BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
10-02A (2022) 01-14

Workplace monitoring in the Radiation Physics and Metrology Laboratory (LAF-RAM)

Castillo [a,b] A.M., Mendoza [a], J.S., Roas [a], N.A.

[a] *Laboratorio de Física de Radiaciones y Metrología LAF-RAM, Universidad Nacional Autónoma de Nicaragua, Managua Rotonda Universitaria Rigoberto López Pérez 150 metros al este, Código postal: 663 Managua, Nicaragua,*

[b] *Centro de Investigaciones y estudios de la Salud de la Universidad Nacional Autónoma de Nicaragua CIES-UNAN Managua, Nicaragua*

acastillos@unan.edu.ni

ABSTRACT

This paper presents the values of environmental equivalent dose H*(10) using thermoluminescent detectors (TLD) from a period of 2019 to 2021 in the Radiation Physics and Metrology Laboratory (LAF-RAM) of the National Autonomous University of Nicaragua, Managua (UNAN-Managua). Fifteen measuring points are monitored on a total of 23 monitoring periods. The selected locations include the public areas, the supervised areas. The characterization of the environmental dosimetry of LAF-RAM was possible finding no significative variations in the temporal evolution of the evaluated periods and the results do not indicate any risk to occupational workers or members of public.

Keywords: **environmental dosimetry, dosimetry system, thermoluminescent dosimeters.**

ISSN: 2319-0612
DOI: https://10.15392/bjrs.v10i2A.2022
Submitted:2022-03-06
Accepted: 2022-07-21

1. INTRODUCTION

The Environmental Dosimeters are calibrated in terms of the ambient dose equivalent, H*(d), this quantity is defined as the dose produced by an aligned radiation field, in an ICRU sphere, at a depth d. For strongly penetrating radiation it is defined at a depth of 10mm and is expressed as H*(10) [1].

In Nicaragua, the Radiation Physics and Metrology Laboratory (LAF-RAM) is located at National Autonomous University of Nicaragua, Managua (UNAN-Managua) and it is the only external dosimetry service provider. The service is performed through the External Dosimetry Laboratory (LDE) that is technically capable of providing whole body dosimetry in terms of personal dose equivalent Hp (10), extremity dosimetry in Hp (0,07) using ring dosimeter, eye lens dosimetry in Hp (3) and for area and environmental monitoring in H*(10).

The dosimetry system in LDE for H*(10) monitoring was calibrated for the first time in 2016 using thermoluminescent detectors (TLD) because of an investigation conducted by Roas [2] on the evaluation of environmental dosimetry at 6 border points in the country. The study was carried out because in 2015 the government of Nicaragua implemented a project to provide an efficient and more automated service to international cargo transportation with the installation of 4 MeV energy scanners at the most relevant border controls. It was then known for the first time what was the contribution of the dose around these scanners for occupational workers [2]. Based on the experience in working with TLD for environmental dosimetry, in 2019 the LAF-RAM begins the area monitoring in fifteen measurement spots distributed in all the different areas of the facility.

The LAF-RAM is structured into four different specialized laboratories namely, the Internal Dosimetry Laboratory (LDI), the Dosimetry Calibration Laboratory (LCD), the Quality Control and Monitoring Laboratory (LCM) and the LDE.

All the information related to the external dosimetry service, dosimetric readers, customer information and dosimeters are secure in the LDE. The LCD consists of a bunker with a gamma irradiator system of ^{137}Cs and 0,84 TBq (at reference date of July 1, 2013) additionally is equipped with two sets of reference ionization chambers for radiation protection and in the control room the irradiator console and the video system. The LDI, performs the services of thyroid uptake for nuclear medicine workers in the country and wipe tests. In the case of LCM for the service of quality controls of X ray equipment the laboratory is provided with radiation protection detectors such as ionisation chambers, multimeters and test objects, moreover a mobile X-ray machine is also located in this laboratory, and it is used only for education and training purposes. The LAF-RAM has research radioactive sources that are stored and secured at the LDI.

Although the LAF-RAM is also licensed to operate radioactive sources for research, most of them are categorized according to the regulatory control as exempt. At the moment they are stored and maintained secure at the LDI.

Moreover, the LAF-RAM has been implementing the Quality Management System since 2017 and it is in the accreditation process of the LDE and LCD, both laboratories have been able to participate in regional intercomparisons organized by the IAEA and have performed the calibrations of their systems with equipment traceable to accredited laboratories thus demonstrating their technical capabilities.

To promote radiation protection, environmental radiation monitoring of a facility such as LAF-RAM is one additional method to ensure that controlled areas and public areas adjacent to radiation sources and X-ray equipment comply. The following work is a review of the results of area monitoring using TLD at the LAF-RAM over a three-year period, in order to periodically characterize the environmental radiation in the most sensitive areas and to evaluate its variations.

2. MATERIALS AND METHODS

The dosimeters were first characterized in LDE in terms of individual sensitivity of the crystal and individual zero-dose sensitivity. They were subjected to a constant heating of 300°C for 15 seconds according to the LDE test method for readings and annealing. Then a batch of 20 dosimeters were used for calibration with coefficients of variation of less than 5% with respect to the response and the batch was divided into two groups, 10 dosimeters were irradiated at 10 mSv and the other 10 dosimeters were used as transport or background. Both the characterization of the dosimeters and the calibration of the system were carried out according to the operating manual of the RADOS Win TLD PRO of the dosimetry readers.

The dosimeters used for the calibration of the dosimetry system were irradiated in 2018 at the Seibersdorf Laboratory of International Atomic Energy Agency (IAEA) in Austria, then these dosimeters were considered the Standard or reference dosimeters.

The system is calibrated based on a local $^{90}Sr/^{90}Y$ irradiator which exposes the dosimeters located on a rotating disc and determining a factor which indicates the exposure as a function of the number of turns to which the dosimeters are exposed and with respect to the reference dosimeters, therefore, the calibration factor for H*(10) found was 319 µSv/turn.

2.1. Materials

The materials used for the measurements are as follows:

TLD specifically prepared for environmental dosimetry which consist of Litium Fluoride doped with Magnesium and Titanium (LiF: Mg,Ti) crystals as shown in Figure 1, the Rados TLD Dosimeter Reader and adhesive materials used to place the TLD on walls and doors.

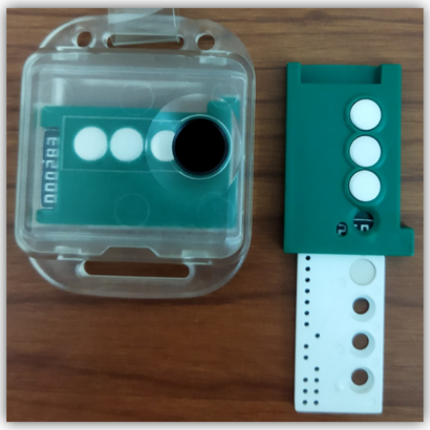

Figure 1. *Type of dosimeter used for monitoring H*(10)*

2.1. Methods

The monitored points are fifteen, distributed in practically all areas of the LAF-RAM, distributed according to the Architectural layout of LAF-RAM [3] of Figure 2, the areas are numbered, for instance 0170 is the bunker, 0050 LCD control room, 004A the source storage room, 0040 X-Ray room, for the LDE there are two spaces presented as 0020 and 0030, the reception is area room is number 0010, management office is 0160, 0150 is the cafeteria, 0130 is teachers' lounge 1 and 0140 teachers' lounge 2, the library is located shown in number 0120, the conference room is number 0110, the warehouse is presented as 0100. In the case of the corridor adjacent to X-ray room is shown in the Figure 2 as the dot in blue. It is important to mention that in the reception room are received the dosimeters and detectors of the service of both LDE and LCD respectively. In LDE there are 4 measuring points between the storage area of the service dosimeters and the working reading area and verify conditions of ambient dose equivalent.

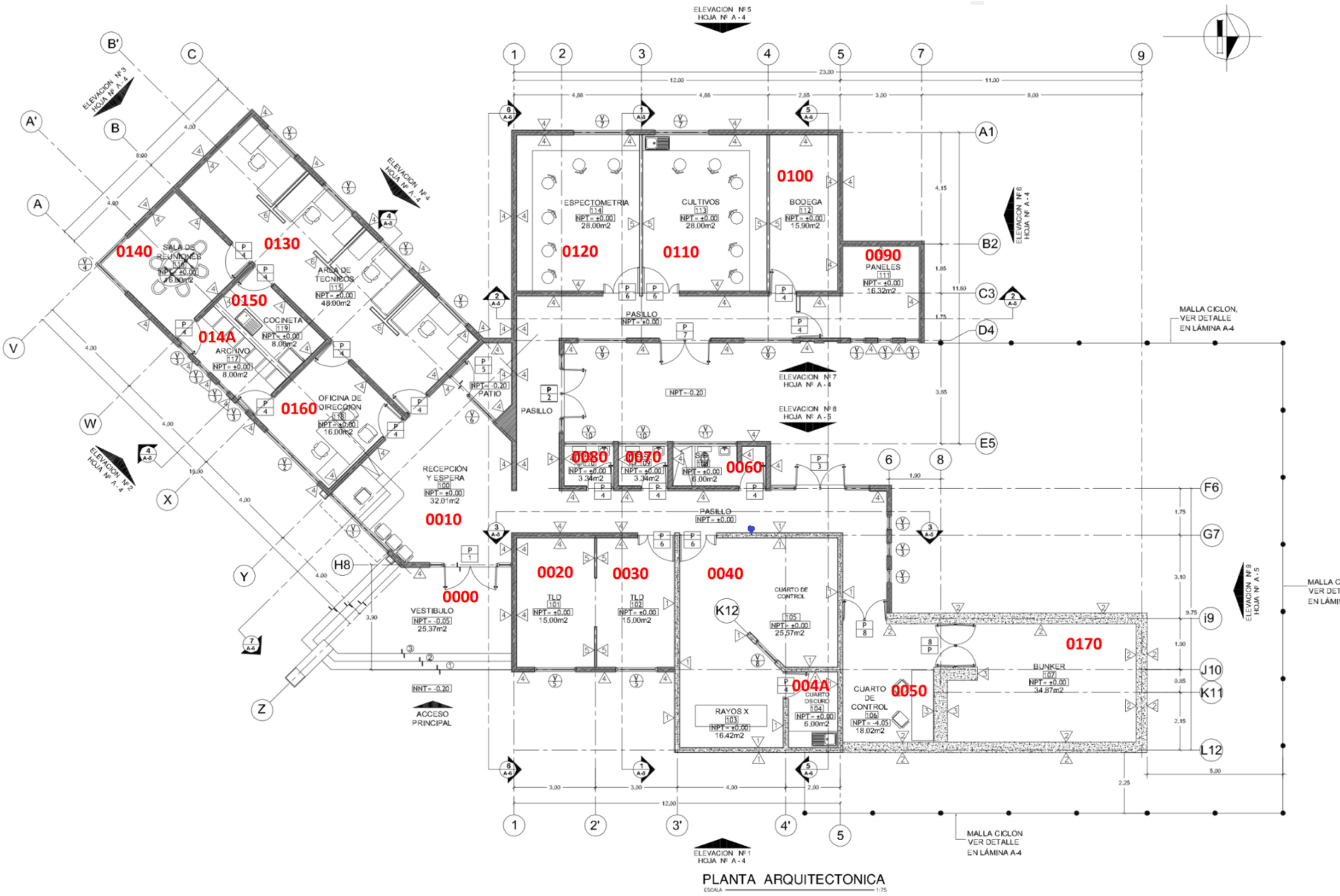

Figure 2. *Architectural layout of LAF-RAM*

Figure 3 shows the arrangement of the dosimeters during each the monitoring period for: 1 corridor adjacent to X-ray room, 2 source storage room door and 3 control room of LCD.

The mobile X-ray equipment consists of a Toshiba X-ray tube fabricated in 2009 with a filtration of 1,3 mm Al / 75 kV and a maximum voltage of 150 kV, the collimator is from RALCO with a filtration of 2 mm Al / 75 kV.

Figure 3. *Example of three measuring points with the TLD arrangement. Photo in the left indicates the dosimeter placed at the entrance door of the area of LCM where the mobile X ray is located, photo in the center shows the dosimeter place at the entrance door of the source storage room and photo in the right side depicts the dosimeter place at the wall between the bunker and the control room in LCD.*

Additionally, a GRAETZ model active area detector was used to measure the environmental dose equivalent rate in the LDE, the control room of LCD and at the door of the source storage room to compare with the results of H*(10) by thermoluminescent dosimeters. The measurements in LDE were performed in three sites: on the working tables, around the dosimeter readers and in the storage racks of the service dosimeters. The measurements were carried out during five days distributed in two times, in the morning and in the afternoon.

3. RESULTS AND DISCUSSION

The H*(10) dose information was collected through the dose reports provided by the LDE for each year. The reports indicate that in 2019 were only 7 monitoring periods starting at the end of February 2019, however for both 2020 and 2021 there were 8 monitoring periods measured. Even though it was set at the LAF-RAM that the monitoring periods for environmental radiation would be every month, in these last two years the capacity of personnel in LDE was affected by the pandemic situation and the monthly monitoring was no longer carried out, thus some monitoring periods were extended up to 2 months.

The Table 1 shows the mean H*(10) for each year and the uncertainty, considering the 15 monitoring points distributed in LAF-RAM. Note that the in 2021 the highest mean H*(10) value can be observed. This also corresponds to the general trend observed in Figure 4. According to the data in the last period of 2020 between 2020-10-01 to 2020-11-27 the average for this period was 0,22 mSv, this was the highest average values of H*(10).

A problem with the nitrogen generator supplying the readers was investigated and identified that it was not working properly and affecting the TLD measurements therefore it was decided to change the nitrogen generator.

Moreover, during the fourth monitoring period of 2021 the highest average of H*(10) was found to be 0,25 mSv because of another malfunction of the nitrogen generator. However, at the end both nitrogen generators went out of service.

Table 1: H*(10) annual average from the 15 measuring points

Year	**H*(10) mSv/year**	**uncertainty s/√n (mSv/year)**
2019	0,70	0,18
2020	0,50	0,12
2021	1,04	0,32

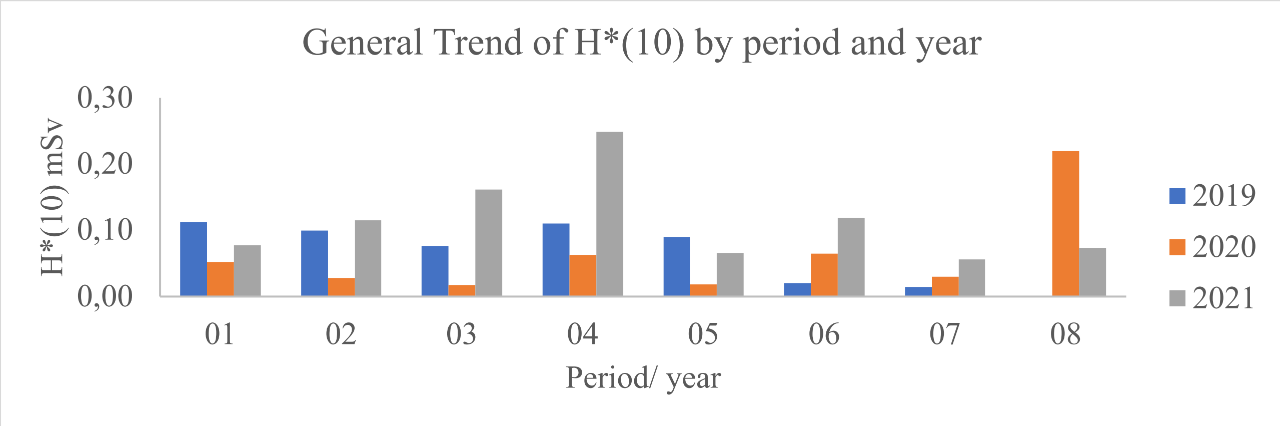

Figure 4. *General trend of H*(10)*

The Figure 5 shows the results of the mean environmental equivalent dose H*(10) for the 15 measurement points and per monitoring period of 2019. The mean H*(10) ranges from values below the minimum detectable of the dosimetry system determined as 0,04 mSv to a maximum measured value of 0.34 mSv. This maximum value was reported by the dosimeter used in the LCM and is likely to be due to scattered radiation detected while performing the quality control of the mobile X-ray equipment in this period. In this case the dosimeter was placed behind the protective barrier over the viewing glass which is not in compliance with the radiation protection requirements because it is not leaded glass (see Figure 6), however the operator remains during irradiation behind the concrete barrier. According to the LAF-RAM safety evaluation report, that considers two scenarios, one taking into account the shielding and the other not including shielding provided by the walls of the facility, there are estimated potential doses between 10-15 mSv/year at a distance of 1.5 m to 2 m from the X-ray tube. Consequently, the recommended procedure has been to ensure that the operator is placed behind the wall of the barrier and using a warning sign is placed when the equipment is in use so that the personnel would avoid circulating around the corridor adjacent to the LCM door where the portable X-ray is located [3].

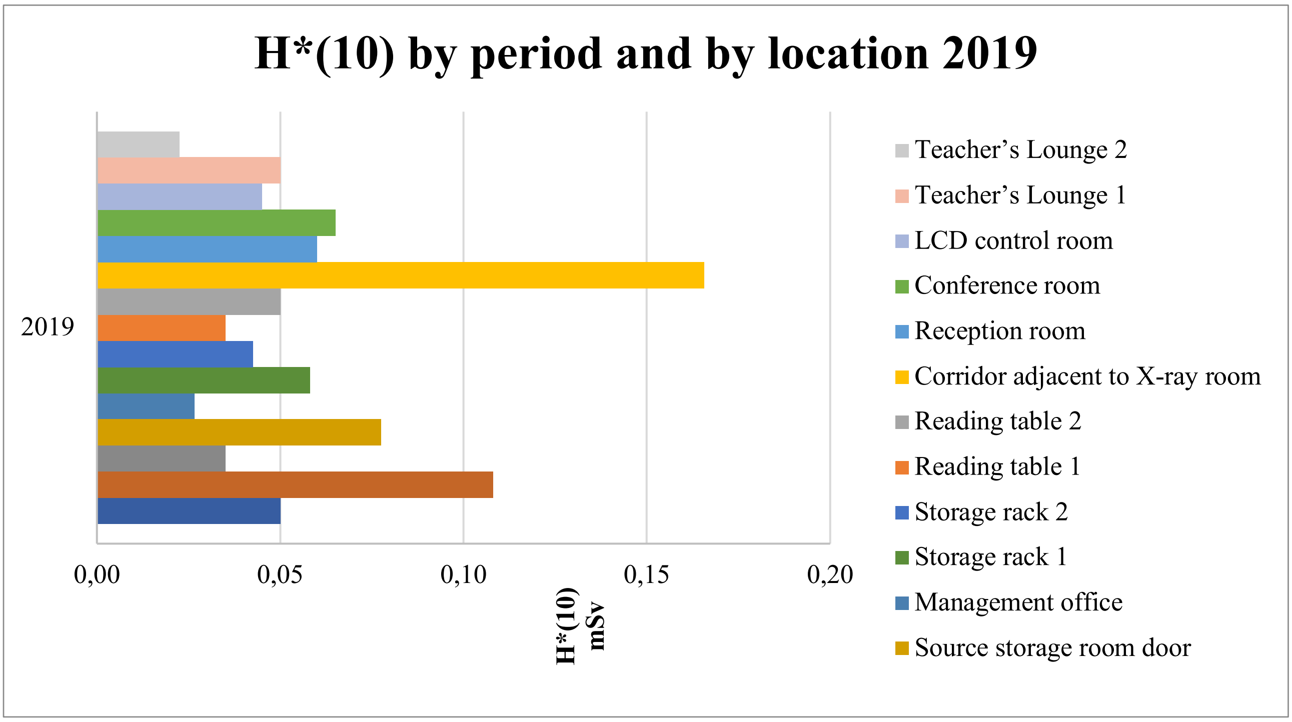

Figure 5. *Comparison of H*(10) for each measuring points and average of 7 monitoring periods*

Figure 6. *The photo on the left shows the dosimeter place onto the viewing window in LCM, the mobile X ray is shown in the photo of the center and the photo in the right is a layout of the LCM in 3D.*

During the year 2020 the mean H*(10) values were below the minimum detectable up to 0,28 mSv for all measurement points. It was detected an increase of H*(10) during the last period of 2020 with a minimum of 0,15 mSv and a maximum value of 0,28 mSv, resulting in a mean of 0,22 mSv only in this period, that is about 5,5 times higher than the mean value of the rest of the periods. According to Figure 7 individually the mean H*(10) of each measurement point is below 0,10 mSv even if the last period is included in the statistics.

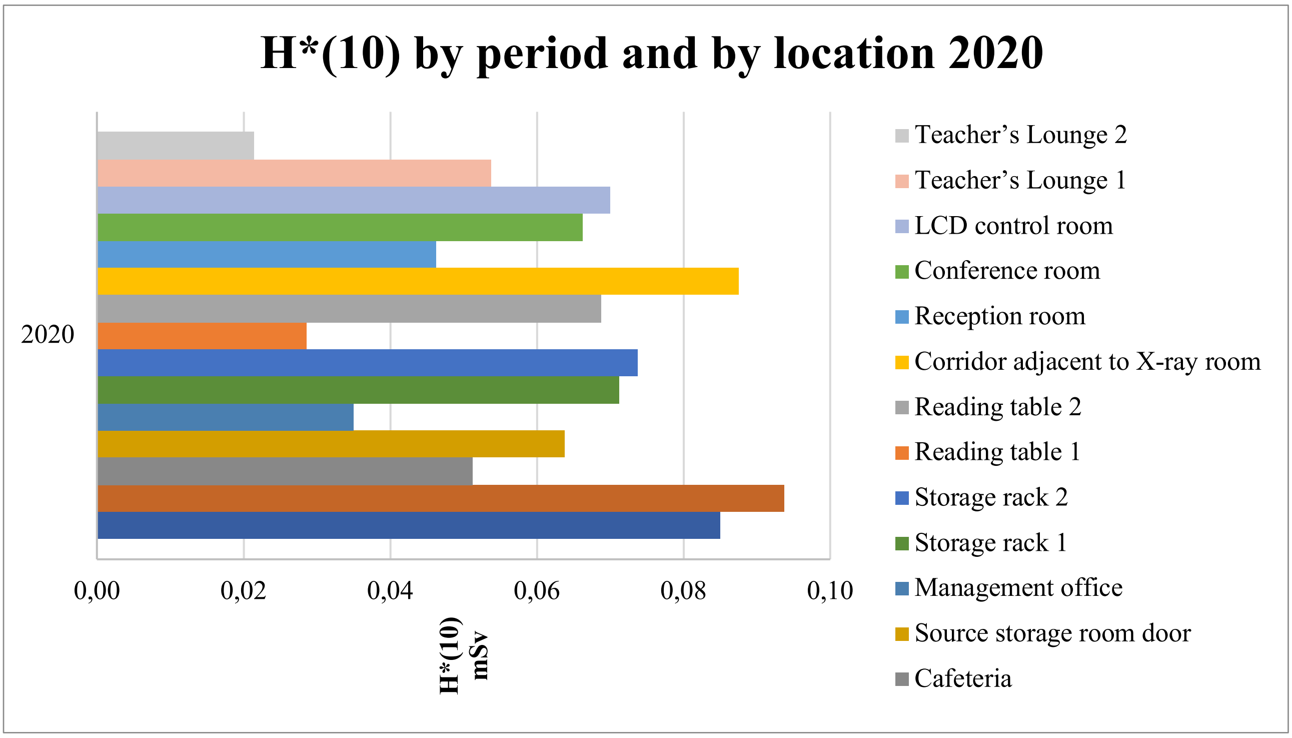

Figure 7. *Comparison of H*(10) for each measuring points and average of 8 monitoring periods*

The Figure 8 is the result of the mean H*(10) of all measuring points in 2021. Compared to the results of Figures 5 and 7 it can be noticed higher mean values in the different measuring points. In 2021 the environmental dose equivalent measurements register values below the minimum detectable of the dosimetry system and a maximum value of 0,36 mSv during the fourth monitoring period, however there was two continue monitoring periods with mean values of 0,16 mSv and 0,25 mSv and correspond to the time period when the two nitrogen generators were having complications with the nitrogen flux, leading to fluctuations in the crystal counts and final dose. Without considering these two periods the mean value for H*(10) obtained for 2021 is 0,08 mSv, this result is below 0,10 mSv as well as the results in 2021.

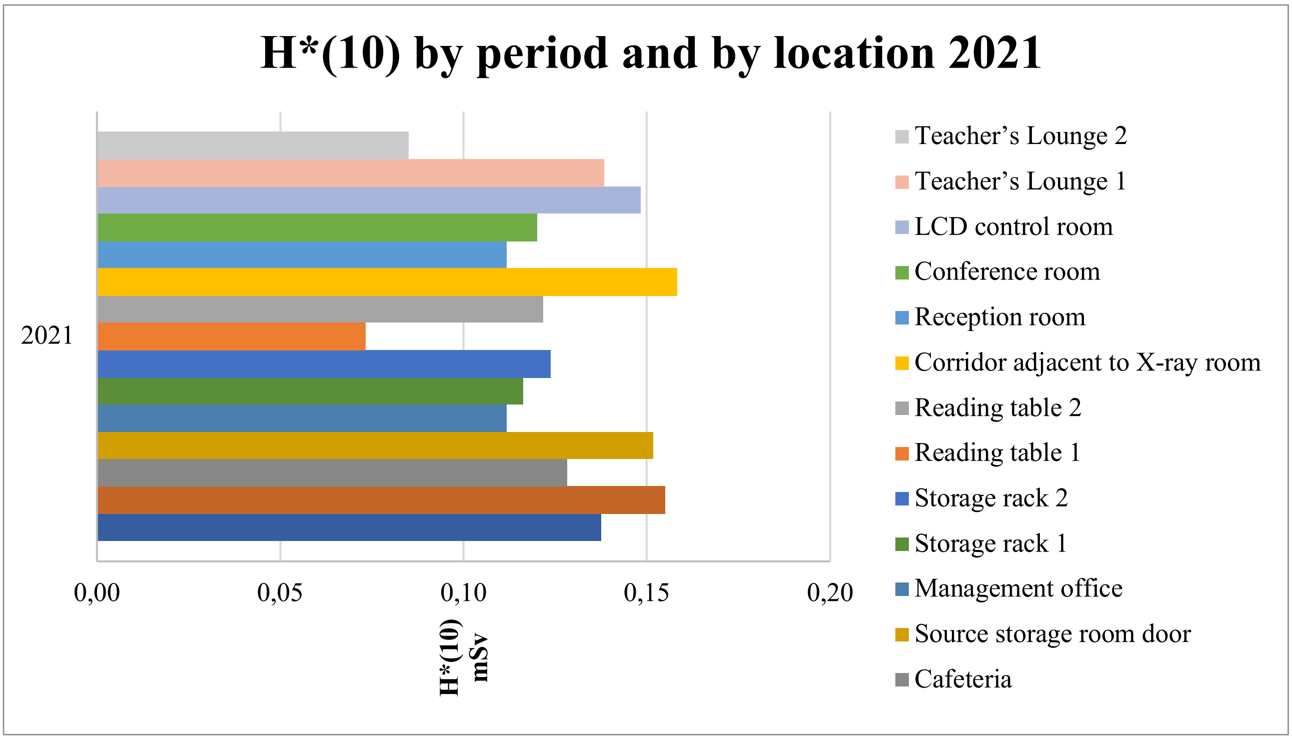

Figure 8. *Comparison of H*(10) for each measuring points and average of 8 monitoring periods*

On the other hand, the measuring results with the GRAETZ are presented in table 2 comparing with the annual averages of H*(10) for control room of LCD, source storage room and the averages of the four measuring points in LDE, the TLD values are the averages for the three years presenting lower values compared to the active detector. The results of the annual H*(10) are higher when performing measurements with the active detector because its sensitivity is noticeable as its dose rate measurement range is between 0 nSv/h - 20 mSv/h according to its manufacturer. It is important to mention that these values do not represent occupational monitoring analysis, therefore these values are conservative.

Table 2: Comparison of Annual H*(10)

	H*(10) mSv/year	
Measuring points	**TLD**	**Active Detector Graetz X5DE**
LCD control room	0,70	1,00
Source storage room door	0,50	1,50
LDE	1,04	1,26

4. CONCLUSION

The mean environmental dose equivalent at LAF-RAM between the years 2019 to 2021 was 0,70 mSv/year with TLD, this is considering in the statistical analysis all monitoring periods including those results increased by the malfunction in the nitrogen flow.

According to the results it was verified the monitoring points that presented higher doses, for example, in the year 2019, the measurement point of the door adjacent to LCM was found that the dosimeter was placed during a period in the viewing window that is not constructed by leaded glass. However, according to the LAF-RAM safety assessment report, a dose analysis was performed for different scenarios based on the measurements made in the monitoring carried out annually, and the risks associated with these doses have a very low risk, furthermore, the pertinent radiological protection procedures have been adopted during the use of the X-ray equipment.

During the period of this study, the results do not indicate risk to occupational laboratory workers such as LCD personnel, in addition, members of the public are also considered, for example, when interested parties or customers request to visit sensitive areas. On the other hand, annual mean doses inside the LDE room were also determined, the results of which can be analyzed with respect to background dose contributions as suitable for dosimeter storage.

In general terms, it allowed characterizing the environmental dosimetry of LAF-RAM in normal exposure situations.

REFERENCES

[1] ICRU- International Commission on Radiation Units and Measurements**. Fundamental Quantities and units for Ionizing Radiation (Revised) ICRU Report 85a,** Bethesda: ICRU, 2011. 38p.

[2] ROAS Z.N. A. **Evaluación de dosimetría ambiental en 6 puestos fronterizos del país utilizando dosímetros termoluminiscentes de febrero a diciembre 2016**. Master [dissertation,internet].Managua: Universidad Nacional Autónoma de Nicaragua, Managua, 2016. Available from: evaluaciÓn de dosimetrÍa ambientAl en 6 puestos fronterizos del paÍs utilizando dosÍmetros termoluminiscentes de FEBRERO a diciembre 2016 (unan.edu.ni)

[3] LAF-RAM. Laboratorio de Física de Radiaciones y Metrología. **Informe de Evaluación de Seguridad** RA-FG-09. Managua Laboratorio de Física de Radiaciones y Metrología, 2020.