Ambient radiation levels in a microPET/CT research laboratory

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Abstract: This study focuses on initial radiological evaluation and the exposure situation related to the worker task in a micro-positron emission tomography/computed tomography laboratory (microPET/CT). Selected and calibrated thermoluminescent dosimeters, TLD, of CaSO4:Dy were used to measure room radiation levels. The detectors were placed in several selected points inside the microPET/CT laboratory and adjacent rooms. In addition, the occupationally exposed workers were monthly evaluated for external and internal exposures. In none of the selected points the dose values exceeded the radiation dose limit established for supervised area, as well as the values obtained in individual monitoring.

Keywords: Thermoluminescense dosimetry, microPET/CT, radiological control, radiation protection.

1. INTRODUCTION

The success of Positron Emission Tomography scanners in humans naturally led to the interest of the pharmaceutical and biomedical companies to engage in the 90s, the development of PET scanners for small animals, called microPET scanner. The main factors behind its development were because existing scanners were not suitable for studies in mice, rats, etc. So a device designed for measurements of animals to be studied ensures a more accurate search and a few sacrificed animals. The scanner price was also considered as an important factor, since the difference in the physical dimensions of a microPET in comparison with a PET application in humans would be much lower [1].

MicroPET scanner present design challenges relative to human PET scanner, especially concerning spatial resolution and sensitivity; the smaller dimensions of mice internal organs demand for better spatial resolution and higher detection efficiency; these demands for new research and development on detection methods for microPET systems. This parallel development of microPET systems is also clearly advantageous to the development of human PET scanners [1].

The purpose of ambient radiation monitoring programs is to assess the radiological conditions in the workplace. The ambient monitoring program will ensure that work conditions are acceptably safe and satisfactory for exposed individuals and that the dose levels established by regulatory authorities (in Brazil, Comissão

Nacional de Energia Nuclear – CNEN), no exceeded [2].

Avila et al., have determined the ambient dose at a nuclear medicine service with TLD-100 and TLD-900 detectors. In the gamma chamber, the rate of ambient dose equivalent was approximately 0.05 µSv/h [3].

Priscila et al., have demonstrated the importance to follow the radiation protection standards in a PET/CT imaging center [4]. The authors concluded that the workers are exposed to doses below the limits established by Brazilian standards.

Since that radiation protection focus the occupational exposure, it is necessary to ensure the compliance with the radiological protection guidelines and national standards [2, 5, 6].

The aim of this study was to carry out the radiological control at a Radiopharmacy research laboratory of the Instituto de Pesquisas Energéticas e Nucleares, IPEN, where there is a microPET/CT system used for research in small animals.

2. MATERIALS AND METHODS

The microPET/CT, ALBIRA brand is located at Radiopharmacy facility, it is an imaging system that can combine up to three imaging techniques, positron emission tomography (PET), positron emission single photon (SPECT) and computed tomography (CT) for use in small animals (mice or rats) generating a wide range of research fields (preclinical). The modular system design allows you to choose one or a combination of these modalities on the same physical structure [7].

The laboratory was built according to the technical characteristics of the installation and use of this equipment and also by radiation protection staff recommendations.

Initially a radiometric survey using a portable detector, an ionization chamber, Radcal, model 9010 (10x5-1800) was conducted for the purposes of knowledge of laboratory background radiation and surrounding areas, as well as check for background radiation influences of the rooms due to the radioisotope production (normal operation).

Moreover, the monitoring area included the use thermoluminescent dosimeters (TLD). The Thermoluminescent dosimeters used was of Calcium Sulfate doped with Dysprosium ($CaSO_4$:Dy). Three detectors are arranged in a plastic badge and pressed in a matrix of polytetrafluorethylene [8, 9].

Nine points were fixed at a height of 1.50m, reproducing the most exposed region of the chest of adult (medium size). These points were previously selected due to probability of occupational exposure. The location of the dosimeters were as follow: one in the preparation/administration of radiopharmaceuticals room (research room); two in the microbiology room, three in the microPET/CT room; one in the animals room; one in the hallway (free area) and one in the biological waste room. The monthly evaluation started from April 2014 to March 2015.

The Thermoluminescent laboratory of IPEN provides the TL results in accordance with the recommendations of CASMIE/IRD. The main uncertainty components associated with the results these measurements are: individual repeatability of TL detector, thermal treatment, batch homogeneity, lower detection limit and reproducibility of TL response batch [8, 9].

The TL response to individual repeatability is better than ±4.34%, the lower detection limit is 50µSv, the reproducibility ±15%, and a confidence level of 95% (k=2) [8-10].

The measurement of exposure rate were performed MicroPET/CT equipment operating with PET and PET/CT functions.

The individual control of IOE (Individual occupationally exposed) was estimated in the period, both for external exposure through TL dosimeter worn on at the individual chest, and for internal contamination, performed by whole body measurements. The monitoring results were evaluated in terms of effective dose [2, 5].

3. RESULTS AND DISCUSSIONS

3.1 Workplace evaluation

The results were obtained from: background, BG, measurements of the room to verify the influence from radioisotope production, the use of microPET/CT operating PET and PET/CT functions and assessment of the ambient dose equivalent reports of nine selected points.

3.1.1 Background measurements of the microPET/CT room

The average exposure rates obtained from BG was (0.33±0.13) µSv/h.

3.1.2 microPET/CT: operating in PET e PET/CT function

The Fluorodeoxyglucose-fluoride-18, ^{18}F-FDG activities used in this study were 37 MBq and 59.2 MBq. The radioactivity present in this molecule acts then as tracer.

The measurements were performed varying the distance: 0.30 m referring to the small animal handling, 1 m referring to the movement of the operator by the equipment room and 2 m related to the control panel of the equipment. The table 1 presents the dose rates due to PET functions exposure.

The distance of 2 m was measured only with the leaded glass closed, having a mean value of (0.11 ± 0.04) µSv/h.

Table 1. Average dose rate due to PET exposure.

Distance	1 m		0.30 m	
	leaded glass		leaded glass	
Activity	closed (µSv/h)	open (µSv/h)	closed (µSv/h)	open (µSv/h
37 MBq	1.6±0.3	2.8±0.3	9.0±0.4	16.0±0.3
59.2MBq	2.5±0.5	4.5±0.5	18.5±3.5	29.0±6.0

In PET function, the dose rate with the leaded glass open represent the exposure rate at which the IOE is exposed when preparing the small animal for imaging. The highest value obtained was 29 µSv/h (table 1), so the IOE working with lower time handling the small animal, lower will be the effective dose received by IOE.

The following parameters for CT function were considered: current of 400µA, 35 kV and an image resolution about 1000 projections in 25 minutes [7]. ^{18}F-FDG activity of 37 MBq was used at a distance of 0.50 m.

The table 2 shows the average dose rate due to PET/CT function exposure.

Table 2. Average dose rate due to PET/CT exposure.

Selected points	Average dose rate (µSv/h)
MicroPET/CT room	0.29±0.02
Hallway	0.17±0.00
Microbiology room	0.14±0.02

In the function PET/CT, the dose rates were measured from the cladding of the equipment, and the results showed to be very close of BG room (0.33±0.13) µSv/h.

3.1.3 Ambient dose equivalent

The results obtained from the ambient dose equivalent of the nine points monitored, during the period studied, are showed in table 3. The values (mSv) were obtained subtracting from the

TL response of dosimeter control. In none of the points selected for measurements the values exceeded the radiation dose limits established by the regulatory authorities [2, 6].

Table 3. Ambient dose equivalent results (mSv) during the period studied.

	Ambient Dose Equivalent in 12-months - H*(10) (mSv)									
	Dosimeter									
Month S%	***Control***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
April	***0.16***	0.33	0.21	0.21	0.20	0.25	0.29	0.19	0.18	0.17
s%	***2.5***	3.8	2.4	1.2	1.4	8.4	1.9	8.3	39	3.3
May	***0.18***	0.16	0.1	0.09	0.09	0.15	0.14	0.08	0.11	0.09
s%	***4.1***	1.1	5.6	6.1	2.0	5.7	1.5	6.5	1.9	2.6
June	***0.18***	0.28	0.10	0.10	0.09	0.23	0.22	0.09	0.10	0.08
s%	***8.1***	2.8	3.4	1.3	13	6.3	12	13	9.5	6.9
July	***0.19***	0.26	0.14	0.15	0.12	**1.52**	0.20	0.10	0.16	0.12
s%	***7.9***	11.3	2.8	2.1	3.7	12.8	7.8	4.4	10.5	3.3
August	***0.31***	0.38	0.15	0.13	0.11	0.49	0.15	0.10	0.13	0.10
s%	***2.6***	*	6.1	6.5	2.6	11.0	8.4	2.5	9.1	5.3
September	***0.13***	0.27	0.13	0.09	0.13	0.20	0.16	0.08	0.10	0.11
s%	***4.5***	10.0	5.2	9.5	1.9	3.3	9.0	6.2	3.0	3.1
October	***0.21***	0.17	0.09	0.10	0.04	0.38	0.11	0.05	0.16	0.15
s%	***4.1***	5.6	4.8	8.9	3.6	9.1	4.2	0.8	1.3	5.5
November	***0.29***	0.13	0.10	0.09	0.08	0.80	0.11	0.04	0.11	0.06
s%	***8.0***	8.1	5.6	1.5	5.2	22.0	4.8	2.1	5.2	7.6
December	***0.20***	0.15	0.08	0.09	0.03	0.33	0.09	0.04	0.14	0.13
s%	***4.1***	5.6	4.8	8.9	3.6	9.1	4.2	0.8	1.3	5.5
January	***0.12***	0.20	0.16	0.13	0.15	0.28	0.18	0.13	0.17	0.15
s%	***5.2***	6.0	7.5	2.3	2.9	8.7	3.2	1.5	2.6	2.9
February	***0.14***	0.19	0.09	0.08	0.12	0.26	0.20	0.08	0.12	0.08
s%	***3.3***	4.1	4.5	3.7	3.2	3.1	15	5.9	7.0	3.1
March	***0.40***	0.12	0.05	0.02	0.03	0.20	0.15	0.03	0.06	0.04
s%	***5.3***	7.2	3.4	2.3	3.7	3.7	8.9	4.6	5.7	5.0

S% Standard deviation percentage of the mean [9]; *Standard deviation greater than 25%.

According to national and international standards the workplaces are classified in two types of area: supervised and controlled [2, 5]. The microPET IPEN facilities are classified as supervised area. Although the monitoring results from selected points showed low doses, there is a potential for contamination.

3.2. Individual monitoring

The workers who are directly involved in the studies or research related to process at microPET/CT follow the recommendations of the radioprotection staff.

The annual effective dose to the three monitored workers in the years 2013 and 2014 was considered as recording level, i.e., 2.4 mSv per year [2].

4. CONCLUSIONS

The results from the evaluation of ambient radiation levels for microPET/CT laboratory were satisfactory, demonstrating that the whole shielding system is appropriate for supervised area, and consequently the workers involved no exceeded the limits established by Brazilian standard. Considering that the facility operates with unsealed radioactive sources, should emphasize the importance of compliance with radioprotection procedures.

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