USE OF THE PASSIVE DOSEMETERS FOR THE MAPPING OF THE RADIATION LEVEL IN AREAS INVOLVED IN WORK WITH RADIOACTIVE SOURCES

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A number of 20 locations in a laboratory, where radioactive sources are used, were surveyed in order to establish the mean level of ambient dose equivalent rate, for a 41 days measurement interval. A total number of 20 dosemeters, each one containing 2 thermoluminescent detectors, GR-200A, passive type, were used. The obtained mean values of ambient dose equivalent rate, allowed for their comparison with the legal requirements, according to the Fundamental Norm of Radiological Security; pertinent propositions for optimization of the manipulation of radioactive sources are made.

Key words: Thermoluminescent dosemeters, ambient dose equivalent level, mapping, radioactive sources.

1. INTRODUCTION

Our Laboratory became expert both in obtaining of Thermoluminescent Dosemeters (TLDs) and in their use for the ambient dose equivalent level monitoring. The dosemeters realized in the laboratory were devoted either for personal dosimetry, as in the case of using LiF:Mg,Ti luminophores, or for the environmental survey, as in the case of preparation and use of $CaSO_4$: Dy detectors [1]. These types of dosemeters were very specialized, as they had particular characteristics. On one side, LiF:Mg,Ti has an effective atomic number $Z_{eff} = 7.4$ very near the tissue mean atomic number, and consequently is very useful for personal dosimetry; on the other side, $CaSO_4$:Dy has a higher Z_{eff}, but is more sensitive, being recommended for environmental area survey [2].

A significant progress was achieved in thermoluminescence dosimetry, with the use of the new, LiF:Mg,Cu,P luminophore, which came in attention starting with the year 1987 [3, 4], when it was used in an international comparison. It cumulates both qualities, having a Z_{eff} tissue equivalent such as the first LiF: Mg,Ti; it is also very sensitive, about 40 times more sensitive than the former one, and consequently it is also suited for environmental survey. It is worldwide used and produced at industrial scale, under the commercial name GR-200A.

The use of this luminophore requires a special attention, due to its high sensitivity and due to its special thermal cycle. On one side the thermal reading and regeneration are carried out at high temperature, 240°C, with a very well controlled regime, a requirement which can be accomplished by a computer controlled oven; on the other side a high quality TL Reader, under controlled cooling of the photomultiplier is required.

Significant results were obtained and reported in our laboratory, by the use of this system. They include the survey of the areas near the particle accelerators, such as the Betatron [5], the nuclear reactor spent fuel repository [6], and most recently the measurement of the very low level of ionizing radiation background, about 50 times less than normal environmental one, in a former salt mine, where an underground laboratory is planned to be established [7].

This paper presents the experimental procedure and the results obtained in the dosimetric survey of a radiologically controlled area (nuclear unit), where radioactive sources are manipulated. Comparison with the legal limits of effective dose values is made, and propositions for improvement are formulated.

2. EXPERIMENTAL PROCEDURE

2.1. CHOICE OF THE SURVEYED AREA

Normally, in a nuclear unit, the ambient dose equivalent rate is approximately constant and an instantaneous measurement, by using an active dose rate meter allows for the evaluation of the long term, a month or a year ambient dose equivalent level. In some laboratories, the manipulation of radioactive sources implies significant variations of the ambient dose equivalent rate, and the most realistic evaluation of the long term dose is achieved by the use of passive thermoluminescent dosemeters. Such a laboratory is the Ionizing Radiation Metrology, Dosimetry and Testing Laboratory (CMRID), where the radioactive sources are kept usually under a lead shielding; they are used in realization of various irradiation stands for equipment calibration or testing, by the remote manipulation of the sources, from a command room. This room is isolated enough from the irradiation hall, assuring the complete shielding for the operational personnel.

2.2. PLACEMENT OF DOSEMETERS

A number of 20 dosemeters, each of them containing 2 detectors, were placed in several locations from various areas of the laboratory. All the radioactive sources were placed inside the lead shield store, being not manipulated during the experiment.

The placement of he dosemeters is described in detail below and presented in Table 1.

A total number of 17 dosemeters were used for the monitoring of the working area, situated at the ground level floor of the building. (i) A number of 8 dosemeters were placed in the irradiation hall, where the radioactive sources are used. They were distributed as follows: three dosemeters, positions A1, A2, A3, on the northern side, one of them, B1, on the eastern side, near the radioactive source store shield wall, two dosemeters on the southern side at a distance of about 5m and 10 m from the store shield, positions C1 and C2, and two on the western side, D1 and D2; particularly position D2 was chosen near the X-ray Generator, out of work during the measurement period. (ii) A number of 2 dosemeters were placed in the transfer enceinte, containing two ^{60}Co sources, positions E1 and E2 in Table 1. (iii) A number of 6 dosemeters were placed in the command room of the Laboratory, positions F1, F2 and F3 on the northern side, the position G1 at the east, while positions H1 and H2 covered the southern side. (iv) One dosemeter, codified I1, was placed at the entrance hall of the building.

A number of 3 dosemeters, J1, J2, J3, were placed on he second floor of the building, in the bureau for personnel permanent stationing. A general map, indicating the placement of the dosemeters in presented on Fig. 1.

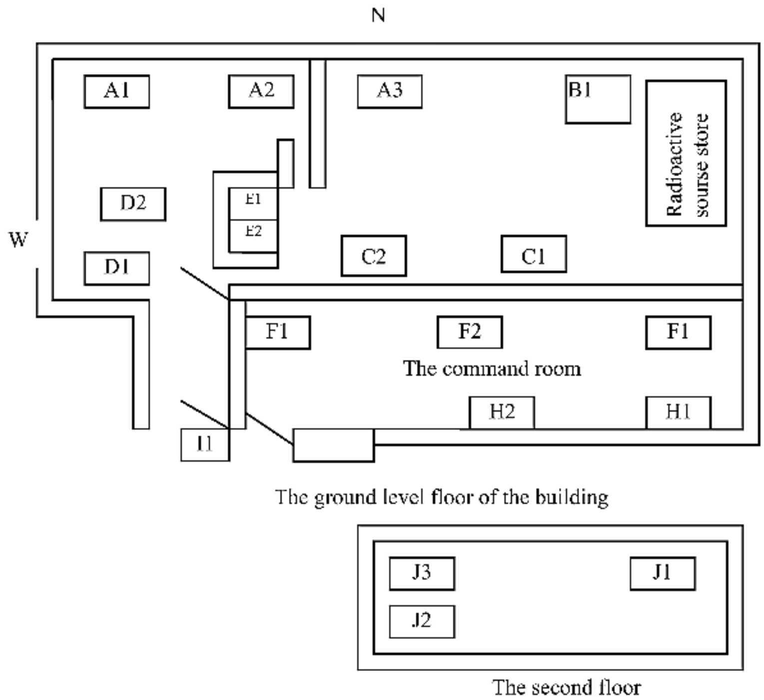

Fig. 1 – The placement of the dosemeters.

2.3. DOSEMETERS AND MEASUREMENTS

The dosemeters contained the three recommended GR-200A high sensitivity detectors, produced by the SANGE Technologies Inc. China. The Thermoluminescent Detector Reader (TLR) was of type 770A, a Polish product. It was operated under controlled water flow, with thermal stabilization of the photomultiplier.

The system was previously calibrated in reference gamma fields, obtained with ^{60}Co and ^{137}Cs standard sources. The response value, expressed in number of counted impulses, was established at the value R = (4.0 ± 0.2) 10^4 imp mSv^{-1}, uncertainty 5% for k = 2, within a measurement interval 0.1 μSv – 100 mSv.

The detectors, freshly regenerated, were placed and exposed to the laboratory level of ambiental effective dose for a 41 days measurement interval. After this period, their registration was read, according to the established procedure [8]. The detectors own background indication, determined by the parallel exposition of some detectors under a lead shielding, was subtracted.

The contribution of the natural component of background, as sum of the cosmic and terrestrial components, was estimated as a mean between several published values for indoor Bucharest area dose equivalent rate values, by taking into account four independent results:

(i) The results of the measurements performed in several areas from Magurele Research Center [2], calculated as the mean value of $CaSO_4$: Dy and GR 200A dosemeters $\dot{H}_{nat}$ = (150 ± 8) nSv/h.

(ii) The mean value determined by us for some Bucharest area flats [2]: $\dot{H}_{nat}$ = (138 ± 6) nSv/h.

(iii) The mean value obtained in our laboratory, calculated as the mean of 3 dosemeters values [7], which was $\dot{H}$ = (108 ± 3) nSv/h.

(iv) The mean indoor gamma dose rate in Bucharest area schools and kindergardens, reported by the Institute of Public Health, Bucharest [9], situated within the interval (65.5–128) nSv/h, with an arithmetic mean value $\dot{H}_{nat}$ = (91 ± 12) nSv/h.

The estimation as arithmetic mean of all these four values is: $\dot{H}_{nat}$ = (122 ± 28) nSv/h; the uncertainty is given for (k = 2).

All the results are presented in Table 1. The value of the ambient dose equivalent rate, due to the radioactive sources, column 5 in Table 1 was calculated as the difference between column 3 values and natural background estimated mean, above presented; the uncertainty of difference resulted combining, in squares, the uncertainties from column 3 and that of the natural background.

3. RESULTS AND DISCUSSIONS

The obtained results, calculated from all the experimental data, obtained in the situation when all the sources are under the lead shielding, are presented in Table 1.

Table 1

Ambient dose equivalent and dose equivalent rate in the CMRID area

No.	Place	Exposure period, [d]	Ambient Dose equivalent, H [mSv]	Ambient dose equivalent rate, $\dot{H}$ [nSv h^{-1}]	Ambient dose equivalent rate, due to radioactive sources [nSv h^{-1}]
0	1	2	3	4	5
1	A1	41	0.146 ± 0.009 (6%)	148 ± 9	Less than 55
2	A2	41	0.162 ± 0.011 (6.7%)	165 ± 11	43 ± 30
3	A3	41	0.413 ± 0.033 (8.2%)	419 ± 34	297 ± 35
4	B1	41	14.84 ± 0.81 (5.5%)	15080 ± 830	14958 ± 830
5	C1	41	0.500 ± 0.027 (5.4%)	508 ± 27	386 ± 39
6	C2	41	0.640 ± 0.047 (7.4%)	650 ± 48	528 ± 56
7	D1	41	0.131 ± 0.011(8.4%)	133 ± 11	Less than 41
8	D2	41	0.139 ± 0.008(5.9%)	114 ± 7	Less than 29
9	E1	41	1.714 ± 0.095 (5.6%)	1740 ± 97	1618 ± 101
10	E2	41	0.828 ± 0.059 (7.1%)	842 ± 60	720 ± 66
11	F1	41	0.124 ± 0.007 (6.0%)	126 ± 8	Less than 33
12	F2	41	0.142 ± 0.084 (5.9%)	145 ± 9	Less than 56
13	F3	41	0.131 ± 0.013 (9.6%)	134 ± 13	Less than 43
14	G1	41	0.143 ± 0.013 (9.3%)	145 ± 13	Less than 54
15	H1	41	0.146 ± 0.014 (9.5%)	148 ± 14	Less than 57
16	H2	41	0.119 ± 0.007(5.5%)	121 ± 7	Less than 29
17	I1	41	0.133 ± 0.008(6.1%)	135 ± 8	Less than 42
18	J1	41	0.115 ± 0.006(5.1%)	117 ± 6	Less than 29
19	J2	41	0.146 ± 0.011(7.2%)	149 ± 11	Less than 57
20	J3	41	0.133 ± 0.007(5.1%)	135 ± 7	Less than 42

From the above presented data, one may conclude: The measured levels of doses, in a 41 days exposition time, are well situated within the measurement interval of the system: 0.1 μSv–100 mSv.

Due to the shielding of the radioactive sources store, the ambient dose equivalent rate levels for the places with long term stationing of the workers: control room, positions F1, F2, F3, G1, H1, H2, entrance hall, position I1, as well as the bureau, positions J1, J2, J3, are situated within the limits of the natural background fluctuations. The situation is similar for the irradiation hall, positions situated far from the sources store: A1, A2, D1, D2. Particularly, the D2 result was predicted, as the X–ray generator was out of work.

A number of places present values of the ambient dose equivalent rate significant different from background. For these points, a separate analysis is necessary to be done.

The maximum annual ambient dose equivalent, according to the Fundamental Norm of Radiological Security, for a worker, is 20 mSv. In the monitored laboratory, one establishes the accomplishment of this legal requirement, by calculating the annual values of ambient dose equivalent due to the radioactive sources (occupational exposure), as follows. One takes into account the dose rates from Table 1, column 5, for those places, where the dose rates are significantly different from background; an annual working interval of 1700 hours is considered. The ambient dose rates, result in the following values of the effective doses, due to the radioactive sources, as presented in Table 2.

From the data presented in Table 2, one may conclude: The highest value, higher than the annual limit of ambient dose equivalent occurs, as expected, near the lead shielding. For this position, it is not permitted to stay all the year long, even with the sources under shielding, as the legally allowed value is exceeded. The other values, in the irradiation hall, are under the annual allowed exposition value, for the public, 1 mSv year^{-1}. The values due to the sources placed in the transfer enceinte, although situated below the legal limit for professionals, are higher than the value for public.

Table 2

Annual ambient dose equivalent due to the radioactive sources

Nr.	Placement	Annual ambient dose equivalent, [mSv]
1	A3	0.51 ± 0.10
2	B1	25.4 ± 1.4
3	C1	0.656 ± 0.066
4	C2	0.898 ± 0.095
5	E1	2.75 ± 0.17
6	E2	1.22 ± 0.11

4. CONCLUSIONS

– The very sensitive Thermoluminescent Dosimetric System, based on the use of GR 200A detectors, was used for the dosimetric survey of entire area of the Ionizing Radiation Metrology, Dosimetry and Testing Laboratory (CMRID) of IFIN-HH; the survey was conducted with the standard sources placed under the lead shielding.

– The registered integral ambient dose equivalent were situated inside the detection interval of the system, assuring generally uncertainties less then 10% (k = 2).

– The ambiental mean ambient dose equivalent levels varied from the background value to a value exceeding the allowed annual limit for professionally exposed personnel; recommendations were formulated in this respect.

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