Environmental monitoring in interventional radiology

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Abstract. The procedures in Interventional Radiology involve long times of exposure and high number of radiographic images that bring higher radiation doses to patients, staff and environmental than those received in conventional Radiology. Currently for monitoring the dose, the thermoluminescent dosimetry use is recommended. The aim of this work was to carry out the monitoring of the environmental scattered radiation inside the IR room using two types of thermoluminescent dosimeters, TLD-100 (reference dosimeter), CaSO4:Dy (synthesized in our laboratory). The results indicate that the TLD-100 is not effective for the environmental monitoring of low-energy Rx rooms. The CaSO4:Dy presented good behaviour over the 6 months of study. The results will be specific to each room so it is recommended such studies as part of the program of quality control of each Rx room.

1. Introduction

The Interventional Radiology (IR) has had a boom in recent years, because of the multiple benefits in the treatment of different diseases with minimum risk; however, we must emphasize the fact that IR procedures provide higher doses of radiation in the diagnosis by images, which requires us to maintain a proper management of the doses given to patients, occupationally exposed workers (OEW) and work environments to reduce the risk of overexposure [1].

Dosimetry is responsible for estimating the dose of radiation received as part of the medical exposure for which relies on different types of instruments, among them the so-called thermoluminescent dosimeters (TLDs) [2, 3].

The TLDs have the property to store part of the energy they absorb when exposed to ionizing radiation. Subsequently, when they are heated they emit this energy in the form of light and, in an ideal system, this is directly proportional to the dose absorbed by the material (thermally stimulated luminescence) [3].

The main available commercial TLDs are based on oxides, fluorides and sulfate doped with rare earths. Currently, the most commonly used thermoluminescent dosimeter is the TLD-100 [4] although this material does not present a very favorable properties for all applications when working with low-energy x-ray [5]. Other materials as the CaSO4:Dy is 50 times more sensitive than the TLD-100 although are not used routinely for the monitoring of doses [6].

The Juarez Hospital in Mexico is one of the hospitals where more RI interventions are performed per year in the Mexico City, so in this work it was conducted the environmental monitoring of its IR room.
using the CaSO₄:Dy synthesized in our laboratory and the TLD-100 at the same time, this last as reference dosimeter for a period of 6 months.

2. Materials and methods
For this study a total of 18 LiF: Mg, Ti chips, commercially known TLD-100 and 18 CaSO₄:Dy discs synthesized in our laboratory (CICATA-Legaria, IPN) were used. The materials were characterized previously dosimetrically for low-energy X-rays [5, 6].

Dosimeters received a standard annealing treatment before exposure to radiation. Depending on the type of material, thermal annealing schemes were: 300°C for 30 minutes to CaSO₄:Dy and 400°C for 1 hour followed by 100°C for 2 hours to TLD-100. The method of slow cooling inside the muffle was used to reach room temperature for all cases.

Thermoluminescent readings were made using a Harshaw 3500 TL analyzer. The heating rate of the TL analyzer was kept at 10°C/s for both materials. The TL emission was integrated from room temperature up to 350°C.

In order to measure the contribution of the radiation dose scattered in the X-ray room, dosimeters were placed in 9 different positions (A1, A2, A3,...,A9), in order to monitor and identify areas of greatest risk of permanency for workers and the dose distribution within the X-ray room, see the figure 1.

![Figure 1. Distribution of dosimeters within the X-ray room.](image)

For positioning in the room the dosimeters were included in a chassis with identical for all geometries and with a 5 mm PMMA filtration, each of these contained 2 TLD-100 chips and two discs of CaSO₄:Dy.

The dosimeters were placed at a height of 150cm above the floor, and were subjected to normal conditions of work within the room for the period of 1 month. TL readings performed 24 hours after they were removed. Finally, the monitoring of the environment was conducted over 6 months.

3. Results and discussion
The dose values determined at different locations in the room of IR for the environmental monitoring of 6 months are shown in table 1.

As you can see from the first five months of monitoring, the TLD-100 showed abnormal behavior, detecting values very near the background radiation in different positions within the room except around the X-ray tube. Therefore, the TLD-100 was not already used in the last month.
Table 1. Medium doses collected by the TLD-100 (D₁) and (D₂) CaSO₄-Dy in different positions within the room of IR (mGy).

| Pos. | 1st month | 2nd month | 3rd month | 4th month | 5th month | 6th month |
|------|-----------|-----------|-----------|-----------|-----------|-----------|
|      | D₁        | D₂        | D₁        | D₂        | D₁        | D₂        | D₁        | D₂        | D₁        | D₂        | D₁        | D₂        |
| A1   | <0.1      | 0.3       | <0.1      | 0.2       | 0.5       | 0.2       | 0.3       | 0.6       | 0.3       | 0.9       | 0.8       | 1.3       | 1.5       |
| A2   | <0.1      | 0.2       | <0.1      | 0.2       | 0.2       | 0.2       | 0.3       | <0.1      | 0.1       | <0.1      | 0.4       | 0.8       | 0.9       |
| A3   | <0.1      | 0.2       | <0.1      | 0.2       | 0.2       | 0.3       | <0.1      | 0.5       | <0.1      | 0.4       | 0.4       |           |           |
| A4   | <0.1      | 0.4       | 0.9       | 0.2       | 0.9       | 1.1       | 1.1       | 1.7       | 1.6       | 1.3       | 1.4       |           |           |
| A5   | 1.1       | 5.2       | 1.1       | 1.3       | 5.8       | 12.5      | 12.5      | 18.4      | 11.7      | 18.5      | 21.8      |           |           |
| A6   | <0.1      | 0.6       | 0.3       | 0.2       | 1.8       | 0.7       | 0.8       | 0.4       | 0.9       | 0.6       | 0.7       |           |           |
| A7   | <0.1      | 0.3       | <0.1      | <0.1      | 0.1       | 0.1       | <0.1      | 0.1       | <0.1      | 0.1       | 0.1       |           |           |
| A8   | <0.1      | 0.2       | <0.1      | <0.1      | 0.3       | 0.4       | 0.2       | 0.5       | 0.2       | 0.6       | 0.5       |           |           |
| A9   | <0.1      | 0.01      | <0.1      | <0.1      | <0.1      | <0.1      | <0.1      | <0.1      | <0.1      | <0.1      | 0.1       | 0.1       | 0.1       |

In the case of the doses reported by the CaSO₄·Dy thermoluminescent dosimeter, an approximate distribution of the dose of radiation in the x-ray room is displayed as shown in figure 2. As you can see, the area of greatest risk of permanence of the OEW, due to higher doses recorded over the six months of this study was around the fluoroscope and to the right side of it.

![Figure 1](image.png)

**Figure 1.** The distribution of the dose of radiation scattered in the room of IR of the Juarez Hospital in Mexico.

These findings were expected due to the configuration of this X-ray room in particular, that is, we think that the distance factor is one of the causes of the distribution of higher doses of the right of the equipment.

From measurements made by the A6 and A7 dosimeters we obtained that the window shield attenuates approximately 5 times scattered radiation that arrives at the control room. On the other hand, the values of the dosimeters in positions A4 and A8, which are on each side of the entrance door to the room of x-ray tube, allows us to ensure that the door is not armored, since detected doses that are attenuated due only to the law of the inverse of the square, i.e., outside the door the dose is 0.54mGy and inside the door is 1.4mGy.

Both halls (dosimeter A9) and the inside of the control room, behind the window with leaded shield (dosimeter A7), the amount of radiation are negligible or is that it corresponds to background
radiation, so it is a safe area, although it is recommended in any way the least number of people in these areas.
The chest X-ray is diagnostic tool most widely used in the population in general. The dose on the surface of entry for one of these chest X-rays is between 0.2 mGy and 0.4 mGy [7, 8, 9]. In this way, a person who stays a full month in a position very close to the X-ray tube will receive the equivalent doses between 25 and 80 chest X-rays. Behind the window which is armored, the dose is equivalent to less than one chest X-ray. This comparison is only to point out the magnitude of the risk of permanence of the OEW in these areas.

4. Conclusions
This work is a study of the measurement of the scattered environmental radiation dose in the room of IR of the Juarez Hospital in Mexico. For the determination of the dose, two types of thermoluminescent dosimeters were used: the TLD-100 which was confirmed as a bad dosimeter to measure environmental scattered radiation and the CaSO4:Dy, which confirmed its effectiveness for this type of measurements of radiation since it is a material more sensitive to radiation.
We can conclude that the dosimeter thermoluminescent most suitable for the determination of environmental dose are the CaSO4:Dy. This type of study should be done in any room that has an X-ray tube in the country in order to know their risk areas as well as to give recommendations to the OEW in these areas.

5. References
[1] Picano E, Andreassi M G and Rehani M 2013 Radiation protection Percutaneous interventional cardiovascular medicine The PCR-EAPCI textbook Europa Edition.
[2] Rivera T 2012 Applied Radiation and Isotopes 71 30
[3] McKeever S W S, Moscovitch M, Townsend P D 1995 Thermoluminescence dosimetry materials: properties and uses (United Kingdom: Nuclear Technology Publishing)
[4] Cameron J R, Zimmerman D, Kenney G, Buch R, Bland R and Grant R 1964 Health Physics 10(1) 25
[5] Fernández S D S, García R., Sanchez D, Ramírez G, Gaona E, De León M A and Rivera T 2016 Applied Radiation and Isotopes 107 340
[6] Fernández S D S, García R, Mendoza J G, Sánchez D, Rodriguez G R, Gaona E and Montalvo T R 2016 Applied Radiation and Isotopes 111 50
[7] European Commission 1999 Guidance on diagnostic reference levels (DRLs) for medical exposures Radiation Protection 109
[8] World Health Organization 1996 International basic safety standards for protecting against ionizing radiation and for the safety of radiation sources
[9] Le J 1999 Guidelines on patient dose to promote the optimisation of protection for diagnostic medical exposures: documents of the NRPB 10(1) 1999 Radiation protection news and notes 46 17
[10] Gray J E, Archer B R, Butler P F, Hobbs B B, Mettler Jr F A, Pizzutiello Jr R J and Yaffe M J 2005 Reference values for diagnostic radiology: application and impact. Radiology 235(2) 354

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