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Personnal Dosimetry, as a Means of Monitoring Workers Under Ionizing Radiation in Madagascar

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Abstract: Personal dosimetry is the means of monitoring workers under ionizing radiation in Madagascar. This dosimetry consists in measuring the operational quantities Hp (10) or Hp (0.07) (equivalent doses to the whole organism and to the skin) and to check that these values do not exceed the authorized annual dose limit. In fact, dose limitation is one of the means of protecting workers against the harmful effects of ionizing radiation. In Madagascar, the Dosimetry and Radiation Protection Department of INSTN-Madagascar has a HARSHAW 6600 personal dosimeter reader. It is a powerful device because it reads automatically and can read 200 cards at one time. Despite the capacity of this device, there is still some manual work to do for data management, by recording in a "log book" the doses read by the reader and joining them in the database of workers. To address the objective of specifically managing the doses received by workers. The goal of this work is to facilitate the reading process of TLDs by recovering the data coming from the reader and by exploiting them in the database of the workers. With more than a thousand personal passive dosimeters distributed to more than 700 workers under ionizing radiation in Madagascar and abroad. This monitoring has been carried out since 1993 until today. If the dose is exceeded, the employer must specify the presumed causes of the excess and inform the INSTN and the labor inspectorate.

Keywords: Dosimetry, Workers, Dose Limitation, Ionizing Radiation

1. Introduction

The harmful effects of ionizing radiation on health appeared from the first uses of sources of ionizing radiation. Clinical cases such as radiodermatitis with tissue necrosis have been observed. And after a few years later, the random effects, mainly leukemia and skin cancer were observed.

These observations have contributed, at the international level, to the development of radiation protection, the objective of which is to avoid the appearance of these acute effects but also to reduce the probabilities of the appearance of radio-induced cancers, in particular, by limiting the doses received by workers [5, 6].

In Madagascar, the use of ionizing radiation sources steadily increases.

2. Materials and Methods

The reading of doses and the use of dosimetric data require the following equipment:

1. A HARSHAW TLD 6600 reader equipped with a gas generator
2. A computer with a printer
3. TLD cards.

2.1. HARSHAW 6600 TLD Reader [3]

The HARSHAW 6600 TLD reader is an automated reader. Therefore it can read 200 cards automatically and continuously.

Characteristics:

1. Model: 6600
2. Serial number: 9809172
3. Manufacturer: BICRONE NE.

It contains:

1. Two cartridges, one refill cartridge, the other discharge cartridge (each cartridge can hold 200 cards) and a drawer for rejected cards.
2. Two photomultiplier tubes (PMT) or channels.
3. A radiating source of Sr-90 activity 0.5 mCi and serial number I-038 used to calibrate the system.
4. A C-14 radioactive source activated by CaF_2 which is used to control the stability of the device, which has an activity of less than 60 mCi and the serial number is G970.
5. A dashboard containing the control keys.
6. An electroluminescent control screen to visualize the reading parameters and thermoluminescence curves.
7. A gas generator that produces a constant flow of nitrogen, with a predefined flow rate and purity when connected to a suitable electrical source. A card can contain one of the following three types of dosimetric cards:
   a) LiF tablets for personal and environmental dosimeters.
   b) "Chipstrates" (EXT-RAD) for end dosimeters.
   c) Rings (DXT-RAD) for end dosimeters.

2.2. Computer

This is the device that stores and processes dosimetric data. The computer must have at least the following configuration:

1. A 386Sx-20 processor
2. A mathematical coprocessor
3. A 6.86 GB hard drive
4. A RAM of 126MB
5. A graphic VGA screen
6. A printer

This computer is accompanied by software for the evaluation and management of radiation doses called TLD-REMS (Radiation Evaluation and Management System).

2.3. TLD

This dosimeter is divided into two parts:

1. The TLD card: The card is made up of two hot-pressed TLDs. These are (LiF) chips whose dimensions are $3.2mm^2$ x 0.38mm and mounted between two sheets on an aluminum substrate. The card is identified by a label (exactly by its bar code) allowing the reader to differentiate the cards one after the other. One corner of the card is checked to ensure correct insertion and orientation when reading in the automatic TLD reader.
2. The card case: The TLD card holder (housing) is designed to be sturdy, fabric equivalent, made of ABS plastic and sealed to keep the card protected from light and moisture, and can be easily opened.

The thermoluminescent dosimeters, commonly called TLD (Thermo Luminescent Dosimeter) that we use are made of lithium fluoride (LiF), in the form of pellets [4]. Under the influence of radiation, these substances undergo changes in their internal structure (Figure 1). If subjected to uniform heating, they return to their initial state, emitting light in an amount proportional to the dose of radiation to which they were subjected.

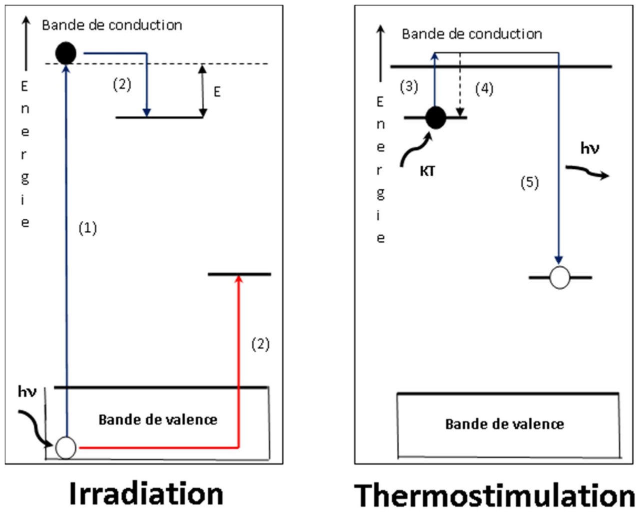

Figure 1. *Schematic diagram of thermoluminescence and thermoluminescent dosimeter TLD.*

The TLD dosimeter is used for the individual dosimetric monitoring of workers under ionizing radiation [5, 9-11]. This requires a badge with at least two pellets, usually one without filtration and the other covered by aluminum screens [7, 16, 17].

There are models in the form of a rectangular plate with two pellets. This plate is placed in a screen holder (Harshaw). In Madagascar, the regulations impose the thermo-luminescent dosimeter as individual reference dosimetry (regulatory dosimeter) [12-14].

Prepared personal dosimeters are distributed to users every three months. A worker professionally exposed to ionizing radiation must always wear his personal dosimeter during his activities and the dosimeter must remain in the workplace at the end of the day. In fact, the measured dose must reflect the amount of radiation received at the workplace and not at home. The dosimeter is returned to INSTN after three months of wear, but before that the worker receives a spare dosimeter to avoid working without dosimetric monitoring during shipment.

The measured doses are processed in a TDDIT computerized dose management system designed by the Dosimetry and Radiation Protection Department of the INSTN. The processing consists of storing the doses and calculating the quarterly and annual doses of the workers. Note that the annual dose is the dose for the last twelve months. The individual doses are confidential, only the employers and workers concerned will receive information on these doses.

Figure 2. *Harshaw 6600 Dosimeter Reader and Associated Software.*

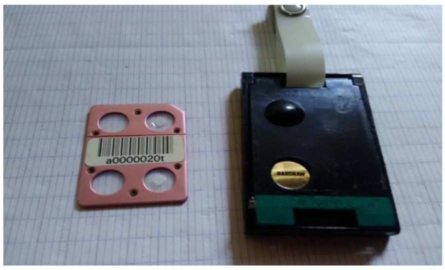

Figure 3. *TLD dosimeter and badge holder.*

2.4. HARSHAW TLD 6600 Reader Workstation Description [3]

The TLD 6600 workstation is a complete, automated set of thermoluminescence measuring instruments. It consists of the TLD 6600 reader, a computer and a printer as shown in the following figure:

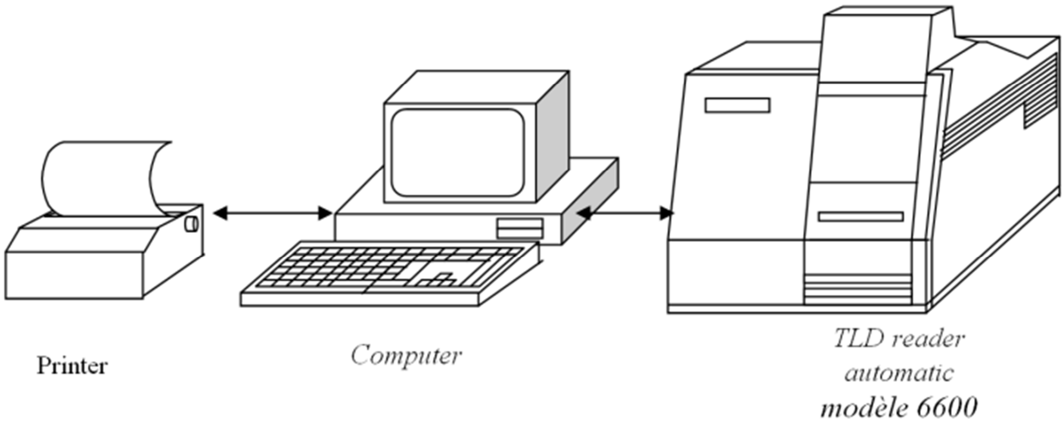

Figure 4. *TLD 6600 reader workstation.*

2.5. Serial port for Reader Communication [15, 17]

The system includes both a computer housed in the reader and a Windows operating system connected to the reader via an RS-232-C serial communication port. The playback functions are split between the reader and the WinREMS software installed in the computer. All data storage and instrument control is performed by this software.

2.6. WinREMS Software [15, 17]

This software controls data storage and measurement parameters:

1) Time and Temperature Profiles (TTP),
2) Reader Calibration Factor (RCF), and
3) Element Correction Factors (ECC).

It allows the user to automatically calibrate the meter and dosimeters in a wide variety of dosimetric units, or to work directly in charge mode. WinREMS displays the result obtained as a curve, stores and transfers the data for subsequent calculation. And it also performs a series of calibration and quality assurance of the reader.

Thanks to it, parallel installations of HARSHAW TLD Readers can be realized.

2.7. Data Transmission

This part defines the data transmission protocol between the software and the Microcomputer.

This part specifies the communication protocol used when a file coming from the Software is transmitted to another microcomputer. REMS is defined as the "issuer" (talker in English) and the central unit as the "receiver" (listener in English). When the data is transferred to the central unit, REMS establishes the communication, sends the data block and ends the communication. Each block must be positively recognized by the receiver before the transmitter sends the next block.

3. Results

3.1. Number of Workers and Potentially Affected Activities

Ionizing radiation is used more and more in the medical sector, which has 135 supervised workers. Beyond this field, around 512 workers work daily in various other sectors (203 in the industrial field, 261 in mining and 48 in research). In total, there are therefore 647 supervised workers in Madagascar.

Table 1. *Distribution of the number of workers supervised depending on the area of intervention.*

Field	Number
Medical	135
Industrial	203
Mining	261
Research	48

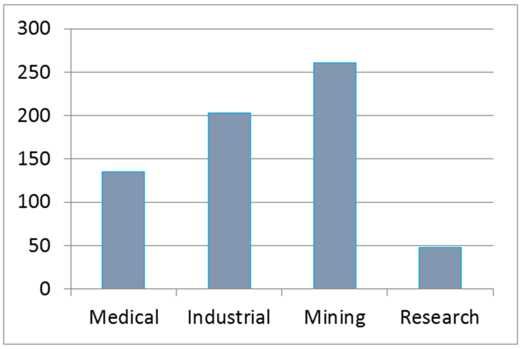

Figure 5. *Distribution of the number of workers supervised depending on the area of intervention.*

3.2. Result of Measurements

The operational quantity used for personal dosimetry is the personal equivalent dose H_p (d) [9]. The reference dose is the H_p dose (10) which is the dose equivalent to a depth of 10 mm of the worker's skin which is equivalent to the whole body dose [1, 2, 5, 8,]. Based on the values in Table 2, the average equivalent dose per worker per quarter is 0.7 mSv. This value shows a constant since 2014.

Table 2. *Equivalent doses since 2014.*

Year	H_p (10) Quarterly (mSv)	H_p (10) Annual (mSv)
2014	0.7	1.7
2015	0.7	1.7
2016	0.7	2.3
2017	0.6	1.4

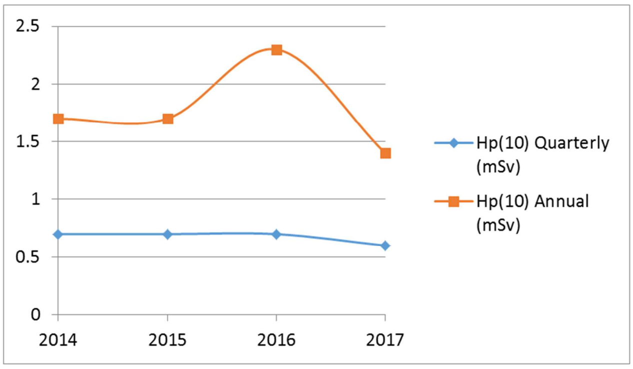

Figure 6. *Equivalent doses since 2014.*

4. Discussion and Conclusion

Advantages and disadvantages of the thermo-luminescent dosimeter (TLD).

From the point of view of dosimetric qualities, the thermo-luminescent dosimeter is very efficient in terms of energy response and sensitivity to low doses.

Main advantages

Dosimetric quality: the dosimeter itself has a better energy response and it can be further improved by adding metal screens of different types to assess the energy of the radiation.

Sensitivity: doses of the order of 0.05 mSv can be easily measured regardless of the energy of the radiation involved.

The possibility of reusing the dosimeter after the measurement: once the dosimeter returns to its original state, it is ready to be used again. The same dosimeter can therefore be assigned to the same person and be used several times. This possibility is interesting especially from a financial point of view, but after a certain number of uses the dosimetric quality deteriorates and it can only be used a number of times limited to about twenty.

The possibility of automation: the badges can be read automatically on measurement chains. The reliability of a proven technique: these dosimeters have been used worldwide for half a century in various fields of radiation protection.

Main Disadvantages

The cost: The dosimeter itself is a bit expensive ($ 70 USD) per unit in addition to shipping and reading costs.

For all these reasons, this dosimeter is therefore more profitable despite its somewhat high cost.

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