Table 9: Measurements of well water and tap water

1997 Date	Sampling site		Activity in Bq/l	
			Total beta	Tritium
22.07	FWPE	Meyrin site - Peney	0.110	< 15
22.07	FWVE	Prévessin - Vengeron	0.100	< 15
22.07	UWPR	Prévessin, fountain	0.150	< 15
22.07	UWSG	St. Genis, fountain	0.032	< 15
22.07	UWVX	Versonnex, fountain	0.042	< 15

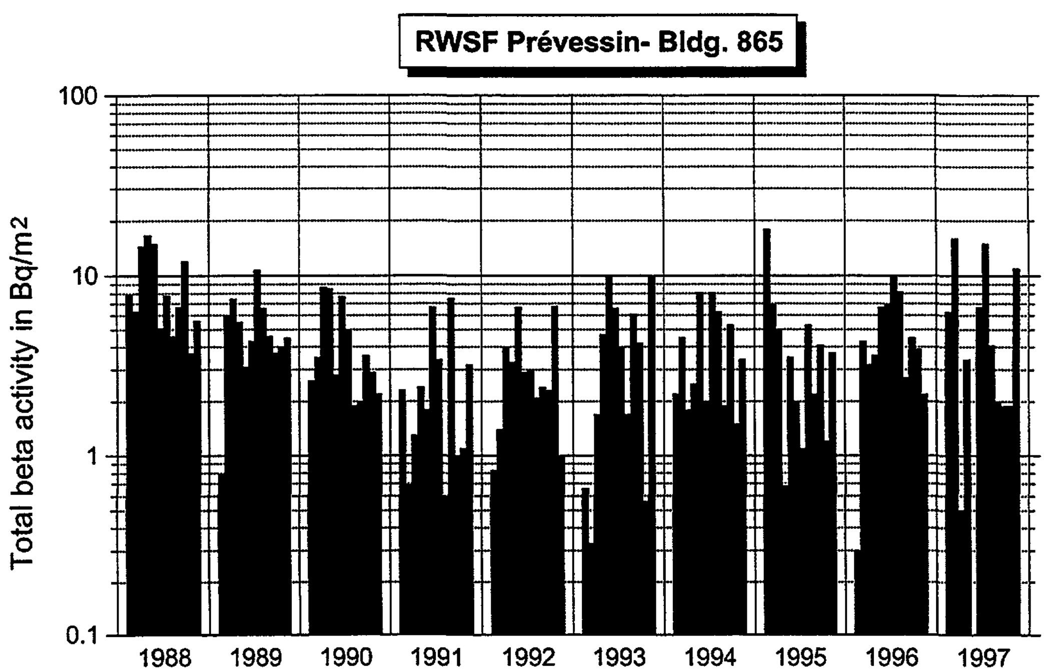

Figure 14: Total long-lived beta activity in precipitation at the Prévessin station RWSF since 1988

6.2.3.3 River sediments and river vegetation

In 1997, river sediment samples were taken more often than usual (see Section 4.4). For the usual routine measurements, the mean beta activity for Le Nant d'Avril, Le Lion, l'Allondon, and La Versoix amounted to 400 Bq/kg of dry weight, including an average ^{40}K content of 275 Bq/kg of dry weight. Other radionuclides identified in all samples were ^{137}Cs (3.2 Bq/kg), and ^{7}Be (29 Bq/kg) (Table 10). Traces of ^{54}Mn in the sediments from the rivers Le Lion (MUL3) and Le Nant d'Avril (MUN4) in the concentrations of 0.76 Bq/kg and 0.14 Bq/kg, respectively, were found. In addition, ^{56}Co was identified in the Nant d'Avril (MUN4), but in the minute concentration of 0.14 Bq/kg. The two latter nuclides may be ascribed to CERN activities.

Table 10: Results of routine measurements of river sediments

1997 Date	Sampling site		Activity in Bq/kg dry weight			
			Total beta	^{40}K	^{7}Be	^{137}Cs
20.06	MUA1	L'Allondon	410	290	7.2	1.7
20.06	MUL3	Le Lion	350	230	85	6.9
20.06	MUN4	Le Nant d'Avril	430	290	14	1.4
20.06	MUV1	La Versoix	410	290	11	2.9

As the water from rivers does not usually contain any artificial radionuclides in measurable concentrations (Table 8), it was decided, in accordance with the recommendations of SÜR in Fribourg, to include samples of river vegetation comprising water plants and moss in the routine programme. The river vegetation, especially moss, filters and concentrates radionuclides from the water. The location of the sampling points is shown in Fig. 3. Table 11 gives the concentrations of nuclides found in all samples, i.e. of natural ^{40}K, natural and artificial ^{7}Be, and man-made but omnipresent ^{137}Cs. The moss from Le Nant d'Avril (MON4) also contained, in trace amounts, radioisotopes of cobalt (^{57}Co, ^{58}Co and ^{60}Co of 1.8 Bq/kg, 0.57 Bq/kg and 1.7 Bq/kg, respectively), ^{54}Mn (1.6 Bq/kg) and ^{65}Zn (1.4 Bq/kg) which could have been produced at CERN. Part of the ^{60}Co might have been deposited in the moss via corrosion fragments from common steel which usually contains this radioisotope. Le Nant d'Avril receives a lot of (non-radioactive) cooling water flowing through steel pipes.

Table 11: Results of routine measurements of river vegetation

1997 Date	Sampling site		Type	Activity in Bq/kg fresh weight		
				^{40}K	^{7}Be	^{137}Cs
25.05	MOA1	L'Allondon	moss	62	88	0.95
29.05	WPL0	Le Lion	plant	189	39	0.34
25.05	WPL3	Le Lion	plant	136	50	0.52
25.05	MON4	Le Nant d'Avril	moss	95	372	5.9
08.06	MOV1	La Versoix	moss	64	74	1.6
08.06	MOV1	La Versoix	moss	59	91	5.7

6.2.3.4 Vegetation

Gamma spectroscopy analysis was performed on seven grass samples after drying. The results of the measurements are listed in Table 12. The average values of the specific activity found were: 803 Bq/kg of ^{40}K, 116 Bq/kg of ^{7}Be, and 1.0 Bq/kg of ^{137}Cs. These values may be compared with the averages of three values obtained for grass sampled at Grangeneuve and Arenenberg by SÜR [11]. They obtained 930 Bq/kg of ^{40}K, 130 Bq/kg of ^{7}Be, and approximately 3 Bq/kg of ^{137}Cs. The values obtained at CERN are comparable to those found elsewhere. A sample of wine produced from grapes collected 400 m south-west of the Proton Synchrotron in 1996 was analysed. The tritium concentration was below the detection limit of 15 Bq/l. The only radionuclide identified in the sample was the natural ^{40}K with a concentration of 18 Bq/l, the same as in the wine of 1995.

Table 12: Results of measurements of grass samples

1997 Date	Sampling site		Activity in Bq/kg dry weight		
			^{40}K	^{7}Be	^{137}Cs
14.05	GRB1	Meyrin site PS	700	100	–
21.05	GRB3	Meyrin New Isolde	600	120	0.99
21.05	GRB4	NE of BA7	990	110	–
14.05	GRC1	Cessy pit 5 LEP	990	85	–
14.05	GRE2	NW of AA	630	84	–
14.05	GRN1	North Area	710	120	–
21.05	GRVE	Le Vengeron (Reference sample)	1000	190	–

7 CONCLUSIONS

CERN's compliance with the national regulations of the host states and its own Radiation Protection standards are assessed with the help of the results of the routine environmental monitoring programme. The results of all the 1997 measurements are tabulated in the quarterly reports of the Environmental Section, to which the interested reader is referred for detailed information [1]–[4].

A summary of CERN's dose limits on stray radiation at the site boundary, and dose limits for airborne or liquid radioactive material are given in Table 13. These limits are laid down in CERN's Radiation Safety Manual, Edition 1996.

Table 13: Dose limits applied at CERN according to ICRP Recommendation 60 and the Radiation Protection Manual [15], [16]. All limits are expressed in effective dose except the one for the fence-post dose which is ambient dose equivalent

	CERN annual dose limit	**Dose limits in Recommendation 60 of the ICRP**
Persons working at CERN †	1 mSv	1 mSv
Fence post dose	1.5 mSv	
Dose to the population outside CERN	0.3 mSv	1 mSv
Exposure due to gaseous releases	0.2 mSv*	
Exposure due to liquid effluents	0.2 mSv*	

† Persons working on the site not belonging to the category of those exposed in the exercise of their profession for whom an annual effective dose of 15 mSv applies.
*The sum of the exposure from gaseous release and liquid effluents must remain below a total dose of 0.3 mSv per year.

In Table 14, reference values for the release of radionuclides from the Meyrin site are given. They were calculated on the basis of the Swiss Richtlinie HSK-R-41/d [12], [13], [14]. For the radionuclide categories mentioned, the most critical radionuclide was assumed (given in parentheses in Table 14). Such an approach introduces an additional conservatism. These values were approved by the Radiation Protection Committee [15]. They must be clearly understood as reference values to which actual releases are compared and eventually transformed into effective doses to the critical group of the population living near the Meyrin site of the Organization. In fact, the releases for each of the radionuclide categories given in Table 14 correspond to an effective dose of 0.2 mSv to the critical group which would then correspond to the annual dose limit for that particular category of radionuclides being released. Therefore, once more, the reference values in Table 14 only serve as a reference, and must not be considered as release limits.

Table 14: Reference values for the release of radionuclides calculated for the Meyrin site on the basis of the Swiss Richtlinie HSK-R-41/d [11], [12], [13]. For each category of radionuclides a release of the given activity in columns 2 or 3 corresponds to an effective dose of 0.2 mSv to the critical group of the population living in the vicinity of the Meyrin site

Reference values	Annual	Daily
Air path in GBq:		
Tritium (as gaseous HTO)	10 000 000	230 000
^{7}Be (as aerosol)	30 000	1400
Beta/gamma activities (T<1 day, ^{11}C)	3 800 000	50 000
Other beta/gamma emitters (T>1 day, ^{60}Co)	40	2
Radioactive iodine (^{131}I)	3 500	30
Alpha emitters (as aerosol, ^{210}Po)	3.7	0.15
Liquid path in TBq:		
Tritium (as HTO)	1 200 000	
^{7}Be	3 600	
Beta/gamma activities (T<1 day, ^{11}C)	57 000	
Other beta/gamma emitters (T>1 day, ^{22}Na)	280	
Alpha emitters (^{210}Po)	0.28	

CERN's actual annual releases for the various categories of radionuclides and their contribution to the effective dose for the critical group are given in Table 15. It should be noted that in this table the total activities released from all points are added up as if they had been released from the Meyrin site only. This approach presents a considerable overestimation of the effective dose to the critical group.

The quantities of radioactivity released into the atmosphere during normal operation of the CERN accelerator installations in 1997 (values for 1996 in brackets) are estimated from the measurements described above to be 22 TBq (18 TBq) of short-lived beta activity in gaseous form, 14 MBq (19 MBq) of long-lived beta activity in the form of aerosols, and 442 MBq (617 MBq) of ^{7}Be.

The quantities of long-lived radionuclides released from CERN were extremely small. The total amount of tritium released into water was 67 GBq which is only a small fraction of the annual release limit. Furthermore, the total beta activity (7.6 MBq) and the release of ^{22}Na (8.1 MBq) are far below the reference values in Table 14. Therefore, the concentration of all possible radioactive nuclides that may have been released through the CERN drainage systems into the neighbouring watercourses remained far below the limit of concentration in water that may be used by the general public.

Table 15: Ambient dose equivalent of stray radiation in μSv and release of radionuclides in GBq from CERN in 1997 and the corresponding effective dose in μSv to the critical group of the population living in the vicinity of the Meyrin site

	Release in 1997	**Effective dose in μSv**
Stray radiation in μSv:[1)]	107	22
Air releases in GBq:		
Tritium (as gaseous HTO)[2)]	*14*	*< 0.001*
^{7}Be (as aerosol)	0.442	0.003
Beta/gamma activities (T<1 day)	22000	1.2
Other beta/gamma emitters (T>1 day)	0.014	0.07
Radioactive iodine	0.00014	< 0.001
Alpha emitters (as aerosol)	0.060	3.2
Liquid effluents in GBq:		
Tritium (as HTO)	*66.8*	*0.011*
^{7}Be	–	–
Beta/gamma activities (T<1 day)	–	–
Other beta/gamma emitters (T>1 day)	0.0076	0.005
Alpha emitters	–	–
Total		**26.5**

1) Ambient dose equivalent of monitor PMS63 with 21% of occupation time assumed

2) All tritium is assumed to be released in the form of water vapour for which the dose factor is highest

The measurements indicate complete compliance with CERN's policy of limiting the dose at the site boundary to less than 1500 μSv [16]. No member of the general public should have received an effective dose in excess of 200 μSv for the year. This is lower than the annual dose limit of 300 μSv to members of the public set by CERN's policy, and substantially lower than the 1000 μSv recommended by the ICRP [17]. The radiological impact of CERN on its environment continued to be exceedingly low.

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