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PART II

RADIATION CONTROL ON THE CERN SITES

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1 INTRODUCTION

The Site Section of the Radiation Protection Group is in charge of general radiation protection activities related to the two CERN sites. During 1997 these activities were:

- stray radiation monitoring,
- radioactive waste management,
- storage of radioactive items,
- radioactive source control,
- radioactive transport,
- control of non-ionizing radiation,
- thermoluminescence dosimetry,
- radioactivity measurements.

A summary of these activities is presented in this part.

2 STRAY RADIATION MONITORING

The network for stray radiation monitoring covers all CERN sites including LEP. The isodose distributions, measured with ^{6}LiF and ^{7}LiF thermoluminescence dosimeters (TLDs) inside cylindrical moderators of 12.5 × 12.5 cm diameter, are presented in Figs. 1 and 2 for the CERN Meyrin and Prévessin sites, respectively [1]. The total ambient dose equivalent values at all positions indicated in these figures are listed in Tables 1a and 1b, together with the ambient dose equivalent due to neutrons, and to gamma radiation and charged particles separately. The ambient dose equivalent due to gamma radiation and charged particles is taken into account only when it exceeds the corresponding average natural background outside CERN by 0.1 mSv or more. For 1997 the natural background outside CERN for the TLD dosimeters was found to be 0.85 mSv from gamma radiation and charged particles, and 0.05 mSv from neutrons. The TLDs were calibrated in the stray radiation field itself by using detectors in all the installed Meyrin Site monitor stations (Fig. 1, position marked S). In this way, the net neutron effect (^{6}LiF–^{7}LiF) is compared with the reading of the Andersson and Braun rem counter, and the gamma dose of the ^{7}LiF detector is compared with the reading of the argon-filled ionization chamber [1]. The calibration constant for neutrons is influenced by the variation in the stray neutron spectrum causing an uncertainty of about 30%, whilst for gamma radiation this is of much less importance, causing an uncertainty of about 10%. The readout of the TLDs was carried out as usual in an automatic Alnor hot-nitrogen TLD reader, whereby all detectors after readout and annealing in this reader were individually calibrated with ^{137}Cs gamma radiation. Comparing the results for 1997 for the Meyrin site (Table 1a) with those for

1996, it can be concluded that around the PS the highest dose levels remained constant with a maximum of 2.35 mSv at position 58, compared with 2.42 mSv in 1996. The maximum neutron dose found in the vicinity of the SPS West Hall (position 40 in Table 1a) increased slightly with 1.97 mSv for 1997 and 1.36 mSv for 1996. The gamma dose at this position is now negligible, whereas in the past it was influenced by the storage of radioactive shielding blocks from the neutrino area nearby (0.23 mSv in 1996). These blocks were completely removed during 1997 and are now stored inside the ISR. A source of stray gamma radiation is the central RP storage area in the centre of the PS ring. Its influence is reflected in the gamma dose at positions 63, 64, 66, and 68 in Table 1a. Since almost all the radioactive material stored outdoors in this area was moved to the old ISR tunnel these doses are at a low level. On the Prévessin site all neutron doses are at a low level and much lower than in 1996, due to the fact that no operation with heavy ions took place. On the other hand, muon doses increased considerably at positions 260 (37.1 mSv) and 261 (2.8 mSv) compared with 1996 (6.3 and 0.6 mSv, respectively). However, position 260 is located in an inaccessible fenced-off area such that no personal exposures can occur. The stray radiation level due to the radioactive storage areas (buildings 917 and 955) on the Prévessin site showed a maximum of 0.37 mSv at position 265. The measurements show that the dose limit of 1.5 mSv was not exceeded at the fences of the CERN sites.

The annual doses registered from 1987 to date at the site monitor stations inside the fenced areas of the Meyrin and Prévessin sites are shown in Table 2, and all values are of a low level. The positions of these monitors are indicated in Figs. 1 and 2 of Part I. The results of fixed gamma and neutron monitors in the site stations for 1997 are presented separately, with natural background included, in Tables 3a and 3b for the Meyrin and Prévessin sites, respectively.

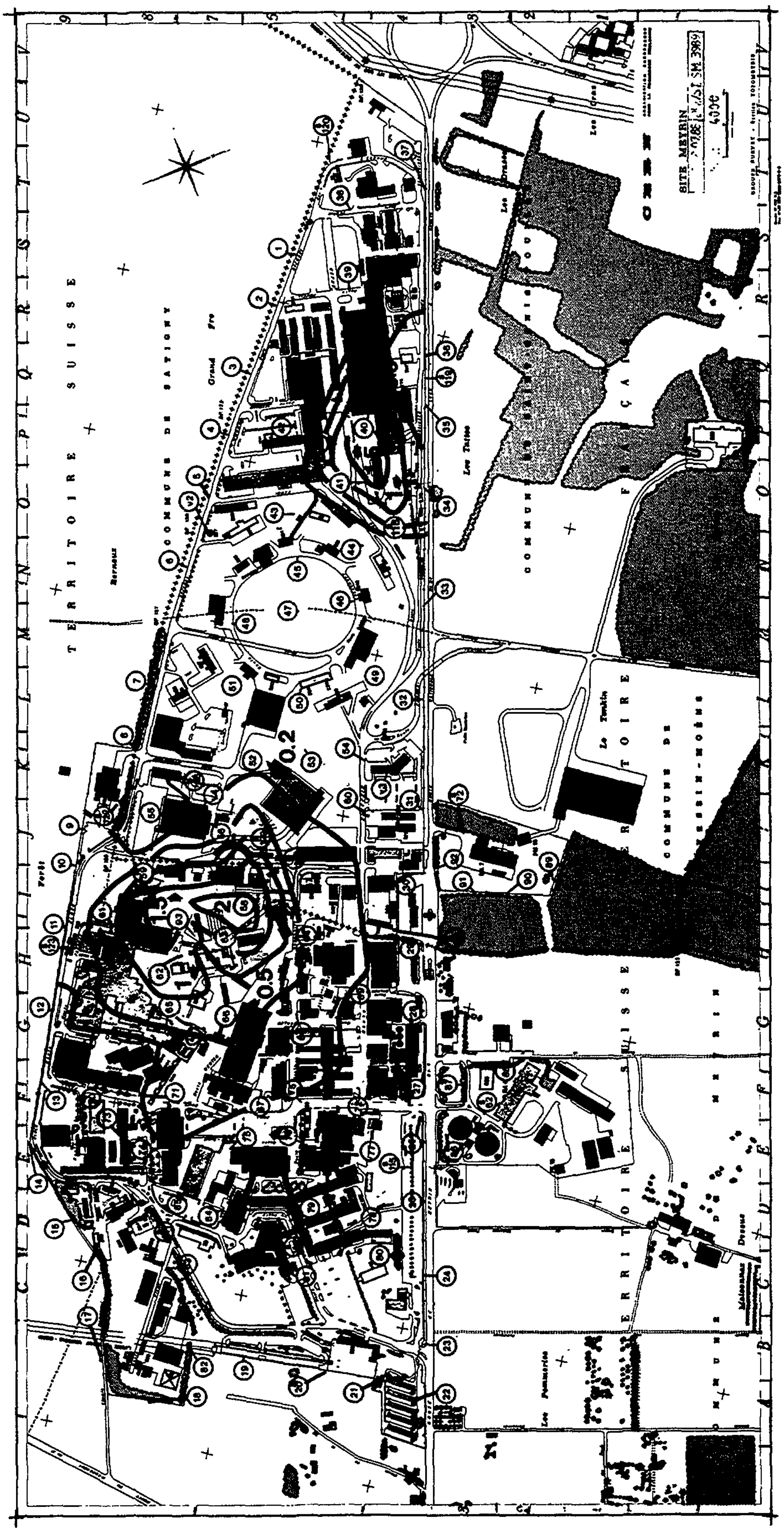

Figure 1: Isodose distribution on the Meyrin site during 1997 (total dose in mSv).

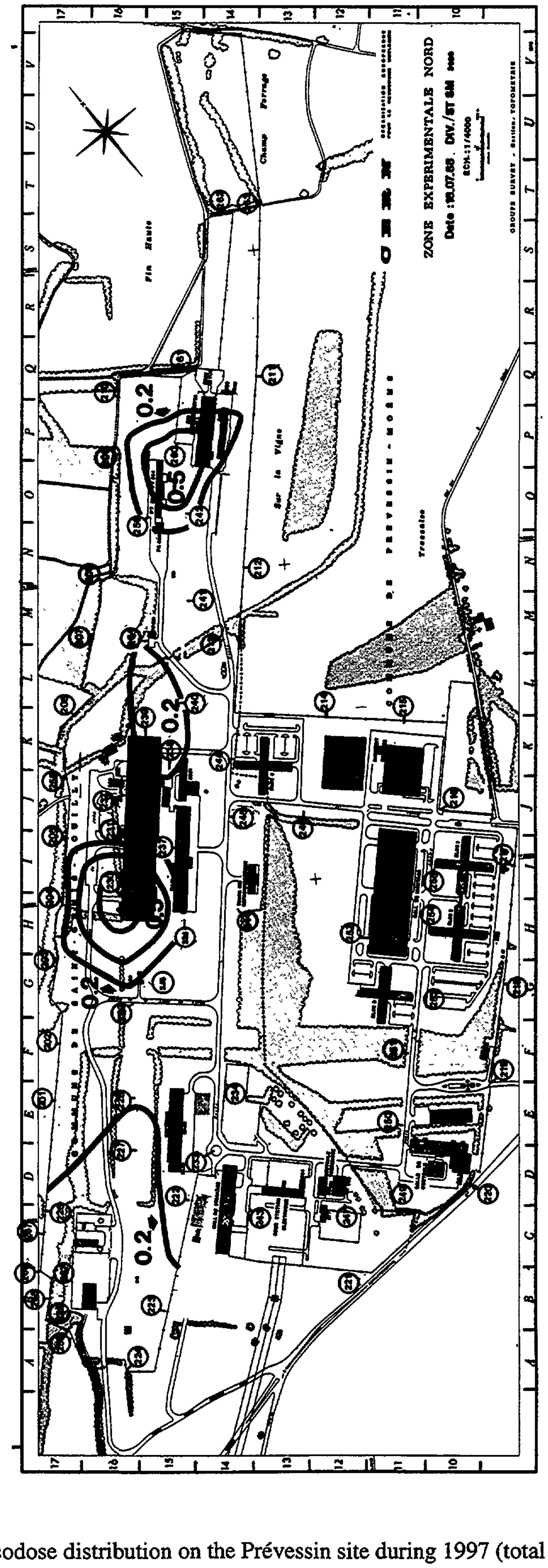

Figure 2: Isodose distribution on the Prévessin site during 1997 (total dose in mSv).

Table 1a: Ambient dose equivalent (mSv) in 1997 due to penetrating radiation measured with ^{6}Lif and ^{7}Lif TLDs on the Meyrin site (natural background subtracted)

Position (see Fig.1)	Neutron dose	Dose due to γ rays + charged part.	Total dose	Position (see Fig.1)	Neutron dose	Dose due to γ rays + charged part.	Total dose
	(mSv)	(mSv)	(mSv)		(mSv)	(mSv)	(mSv)
1	0.02	< 0.1	–	48	0.04	< 0.1	–
2	0.07	< 0.1	–	49	0.04	< 0.1	–
3	0.03	< 0.1	–	50	0.04	< 0.1	–
4	0.06	< 0.1	–	51	0.06	< 0.1	–
5	0.03	< 0.1	–	52	0.13	0.1	0.23
6	0.01	<0.1	–	53	0.09	< 0.1	–
7	0.04	< 0.1	–	54	0.13	< 0.1	–
8	0.14	< 0.1	–	55	0.19	< 0.1	–
9	0.23	< 0.1	–	56	0.30	0.1	0.40
10	0.28	< 0.1	–	57	0.34	0.11	0.45
11	0.26	< 0.1	–	58	1.57	0.78	2.35
12	0.15	< 0.1	–	59	1.69	0.19	1.88
13	0.05	< 0.1	–	60	0.11	< 0.1	–
14	0.05	< 0.1	–	61	0.65	0.13	0.78
15	0.03	< 0.1	–	62	1.23	0.11	1.34
16	0.01	< 0.1	–	63	0.28	0.48	0.76
17	0.01	< 0.1	–	64	0.32	0.20	0.52
18	< 0.01	< 0.1	–	65	0.18	< 0.1	–
19	0.03	< 0.1	–	66	0.22	0.3	0.52
20	0.03	< 0.1	–	67	0.10	< 0.1	–
21	0.01	< 0.1	–	68	0.18	< 0.1	–
22	0.02	< 0.1	–	69	0.09	< 0.1	–
23	0.03	< 0.1	–	70	0.05	0.12	0.17
24	0.02	< 0.1	–	71	0.18	0.11	0.29
25	0.05	< 0.1	–	72	0.10	< 0.1	–
26	0.06	< 0.1	–	73	0.05	< 0.1	–
27	0.07	< 0.1	–	74	0.08	< 0.1	–
28	0.05	< 0.1	–	75	0.12	< 0.1	–
29	0.10	< 0.1	–	76	0.08	< 0.1	–
30	0.09	< 0.1	–	77	0.11	< 0.1	–
31	0.04	< 0.1	–	78	0.02	< 0.1	–
32	0.05	< 0.1	–	79	0.02	< 0.1	–
33	0.07	< 0.1	–	80	0.03	< 0.1	–
34	0.15	< 0.1	–	81	< 0.01	< 0.1	–
35	0.46	< 0.1	–	82	0.01	< 0.1	–
36	0.26	< 0.1	–	83	0.01	< 0.1	–
37	0.03	< 0.1	–	84	0.03	< 0.1	–
38	0.02	< 0.1	–	85	0.04	< 0.1	–
39	0.02	< 0.1	–	86	0.06	< 0.1	–
40	1.97	< 0.1	–	87	0.02	< 0.1	–
41	0.19	< 0.1	–	88	0.03	< 0.1	–
42	0.09	< 0.1	–	89	0.01	< 0.1	–
43	0.06	< 0.1	–	90	0.02	< 0.1	–
44	0.05	< 0.1	–	91	0.05	< 0.1	–
45	0.04	0.1	0.14	92	0.05	< 0.1	–
46	0.01	0.1	0.11	93	0.75	< 0.1	–
47	0.03	< 0.1	–				–

Table 1b: Ambient dose equivalent (mSv) in 1997 due to penetrating radiation measured with ^{6}Lif and ^{7}Lif TLDs on the Prévessin site (natural background subtracted)

Position (see Fig.1)	Neutron dose	Dose due to γ rays + charged part.	Total dose	Position (see Fig.1)	Neutron dose	Dose due to γ rays + charged part.	Total dose
	(mSv)	(mSv)	(mSv)		(mSv)	(mSv)	(mSv)
201	< 0.01	< 0.1	–	235	0.02	0.15	0.17
202	< 0.01	< 0.1	–	236	0.02	< 0.1	–
203	0.02	< 0.1	–	237	0.04	< 0.1	–
204	0.01	< 0.1	–	238	0.04	0.16	0.20
205	0.02	< 0.1	–	239	0.04	0.18	0.22
206	< 0.01	< 0.1	–	240	< 0.01	0.21	–
207	< 0.01	< 0.1	–	241	< 0.01	< 0.1	–
208	< 0.01	< 0.1	–	242	0.02	< 0.1	–
209	0.02	< 0.1	–	243	0.01	< 0.1	–
210	0.03	0.12	0.15	244	0.01	< 0.1	–
211	< 0.01	< 0.1	–	245	0.02	< 0.1	–
212	< 0.01	< 0.1	–	246	< 0.01	< 0.1	–
213	< 0.01	< 0.1	–	247	0.03	< 0.1	–
214	< 0.01	< 0.1	–	248	0.01	< 0.1	–
215	0.07	< 0.1	–	249	< 0.01	< 0.1	–
216	< 0.01	< 0.1	–	250	0.01	< 0.1	–
217	0.03	< 0.1	–	251	< 0.01	< 0.1	–
218	< 0.01	< 0.1	–	252	0.02	< 0.1	–
219	< 0.01	< 0.1	–	253	0.01	< 0.1	–
220	0.01	< 0.1	–	254	< 0.01	< 0.1	–
221	0.02	< 0.1	–	255	0.01	0.11	0.12
222	0.03	< 0.1	–	256	0.02	0.36	0.38
223	0.06	0.19	0.25	257	< 0.01	0.37	–
224	0.04	0.25	0.29	258	0.01	< 0.1	–
225	0.01	0.26	0.27	259	< 0.01	0.14	–
226	< 0.01	0.21	–	260	0.89	36.2	37.1
227	0.09	0.16	0.25	261	< 0.01	2.81	–
228	< 0.01	0.16	–	262	< 0.01	< 0.1	–
229	0.02	< 0.1	–	263	< 0.01	< 0.1	–
230	0.24	1.22	1.46	264	< 0.01	0.25	–
231	0.10	< 0.1	–	265	< 0.01	0.37	–
232	0.07	< 0.1	–	266	< 0.01	0.27	–
233	< 0.01	< 0.1	–	267	< 0.01	0.25	–
234	0.02	< 0.1	–				–

Table 2: Annual total ambient doses equivalent (mSv) at site stations inside fenced areas
(natural background substracted)

Site	Monitor PMS	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997
Meyrin	112	0.00	0.06	0.00	0.00	0.09	0.12	0.13	0.00	0.04	–000
	116	0.27	0.27	0.27	0.09	0.30	0.50	0.38	0.31	0.44	–0.41
	123	0.06	0.19	0.15	0.18	0.20	0.23	0.14	0.35	0.20	–0.47
	128			0.88	1.08	0.87	0.93	0.82	0.95	0.94	–0.94
	129			0.33	0.3	0.41	0.42	0.30	0.55	0.48	–0.50
Prévessin	803	0.02	0.03	0.02	0.00	0.00	0.07	0.24	0.17	0.05	–0.04
	804	0.33	0.13	0.07	0.32	0.59	0.75	0.21	0.86	0.21	–0.06
	811	0.00	0.09	0.00	0.08	0.24	0.35	0.01	0.06	0.17	0.00

Table 3a: Measurements of the Meyrin site monitors during 1997
(The total dose is in mSv and the mean dose rates in μSv/h.) Monitors located inside fenced areas

	PMS 112	PMS 116	PMS 123
Total dose	0.79	1.19	1.25
γ dose	0.72	0.89	0.97
n dose	0.07	0.30	0.28
Mean dose rate	0.09	0.13	0.13
Mean γ dose rate	0.08	0.10	0.10
Mean n dose rate	0.01	0.03	0.03

Table 3b: Measurements of the Prévessin site monitors during 1997
(The total dose is in mSv and the mean dose rates in μSv/h.) Monitors located inside fenced areas

	PMS 810	PMS 803	PMS 804	PMS 811
Total dose	1.08	0.82	0.85	0.70
γ dose	0.99	0.75	0.76	0.62
n dose	0.09	0.07	0.09	0.08
Mean dose rate	0.12	0.09	0.10	0.08
Mean γ dose rate	0.11	0.08	0.09	0.07
Mean n dose rate	0.01	0.01	0.01	0.01

2.1 Personal exposures due to stray radiation

The maximum possible personal exposure outside controlled radiation areas can be estimated from Tables 1a and 1b, assuming a presence of 21% of the time on the CERN site. It can be concluded that in 1997 all these exposures remained well below the annual effective dose limit of 1 mSv for persons of the general public. In fact, the area around position 260 where the highest dose level was registered on the Prévessin site is located inside a fenced area. The maximum dose which could have been received in an accessible area is 0.49 mSv at position 58. It should be noted that this area is not permanently occupied. The collective dose for a population of 12 196 persons on the CERN site was found to be 0.10 manSv with an average individual dose for 1997 of 0.008 mSv. This collective dose value is based on the names of all persons in the CERN personnel database having an address in a building. However, many people stay at CERN much less than 21% of the time. Therefore the estimated collective dose should be considered as an absolute upper limit. The evolution of the collective dose since 1976 is presented in Table 4. As can be seen, the collective dose for 1997 is at the lowest level since measurements using integrating thermoluminescent dosemeters began.

Table 4: Collective dose equivalent since 1976 determined using the TLD system

Year	Collective equivalent (man-Sv)	Average[a)] individual dose equivalent (mSv)
1976	0.81	0.16
1977	0.83	0.17
1978	0.80	0.16
1979	0.70	0.14
1980	0.46	0.09
1981	1.30	0.24
1982	1.47	0.22
1983	0.63	0.09
1984	0.79	0.10
1985	0.61	0.08
1986	0.38	0.05
1987	0.35	0.04
1988	0.24	0.03
1989	0.28	0.03
1990	0.36	0.04
1991	0.33	0.03
1992	0.19	0.02
1993	0.11	0.01
1994	0.13	0.01
1995	0.17	0.015
1996	0.13	0.011
1997	0.10	0.008

a) CERN population outside controlled areas

2.2 Monitoring for LEP

In the framework of the LEP project, pre-operational background measurements using ^{7}LiF TLDs were started in 1985 at 10 positions on Swiss territory, in collaboration with the Swiss authorities (Commission fédérale de Surveillance de la Radioactivité). The Swiss TLD measurements are carried out by the Institut de Radiophysique appliquée (IRA), Lausanne, in parallel with the CERN measurements, on a quarterly basis. The results are compared with those from the standard CERN argon-filled ionization chambers at seven positions. The positions of the detectors are indicated in Fig. 3, whilst the CERN and IRA annual results for 1997 are given in Table 5, together with the annual data since 1993. The IRA values are, on average, somewhat higher than the TLD and ionization chamber results of the RP Group, partly because the IRA natural LiF TLDs are also sensitive to neutrons, although the measurements concern only gamma and charged particle radiation. The CERN TLDs are exposed in Alnor holders behind 300 mg/cm^2 of plastic. RP monitor station measurements were started on French territory in 1987 in one position near LEP PA5. The results are given under position 11 in Table 5.

As usual the dose values inside the customs offices at Mategnin and Vireloup (positions 9 and 10) are lower than the dose values registered outdoors (positions 1–8).The results in Table 5 are, on average, identical to the doses measured before the start-up of LEP and show that the operation of LEP has not increased the radiation level at these positions. The TLD measurement positions at the LEP islands of these detectors are indicated in Fig. 4, whilst the dose results for 1997 are presented in Table 6. They are all at natural background level except at position P11. The relatively high dose at this position can be explained by the fact that during 1997 industrial radiography took place in this area. Elsewhere the results are all at natural background level. TLDs are also installed in the underground areas of LEP. Their results are reported in the Annual Radiation Report concerning LEP [2].

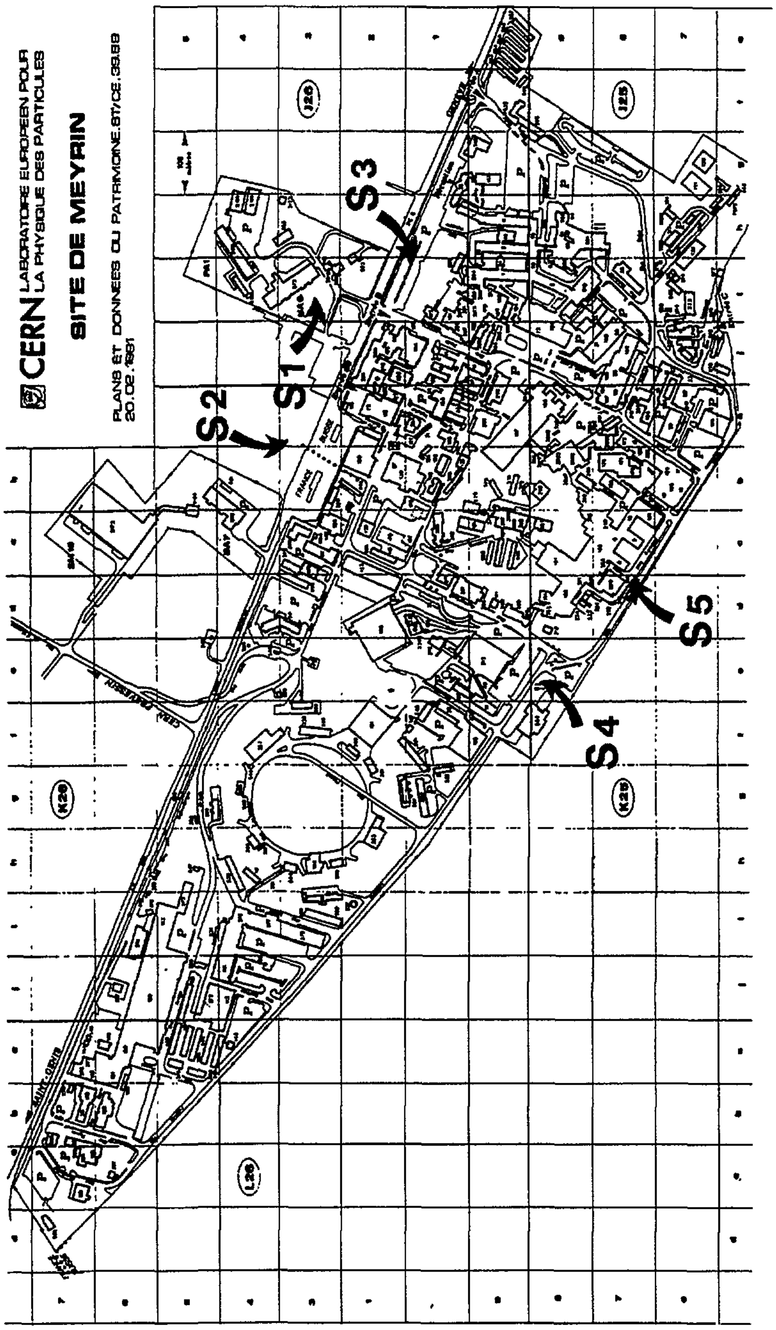

Figure 3: Position of IRA and RP detectors in the CERN environment (Meyrin site)

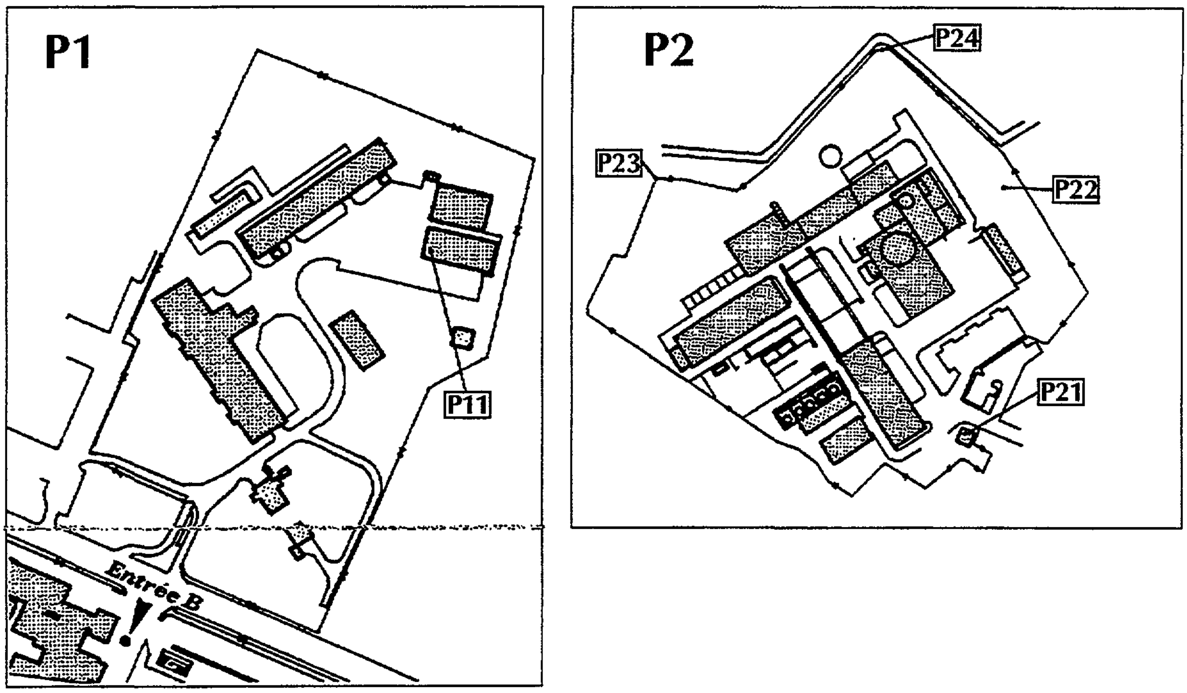

Figure 4: TLD positions at LEP islands 1 and 2

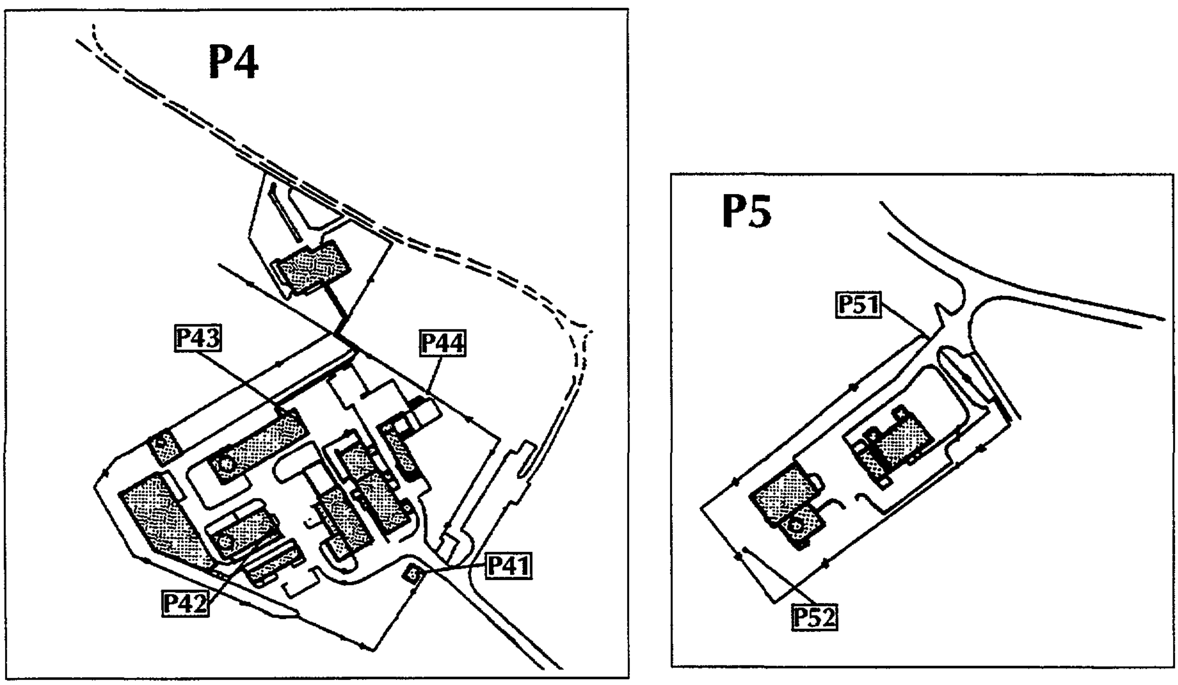

Figure 4: TLD positions at LEP islands 4 and 5

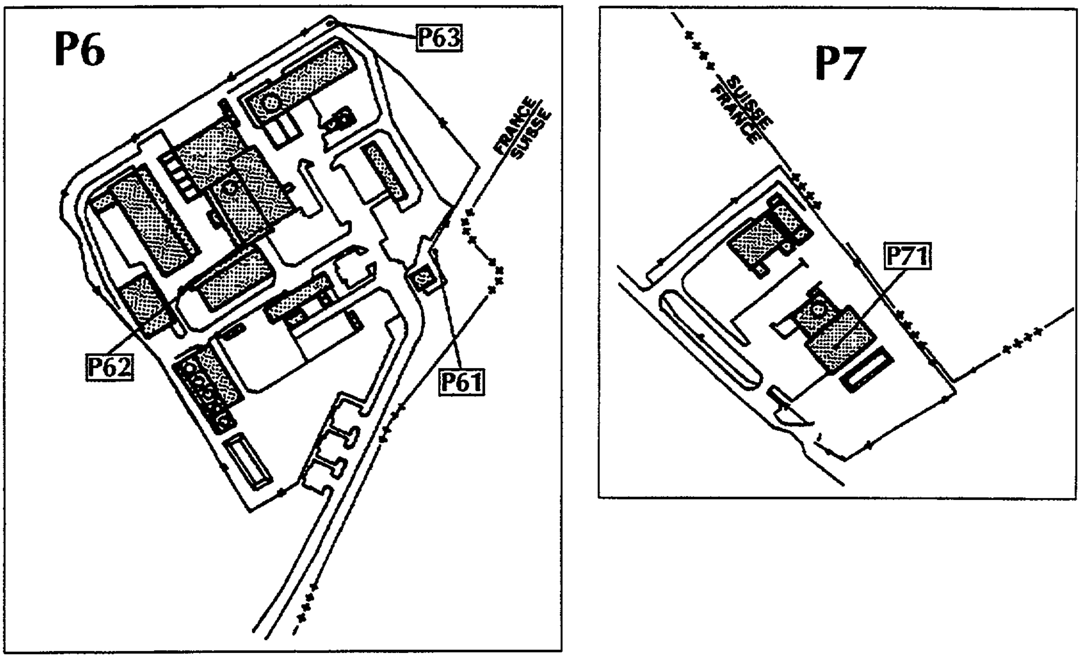

Figure 4: (cont.) TLD positions at LEP islands 6 and 7

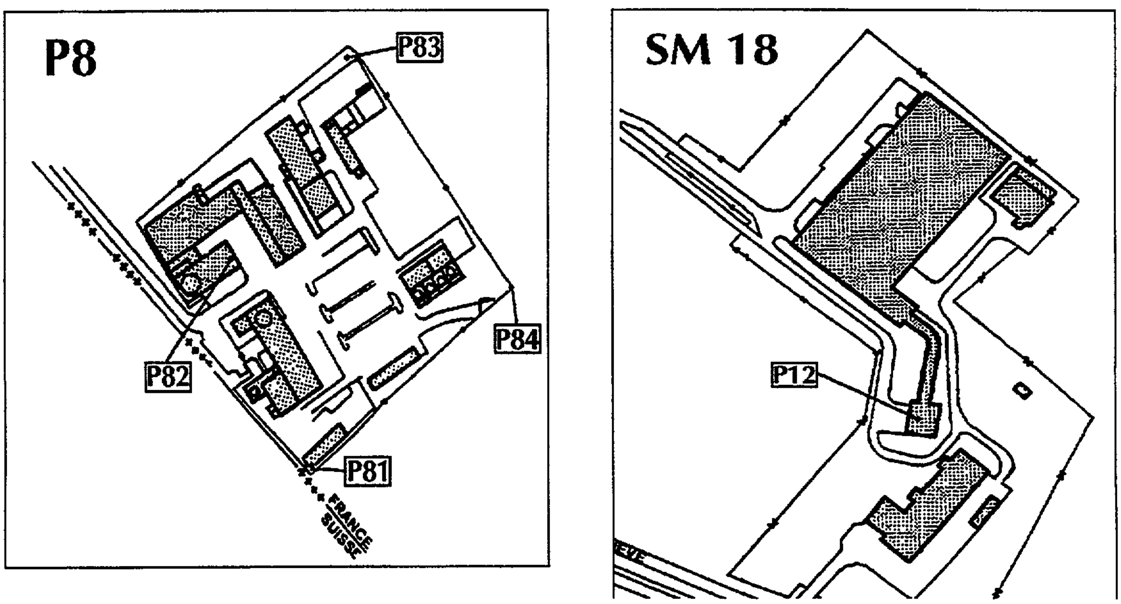

Figure 4: (cont.) TLD positions at LEP islands 8 and 18

Table 5:
Annual results of gamma dosimetry measurements around the CERN site (results in mSv). Natural background dose included

Position	Ionization chamber						TLD CERN						TLD IRA Lausanne					
	1993	1994	1995	1996	1997	Average	1993	1994	1995	1996	1997	Average	1993	1994	1995	1996	1997	Average
1	0.67	0.70	0.73	0.72	0.74	0.73	0.63	0.69	0.70	0.67	0.65	0.66	0.84	0.85	0.81	0.90	0.76	0.83
2	0.74	0.71	0.87	0.75	0.73	0.76	0.64	0.67	0.74	0.68	0.68	0.68	0.87	0.91	0.86	0.98	0.84	0.89
3	0.63	0.67	0.74	0.80	0.71	0.71	0.69	0.65	0.72	0.66	0.66	0.67	0.79	0.86	0.77	0.92	0.80	0.82
4	0.75	0.68	0.83	0.81	0.84	0.78	0.67	0.63	0.73	0.66	0.66	0.67	0.90	1.01	0.85	0.97	0.89	0.92
5	0.69	0.72	1.02	0.73	0.97	0.83	0.73	0.75	0.80	0.76	0.75	0.75	0.95	1.06	0.98	1.07	0.96	1.00
6	0.79	0.70	0.72	0.70	0.71	0.72	0.59	0.56	0.64	0.63	0.65	0.61	0.72	0.77	0.71	0.83	0.74	0.75
7	–	–	–	–	–	–	0.71	0.72	0.80	0.76	0.76	0.75	0.88	0.99	0.92	0.96	0.87	0.92
8	0.71	0.72	0.74	0.73	0.80	0.74	0.63	0.63	0.69	0.64	0.63	0.64	0.72	0.84	0.73	0.82	0.74	0.77
9	–	–	–	–	–	–	0.52	0.51	0.60	0.55	0.56	0.55	0.66	0.74	0.66	0.80	0.68	0.71
10	–	–	–	–	–	–	0.54	0.53	0.66	0.56	0.58	0.57	0.68	0.71	0.70	0.75	0.71	0.71
11a)	0.71	0.77	0.81	0.74	0.74	0.75	0.73	0.66	0.81	0.67	0.65	0.70	–	–	–	–	–	–
Average	0.71	0.71	0.80	0.75	0.78	0.75	0.64	0.64	0.71	0.66	0.65	0.66	0.80	0.87	0.88	0.90	0.80	0.83

a) LEP station Cessy.

Table 6: Dose results at LEP surface areas for 1997. Natural background dose included

TLD position (see Figs. 4)	Dose due to γ rays + charged particles (mSv)	Neutron dose (mSv)	Dose due to γ rays + charged particles (mSv) OPRI results*	
P11	0.63	0.1		
P12	3.85	0.1		
P21	0.63	0.06	D1	0.56
P22	0.87	0.02		
P23	0.89	0.03		
P24	0.85	0.06		
P41	0.67	0.05	D2	0.70
P42	0.63	0.11		
P43	0.62	0.06		
P44	0.95	0.06		
P51	0.83	0.06		
P52	0.82	0.05		
P61	0.72	0.07	D3	0.64
P62	0.60	0.10		
P63	0.95	0.06		
P71	0.69	0.06		
P81	0.91	0.08	D4	0.70
P82	0.69	0.08		
P83	0.87	0.05		
P84	0.79	0.06		

*Office de Protection contre les Rayonnements Ionisants. Results for six months multiplied by two.

3 RADIOACTIVE MATERIAL MANAGEMENT

3.1 Radioactive waste

3.1.1 Solid waste

In 1997, the central storage area in the centre of the PS ring received a total volume of 126 m^3 of various activated materials, such as cables and accelerator components (see Fig. 5). Upon arrival, all material is sorted and, if necessary, stored according to its specific activity and corresponding year of elimination. For elimination, the specific activity of any item must nowhere exceed the exemption limits laid down in the new Swiss Ordinance of 1994 and the CERN Radiation Safety Manual of 1996, and the dose rate 10 cm from its surface must not exceed 0.1 μSv/h anywhere. The most restrictive exemption limit for beta/gamma emitters is 1 Bq/g for example for ^{60}Co. Using these limits as the criteria for unrestricted release it was possible to eliminate for recycling from the central storage area 25.3 t of iron for reuse during 1997. This brings the total amount of scrap material eliminated as inactive to 802 t since 1980. In addition, 58 m^3 of various materials such as electrical cables, lead aluminum and stainless steel were eliminated as inactive material. The annual release of non-radioactive scrap since 1980 is summarized in Fig. 6. It should again be underlined that the exemption limits mentioned before are considered as upper limits nowhere to be exceeded anywhere in any item. As a rule the material released contains no detectable amounts of radioactivity. In addition, waste material unsuitable for reuse or recycling, consisting mainly of various plastics (cable insulation, etc.) and air filters, was released using the above-mentioned limits. This year, after detailed measurements, 31 m^3 of material was released as inactive, bringing the total amount released since 1981 to 227 m^3. Whenever possible, metal scrap is reduced in volume and stored in 1 m^3 metal containers. Prior to storage detailed dose rate and weight measurements are made and the containers are labelled accordingly. All the relevant technical details for these containers are introduced in a database. These containers are now all equipped with a top lid for long-term storage. Until 1997, electrical cables, with the exception of power cables, were placed in metal baskets on wooden pallets (volume 0.7 m^3). In 1997 it was decided to use 1 m^3 metal containers for activated cables as well, and to discontinue the use of baskets. For power cables, volume reduction is carried out as far as possible by stripping off the (inactive) insulation and compressing the remaining active aluminum and copper into blocks of $40 \times 40 \times 40$ cm^3.

The CERN recuperation service area is checked daily for radioactive items, in particular to ensure that they are not released for sale. In 1997, 27 items with dose rates in contact up to 5 μSv/h were found in this area. Among these items were containers with scrap material, electrical cables, etc. This is a slight increase compared to last year, which underlines the need for these checks in order to ensure that no radioactive material leaves the CERN site. The procedure for the release of material from the CERN recuperation service has been improved this year.

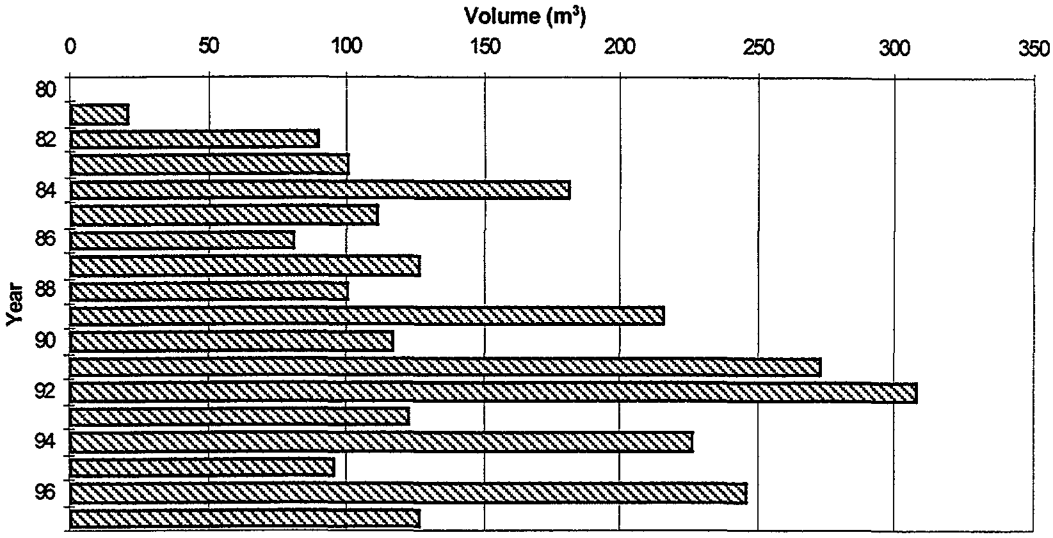

Figure 5: Annual influx of radioactive waste

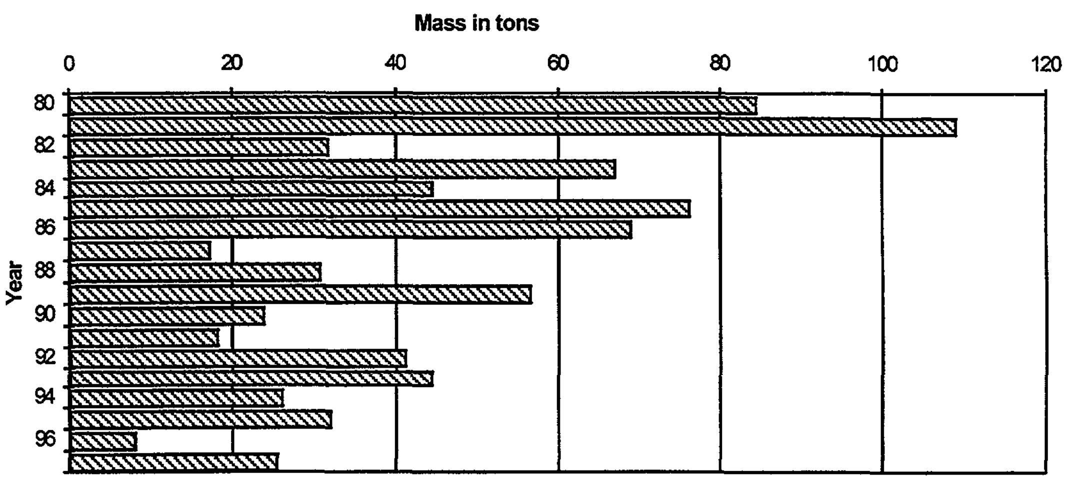

Figure 6: Annual release of non-radioactive scrap

3.1.2 Liquid waste

The TIS/RP evaporation plant installed in the central storage area (building 574) was used for the decontamination of slightly radioactive water from the V_0 pit. A total of 1000 l was treated containing 1.66 kBq/l of specify activity (principal radionuclide ^{22}Na). The decontaminated water was released after a final check of its residual activity. Since 1989 the RP evaporation plant has treated 30 m^3 of water.

In 1997, the V_0 on-line evaporation plant generated 118 kg of solid waste of specific activity between 2.102 and 2.103 Bq/g after evaporation. The total ^{22}Na activity in this waste was estimated to be 93.7 MBq. More details concerning RP activities in the field of radioactive waste can be found in Ref. [3] .

3.2 Radioactive material storage

The storage of radioactive material is divided into two parts:

- predisposal storage of activated scrap materials.
- storage of items for reuse (magnets, etc.).

Predisposal storage

The predisposal storage of radioactive scrap materials can be summarized as follows for the areas occupied by the CERN Radiation Protection Group:

a) *TT1 tunnel (transfer tunnel to the former ISR)*

This area is used for the storage of activated electrical signal cables stored in 0.7 m^3 baskets on wooden pallets. During 1997, 80 baskets were brought to this tunnel. At the end of 1997, 576 baskets are now stored in this area (total volume 403 m^3) and are sorted according to the measured dose rate. Conditioning in baskets is unsuitable for long-term storage. Furthermore, this area will soon be reaching saturation point, and methods to reduce this volume will therefore be explored.

b) *TT7 tunnel*

This tunnel, which was used in the past for the PS oscillating neutrino experiment, is completely occupied by 400 m^3 of 1 m^3 containers filled with activated scrap materials (iron + steel). The total weight is estimated to be about 300 t.

c) *Former ISR tunnel*

In the former ISR tunnel two areas are in use for the predisposal storage of radioactive scrap materials:

– The area between I2 and I3

This area has been in use since the dismantling of the ISR magnets in 1994. At the end of 1997 the following items were stored in this area:

1. Copper coils remaining from the dismantling of the ISR magnets. The total copper weight is estimated to be 288 t. These coils are only slightly radioactive and partly even below the CERN exemption limits. However, they will be kept as the ^{60}Co activity is in all cases easily detectable.

2. ANDRA containers (total number 43) of 10 m^3 filled with radioactive scrap from the dismantling of the old neutrino tunnel. Total activity at the end of 1997: 49.5 GBq (^{22}Na) and 2.3 TBq (^{60}Co +^{54}Mn) for a total weight of 191 t. The elimination of these containers appears to be a very time-consuming activity.
   In 1997, CERN submitted the necessary documents to ANDRA to obtain a so-called 'agrément du colis'.

3. Irradiated ISOLDE targets
   Three fibre-reinforced concrete containers of 5 m^3 are used for the storage of irradiated ISOLDE targets. At the end of 1997, 61 targets containing beta/gamma emitters, and 15 heavy U and Th targets containing alpha-emitters were stored in these containers. The irradiation history, physical parameters, and dose rates in contact and at 1 m are known for all targets and have been registered.

4. Miscellaneous items
   An important volume of radioactive shielding blocks is stored in the former injection region of the ISR. Nearby various parts of the former ISR are stored, such as beam dumps, magnet supports and septum magnets. This area will have to be emptied in the not too distant future (end 1998), so that it can be used for the LHC project. A large quantity of material was therefore already removed in 1997 (e.g. ISR magnet yokes and supports, 342 containers of 1 m^3). However, for the material listed under 1–4, the ISR area between I4 and I5 (see below) is too small to include all items and an extension of this area will have to be envisaged.

In this context it should be mentioned that the ISR magnet yokes which were only slightly radioactive have been converted into shielding blocks for the future LHC beam dumps. In this way not only valuable storage space in the ISR was liberated, but also 1496 t of iron (68 magnets yokes) were recycled. The small activity of the yokes is of no concern as these future shielding blocks will, in any case, be activated in the LHC.

- The area between I4 and I5

  This area was designated as a storage area for radioactive material in 1997 to receive items for which the storage conditions needed improvement. It contains the following radioactive materials:

  1. A total of 509 containers of 1 m^3 (weight 371 t) filled with Al, Fe and Cu scrap. All data concerning material, dose rate, and weight are available in the database MACSTOCK.

  2. Eighteen transport containers of 17 m^3 each. Total volume 306 m^3 and weight 214 t. Some of this material is of low specific activity (e.g. compressed Al cables) and could be eliminated as inactive material.

  3. Four shielded containers of $4 \times 2 \times 2$ m^3 with a concrete wall thickness of 24 cm which fulfill the requirements of the Swiss waste agency NAGRA for future storage in their depository. Some of them contain highly radioactive items. Six others were filled in the centre of the PS ring and will be transferred to the I5 area in 1998. These containers will have to be stored until Switzerland has its depository ready in the next century.

  4. A shielded area was created to store large and/or heavy highly radioactive items which cannot be stored in shielded containers. It contains, for example, blocks from the former neutrino tunnel, etc. previously stored in a shielded area in the vicinity of building 180.

At the end of 1997 practically all radioactive scrap materials were either stored in the areas mentioned above or in closed shielded containers waiting to be moved.

d) The storage area in the centre of the PS ring

Buildings 573 and 574 are used for the reception, sorting, and conditioning of radioactive material. Once conditioned the scrap materials are transferred in their containers to the ISR area. Other radioactive waste is conditioned in building 574 for transfer to PSI. Building 131 is used for the intermediate storage of radioactive waste other than scrap materials.

During 1997, the conditioning of material until then stored in a shielded open air area was completed. The material was conditioned in unshielded containers and transferred to the I5 area. The remaining part was conditioned in six shielded containers (volume: 48.8 m^3) and is awaiting improved transport tools in order to be transferred to the ISR.

As the material stored on the Car Park of building 180 and in a tent near building 917 has been sent to the ISR, one can conclude that at the end of 1997 all radioactive material present on the CERN sites is conditioned and stored under excellent conditions.

Storage of items for reuse (magnets, etc.)

At present building 225 belonging to the storage area in the centre of the PS ring is mainly used for the storage of items from PS Division and for items containing depleted uranium, and at present is completely full. Items from SL and PPE Divisions are usually stored in buildings 917 and 955 on the CERN Prévessin site.

More details regarding the Site Section's storage and disposal activities can be found elsewhere [3]. It should be mentioned here that activities such as the handling and cutting of radioactive material are only carried out under rigorous radiation protection control. Regular surface contamination checks at 13 positions in all areas, and also checks of the effluent surface water from the open-air storage area, are carried out. During the year surface contamination levels stayed well below the limits fixed in the CERN Radiation Safety Manual, as did the specific activity of the mud in the two decantation pits. Only trace amounts of corrosion products were detected in the mud, mainly ^{60}Co, ^{22}Na and ^{54}Mn. The total specific activity corresponds to 0.5 and 0.05 of the exemption limit, respectively, for the two pits.

Personal exposures were at a low level in 1997. The person working permanently for the storage and disposal of radioactive items received an annual dose of 0.9 mSv (1996: 1.1 mSv), with a maximum monthly dose of 0.3 mSv. Finally, in spite of great recycling efforts, the amount of material that arrives at the central storage area is greater than what can be released as inactive scrap. In 1997, an order was placed for melting 14 t of aluminum scrap in Sweden, and the material was prepared for shipment. After melting, the aluminum will stay in Sweden but the activity (^{22}Na) concentrated in the slag and filters will be sent back to CERN.

3.3 Radioactive waste disposal

During 1997 one shipment of radioactive waste was prepared for shipment to PSI Villigen for final disposal via NAGRA comprising two containers of 30 l, 11 containers of 100 l, and 15 containers of 200 l, with a total activity of 67.8 MBq (beta/gamma) + 4.4 MBq (alpha). The 30 l containers were filled with old radioactive sources in the framework of the project to replace obsolete sources (see also Section 4). The 100 l and 200 l containers were filled with the usual contaminated or activated items from CERN accelerator operation and nuclear chemistry. The total mass of this shipment was 845 kg. The activity in the containers was determined by gamma spectrometry [3]. The shipment of this waste to PSI took place in May 1997.

4 RADIOACTIVE SOURCES

The source tally as at 31 December 1997 was 1107 (1996: 1194), with 406 in stock and 701 on loan with 154 users. During the year, 53 new sources were registered and 140 sources were taken out of the source register for the following reasons:

- 38 sources were shipped to PSI Villigen for disposal,
- six sources were shipped to destinations outside CERN,
- four sources were lost, but their activity was well below the limit of exemption under both French and Swiss law,
- seven sources of activity above the exemption limit were declared lost in 1997:

Registration number	Radionuclide	Activity	Registered user
1208 RP	^{241}Am	31 kBq	B. Kolb, PPE
2462 RP	^{55}Fe	8.5 MBq	F. Piuz, PPE
2635 RP	^{55}Fe	12.5 MBq	F. Sauli, PPE
3496 RP	^{241}Am	5 kBq	F. Bordachini, PPE
2429 RP	^{241}Am	0.5 kBq	W. Huta, PPE
2431 RP	^{241}Am	0.55 kBq	W. Huta, PPE
3543 RP	^{241}Am	37 MBq	M. Doser, PPE

- 85 sources were taken out of the inventory in view of future disposal.

It should be underlined that usually sources which could not be shown to the RP technician during his periodic inspection and consequently were declared lost are still on the CERN site and are found later.

Routine inspections and leak tests (56) were carried out with a frequency depending on the hazard classification of the sources concerned. These leak tests revealed no significant contamination. Apart from preparing the statistical data presented here, much time was spent on giving advice to users (mainly PPE physicists) regarding the sources to be employed in their experiments, on designing and constructing special source holders, and on the transportation of sources to experimental areas. The importance of the Site Section activities in the field of radioactive sources can also be judged from the wide variety of radionuclides in use at CERN. As many as 43 different types of source are at the disposal of the CERN physics community. A breakdown of sources is presented in Table 7. In the framework of the CERN project to replace old sources, a large number were again eliminated as radioactive waste or prepared for future disposal (123 in 1997 compared with 156 in 1996), and replaced by fewer new ones (53 in 1997 compared with 115 in 1996). The object of this project which is now almost complete is to replace and eliminate all sources older than 15 years (the recommended lifetime for most commercial sources). All new sources have been mounted in new holders as part of the project for the replacement of radioactive sources. This project will continue in the coming years.

Table 7: Distribution of radioactive sources according to their radionuclide composition

Radionuclides	Total activity (Bq)	Total number	In use
^{3}H	2.5×10^{12}	7	3
^{14}C	1.4×10^{7}	15	6
^{22}Na	1.4×10^{7}	37	22
^{36}Cl	3.7×10^{6}	7	4
^{54}Mn	3.5×10^{7}	10	2
^{55}Fe	1.1×10^{10}	199	147
^{57}Co	1.6×10^{8}	28	20
^{58}Co	1.9×10^{7}	2	0
^{60}Co	2.6×10^{10}	71	49
^{63}Ni	8.3×10^{7}	17	3
^{65}Zn	4.0×10^{7}	5	1
^{85}Kr	2.3×10^{7}	1	0
^{90}Sr	1.0×10^{10}	121	91
^{93m}Nb	1.0×10^{5}	2	2
^{106}Ru	8.6×10^{6}	93	58
^{109}Cd	2.5×10^{8}	31	16
^{75}Se	1.0×10^{6}	3	1
^{134}Cs	2.2×10^{7}	2	0
^{137}Cs	2.1×10^{12}	85	54
^{133}Ba	7.3×10^{6}	16	8
^{83}Rb	2.8×10^{6}	3	2
^{147}Pm	3.9×10^{5}	2	1
^{152}Eu	1.3×10^{7}	17	9
^{192}Ir	1.6×10^{12}	1	1
^{88}Y	1.2×10^{7}	7	3
^{204}Tl	1.9×10^{5}	2	1
^{210}Pb	8.8×10^{7}	2	1
^{207}Bi	4.0×10^{6}	43	19
^{226}Ra	8.8×10^{5}	4	2
^{228}Th	3.7×10^{5}	4	3
U_{nat}	1.4×10^{7}	24	10
^{233}U	5.5×10^{6}	2	0
^{235}U	1.5×10^{5}	2	0
^{237}Np	2.6×10^{6}	3	1
^{238}Pu C	9.7×10^{9}	2	0
^{238}Pu Be	1.8×10^{12}	1	1
^{239}Pu	5.7×10^{4}	7	5
^{239}Pu Be	7.7×10^{10}	1	1
^{241}Am	1.9×10^{11}	196	159
^{241}Am Be	2.6×10^{10}	12	6
^{241}Am Li	4.1×10^{8}	2	2
^{244}Cm C	9.7×10^{7}	1	1
^{252}Cf	1.8×10^{7}	6	1

5 TRANSPORT OF RADIOACTIVE MATERIAL

The Section organized a total of 72 shipments of radioactive items to destinations in 18 countries. These shipments (listed in Table 8) concern only transport outside CERN. The number of transportations increased compared with 1996 (56). Most of the shipments concern radionuclides produced in the ISOLDE facility and irradiated components for future LHC detectors. The shipment of radioactive waste to PSI, Villigen (72 MBq) must be added to the shipments listed in Table 8.

Table 8: Radioactive transport in 1997

Date	Destination	Package type	Activity (principal radionucl.)	No. U.N.*
06.01	Kocise (SK)	Excepted	8.3 kBq (Be7)	2910
20.01	Cambridge(USA)	Type A	184 MBq (Na22)	2982
10.02	Udine (I)	Type A	434 kBq (Am241)	2982
10.02	Barcelona (SP)	Excepted	417 kBq (Fe55)	2910
17.02	Geneva (CH)	Excepted	161 kBq (Fe55)	2910
27.03	Udine (I)	Excepted	37MBq (Sr90)	2910
10.04	Barcelona (SP)	Type A	165 MBq (Cs137)	2982
28.04	Storrington (GB)	Excepted	150 MBq (Co60)	2910
06.05	Oslo (N)	Excepted	180 kBq (Sr82)	2910
13.05	Mainz (D)	Excepted	19 MBq (Rb83)	2910
14.05	Konstanz (D)	Excepted	6 MBq (Tm167)	2910
14.05	Konstanz (D)	Excepted	6 MBq (Yb169)	2910
21.05	Grenoble (F)	Excepted	102 kBq (Na22)	2910
21.05	Berlin (D)	Excepted	8 MBq (Sr85)	2910
26.05	Le Plessis (F)	Excepted	66 MBq (Am241)	2910
04.06	Grenoble (F)	Excepted	148 kBq (U233)	2910
19.06	Freiburg (D)	Excepted	2 kBq (As74)	2910
23.06	Grenoble (F)	Excepted	540 MBq (Tc99)	2910
27.06	Konstanz (D)	Excepted	4 MBq (Au191)12MBq(Au193)	2910
02.07	Munich (D)	Excepted	18 MBq (Hg195)	2910
02.07	Stuttgart (D)	Excepted	2 MBq (Au195)	2910
07.07	Berlin (D)	Excepted	1 MBq (Pt188)	2910
14.07	Rehovot (Israel)	Excepted	31 MBq (Be7)	2910
21.07	Bonn (D)	Excepted	36 MBq (Br77)	2910
21.07	Saarbrücken (D)	Excepted	15 MBq (Br77)	2910
21.07	Freiburg (D)	Excepted	8 MBq (Br77)	2910
21.07	Oxford (GB)	Excepted	1.9 MBq (Se75)	2910
22.07	Berlin (D)	Excepted	2.5 MBq (As73)	2910
23.07	Shanghai (China)	Type A	3.6 MBq (Na22)	2982
02.07	Munich (D)	Excepted	18 MBq (Hg195)	2910
02.07	Stuttgart (D)	Excepted	2 MBq (Au195)	2910
07.07	Berlin (D)	Excepted	1 MBq (Pt188)	2910
14.07	Rehovot (Israel)	Excepted	31 MBq (Be7)	2910
21.07	Bonn (D)	Excepted	36 MBq (Br77)	2910
21.07	Saarbrücken (D)	Excepted	15 MBq (Br77)	2910

Date	Destination	Package type	Activity (principal radionucl.)	No. U.N.*
21.07	Freiburg (D)	Excepted	8 MBq (Br77)	2910
21.07	Oxford (GB)	Excepted	1.9 MBq (Se75)	2910
22.07	Berlin (D)	Excepted	2.5 MBq (As73)	2910
23.07	Shanghai (China)	Type A	3.6 MBq (Na22)	2982
28.07	Mainz (D)	Type A	10 MBq (Rb83)	2982
29.07	Munster (D)	Excepted	3 MBq (As73)	2910
30.07	Orlando (USA)	Excepted	30 MBq (As73)	2910
14.08	Saarbrücken (D)	Excepted	12.6 MBq (Ag111)	2910
14.08	Dublin (Ir)	Excepted	12 MBq (Ag111)	2910
14.08	Berlin (D)	Excepted	0.1 MBq (Ag111)	2910
16.08	Berlin (D)	Excepted	1 MBq (Ag111)	2910
26.08	Wollongong (Aust)	Excepted	20 kBq (Be7)	2910
28.08	Mainz (D)	Excepted	1 MBq (Pt188)	2910
08.09	Porto (P)	Excepted	117 kBq (Sr85)	2910
17.09	Birmingham (UK)	Excepted	210 kBq (Be7)	2910
19.09	Bonn (D)	Excepted	3.8 MBq (Yb169)	2910
22.09	Manchester (UK)	Excepted	10 kBq (Po208)	2910
24.09	Geneva (CH)	Type A	185 MBq (Tb152	2982
30.09	Konstanz (D)	Excepted	1 MBq (Yb169)	2910
09.10	Wuppertal (D)	Excepted	15 kBq (Be7)	2910
09.10	Berlin (D)	Excepted	100 kBq (Pt188)	2910
20.10	Tsukuba-shi (J)	Excepted	17 kBq (Na22)	2910
21.10	Freiburg (D)	Excepted	13 MBq (Ag111)	2910
21.10	Iena (D)	Excepted	14 MBq (Ag111)	2910
21.10	Saarbrücken (D)	Excepted	13 MBq (Ag111)	2910
21.10	Berlin (D)	Type A	15 MBq (Ba140–La140)	2982
23.10	Berlin (D)	Excepted	4 MBq (Ag111)	2910
27.10	Oxon (GB)	Excepted	26 kBq (Na22)	2910
03.11	Konstanz (D)	Excepted	400 kBq(Be7)	2910
03.11	Dublin (Ir)	Excepted	80 kBq (Be7)	2910
04.11	Rehovot (Israel)	Excepted	120 MBq (Be7)	2910
04.11	Konstanz (D)	Excepted	1 MBq (Sr89)	2910
06.11	Johannesburg (SA)	Excepted	70 kBq (In111)	2910
11.11	Kogarah (AUS)	Type A	6 MBq (Ra225)	2982
14.11	Johannesburg (SA)	Excepted	70 kBq (In111)	2910
04.12	Chilton(UK)	Excepted	197 kBq (Be7)	2910
04.12	Munich (D)	Excepted	77 kBq (Be7)	2910
08.12	Amsterdam(NL)	Excepted	100 kBq (Be7)	2910
09.12	Madrid(SP)	Excepted	1 kBq (Gd148)	2910
10.12	Haag (CH)	Excepted	100 kBq (Co60, Sc46)	2910

*Classification according to IAEA

6 CONTROL OF NON-IONIZING RADIATION

The Site Section has the task of evaluating the hazards of non-ionizing radiation exposure, especially in connection with lasers, microwaves, UV radiation, and magnetic fields. The system used at CERN for the registration and inspection of lasers is similar to the one used for radioactive sources. Warning signs and labels, as laid down in TIS Safety Instruction 22, have been installed wherever possible. By the end of 1997, safety assessments and registrations were completed for 344 lasers. Of all the non-ionizing radiation sources at CERN, lasers still present the main hazard. The increase in the number of semiconductor lasers used in data transmission is of increasing concern. No exposure incidents were reported in 1997. Safety briefings were held with teams of laser users. A list of lasers registered at CERN is presented in Table 9. In view of the occupational hazard presented by the use of lasers, the Medical Service is kept informed about the users of each laser installation. The Site Section also made assessments of, and gave advice on, a wide variety of other non-ionizing radiation sources, such as magnetic fields (ELF and d.c.), RF systems, and UV radiation. For instance, ELF measurements were carried out in buildings in the vicinity of electrical power lines following complaints about the perturbation of video displays and electrical alarm clocks.

Table 9: Registered lasers at CERN

Type	He-Ne	YAG YLF	N_2	Ar^{++} Kr^{++}	Semiconduc-tors	CO_2	Others: Dye, Cu, Xe-Cl, He-Cd
Wavelength (nm)	633	1064, 532, 1047, 523, 266, 261	337	488, 514, 410, 520, 650	670, 1300	10600	–
Class IV	0	29	3	6	0	3	12
Class III B	81	3	70	2	81	0	4
Class III A	29	0	0	0	3	0	0
Class II	17	0	0	0	7	0	0
Class I	0	0	0	0	2	0	0
Total	127	32	73	8	93	3	16

7 THERMOLUMINESCENCE DOSIMETRY

Thermoluminescence dosimeters are in routine use for environmental monitoring (see Section 2), and for area monitoring around the PS, AA, SPS West Area, and LEP. These applications involve about 2000 TLDs which are evaluated with the automatic Alnor reader linked to a PC for data handling. For single detectors the Harshaw Atlas reader is still used. Single Harshaw TLD-100 LiF (Mg, Ti) detectors are employed for fingertip dosimetry (total number of measurements in 1997: 17, maximum dose 2 mSv). For research purposes a Harshaw 3500 manual reader is used in conjunction with the CERN MINUIT program for glow-curve deconvolutions of LiF. In the framework of the collaboration with the University of

Thessaloniki, studies were made on thermal gradient effects on the thermoluminescence glow-curves [4] and glow-curve deconvolution functions for first, second and general order of kinetics [5]. A special study was started on the possibility of using the extremely sensitive Al_2O_3:C TL material both as a TL detector and as a TSEE (thermally stimulated exoelectron emission) detector, whereby the exoelectrons emitted by an irradiated detector produce a TL signal in a second detector. An experimental apparatus has been constructed and is presently being tested in Thessaloniki.

Finally, a study was made on the use of ^{6}LiF TL detectors in personal monitoring by positioning them in the armpit of individuals. In this way the upper arm acts as an additional moderator. The first results indicate a higher sensitivity and better energy response than conventional Albedo systems.

8 SPECTROMETRY

During 1997, a total of 746 analyses were made by the Section's gamma spectrometry system using an intrinsic Ge detector (1996: 906). As usual most of these analyses concerned samples of activated material from the radioactive storage area and samples from the ISOLDE facility. The importance of this installation is not only shown by the number of measurements made but also by the value of the results for the release of scrap materials for unrestricted reuse.

9 MISCELLANEOUS ACTIVITIES

The Site Section of the RP Group carried out a number of other tasks in addition to those described above:

1. The radiation hazard due to X-ray-producing installations was evaluated in different areas.

2. Whole body counting was organized for 25 persons working for the ISOLDE Group (PE 14, PS 1, LHC 5) and RP Group (5). No case of internal contamination was found during these routine examinations with the whole body counter of the Hôpital Cantonal, Geneva.

10 CONCLUSION

The numerous activities of the Site Section described above, were, in 1997, similar in number and in volume as in previous years. Special emphasis was put on projects concerning radioactive material storage and the elimination and replacement of radioactive sources. Collaboration in the field of thermoluminescence dosimetry with the University of Thessaloniki continued successfully.

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