2015 International Nuclear Atlantic Conference - INAC 2015
São Paulo, SP, Brazil, October 4-9, 2015
ASSOCIAÇÃO BRASILEIRA DE ENERGIA NUCLEAR - ABEN
***ISBN:* 978-85-99141-06-9**

RADIOLOGICAL CONTROL OF A MICROPET/CT LABORATORY

Daniele M. Sarmento[1], Matias P. Sanches[2] and Janete C.G.G. Carneiro[3]

Instituto de Pesquisas Energéticas e Nucleares (IPEN / CNEN - SP)
Av. Professor Lineu Prestes 2242
05508-000 São Paulo, SP
[1]dms.danica@gmail.com.br
[2]msanches@ipen.br
[3] janetgc@ipen.br

ABSTRACT

This paper presents the radiological control of a research laboratory in order to satisfy national standards and international recommendations. The microPET/CT laboratory in IPEN uses an Albira system for research purposes in small animals. This study focuses mainly to carry out an initial radiological evaluation and the exposure situation related with the task. The assessment of workplace conditions and individual exposures constitutes as integral part of the operational monitoring programme. Initially, the radiometric survey in laboratory has been carried out using an ionization chamber Radcal 9010 (10x5-1800). In addition, nine monitoring points with potential exposure were selected, where thermoluminescent dosimeters, TLDs, of CaSO4:Dy, were positioned. The occupationally exposed workers were monthly evaluated for external exposures using TL dosimeters, worn on the surface of the body. For internal exposure, the evaluated period was approximately one year starting on April 2014. The average effective dose of the occupationally exposed workers did not exceed 2.4 mSv in the year of 2014, which is equal to the recording level. The workplace, microPET/CT laboratory, is classified as supervised area and the monitoring results in the evaluated period, are within the dose limits established by national standard, as well as the values obtained in individual control.

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].

Positron Emission Tomography, PET is a functional technique of medical imaging, i.e., the point is to visualize body regions where physiological activity, such as blood flow or cell growth is taking place, therefore a positron source is needed in the specific spot one wants to visualize. The use of radioactive elements such as ^{18}F is linked to an organic molecule that plays some role in a given type of physiological activity. The Fluorodeoxyglucose-fluoride-18, FDG-^{18}F, is one of these carrier molecules and also one of the most commonly used in oncology. The radioactivity present in this molecule acts then as tracer of this physiological activity [1].

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].

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

2. METHODOLOGY

The microPET/CT, ALBIRA brand of the CR facility 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 [6].

The facilities were built according to the technical characteristics of the installation and use of this equipment and also by radiation protection staff recommendations, due to handling of radioisotopes and radiopharmaceuticals. In addition, the CR facility also features a research and development laboratory in the biological area for handling and maintenance of small animals.

This study aimed the radiological control including monitoring the workplace (area monitoring) and the individual monitoring of the IOEs.

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 CR production (normal operation).

Moreover, the monitoring area included the use thermoluminescent dosimeters (TLD), CaSO4: Dy. Nine points were fixed at a height of 1.50m, as shown in Fig. 1. 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 April 2015.

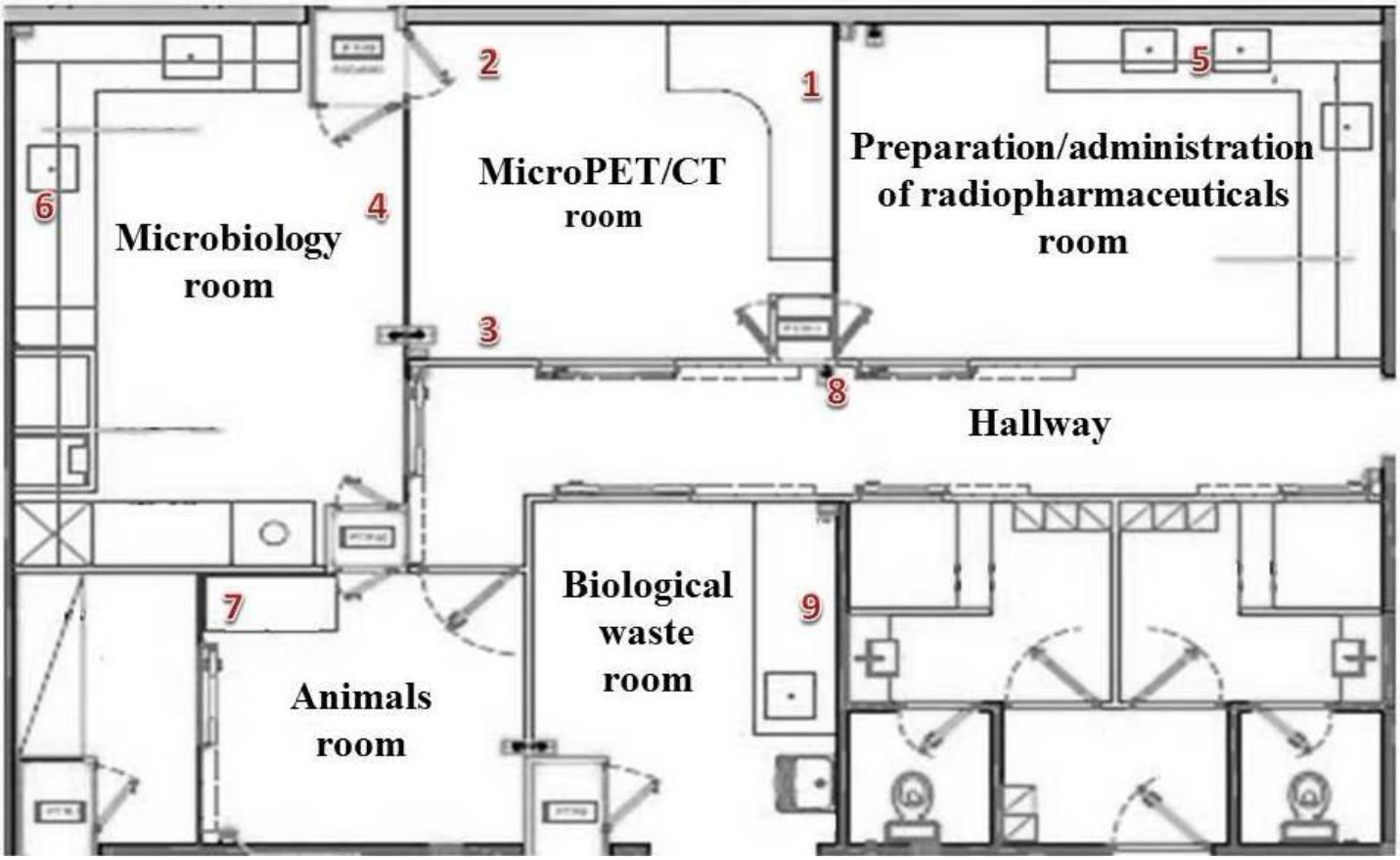

Figure 1: Disposition of the nine TL dosimeters in microPET/CT laboratory.

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

The individual control of IOEs was estimated in the period, both for external exposure through TL dosimeter worn on at the individual chest, as for internal contamination, performed by whole body measurements. The results of these monitoring processes, obtained through the consultation of radioprotection records were evaluated in terms of effective dose [7, 8].

3. RESULTS AND DISCUSSIONS

3.1. Workplace Evaluation

The results were obtained from: background measurements of the room (BG), to verify the influence of the production operation (normal operation) by exposure rate measurements; measures of exposure rate arising from the use of microPET/CT operating PET and PET/CT functions; and finally assessment of the ambient dose equivalent reports of nine selected points.

3.1.1. Background Measurements (BG) of the Laboratory

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

3.1.2. Exposure Rate of the Micropet/CT Operating With PET and PET/CT Functions

3.1.2.1. Function PET

FDG-^{18}F activities used: 37MBq and 59.2MBq.

The measurements were performed varying the distance: 0.30m (referring to the small animal handling), 1m (referring to the movement of the operator by the equipment room) and 2m (related to the control panel of the equipment as shown in Fig. 2.

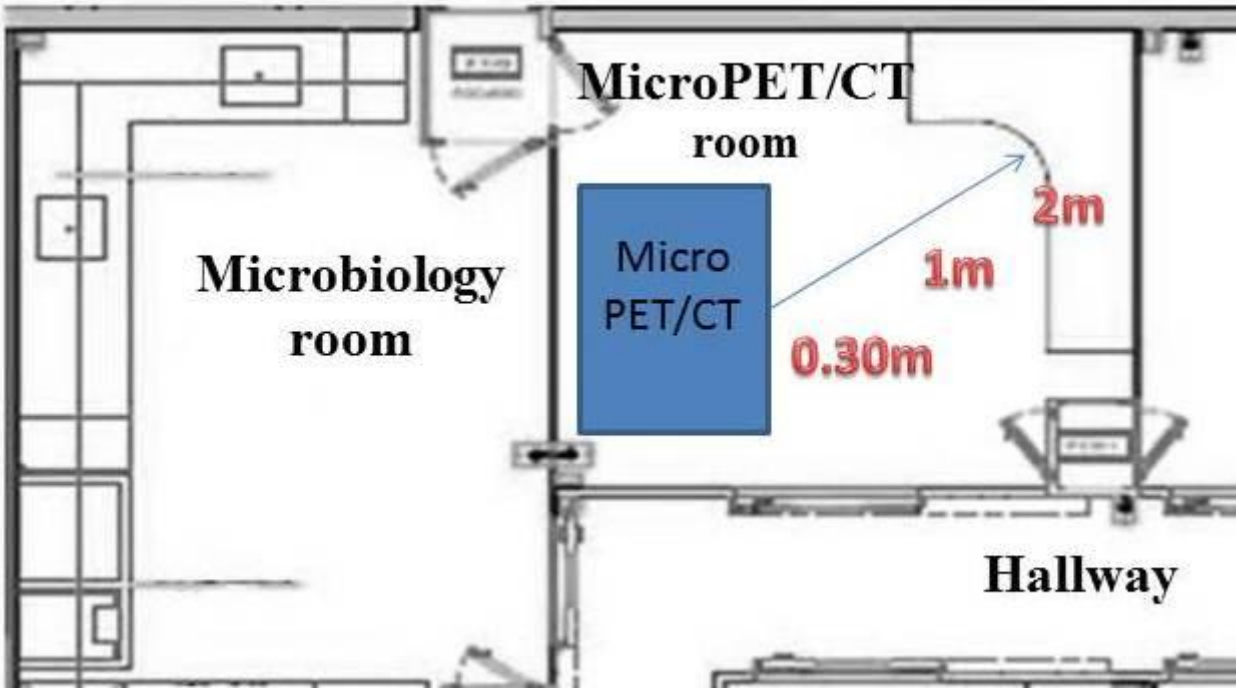

Figure 2: Distance measurements performed the leaded glass to the operator's table using the PET function.

The measurement of the exposure rates obtained, in the three points (distances) were converted into dose rate [6] as shown in Tab. 1.

Table 1: Average dose rate due to exposure in the PET equipment function

	1m				0.30m			
Activities	leaded glass closed (µSv/h)	S	leaded glass open (µSv/h)	S	leaded glass closed (µSv/h)	S	leaded glass open (µSv/h)	S
37 MBq	1.6	0.3	2.8	0.3	9	0.4	16	0.3
59.2 MBq	2.5	0.5	4.5	0.5	18.5	3.5	29	6

S. Standard deviation.

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

3.1.2.2. Function PET/CT

Using the CT function with higher current (400μA), higher voltage (45kV) and greater image resolution (1000 projections in 25 minutes) [6] and 37MBq activity of FDG-^{18}F at a distance of 0.50m.

The Fig. 3 illustrates the points of monitoring, related to the movement of persons in the microbiological laboratory room, the hall and the microPET/CT room.

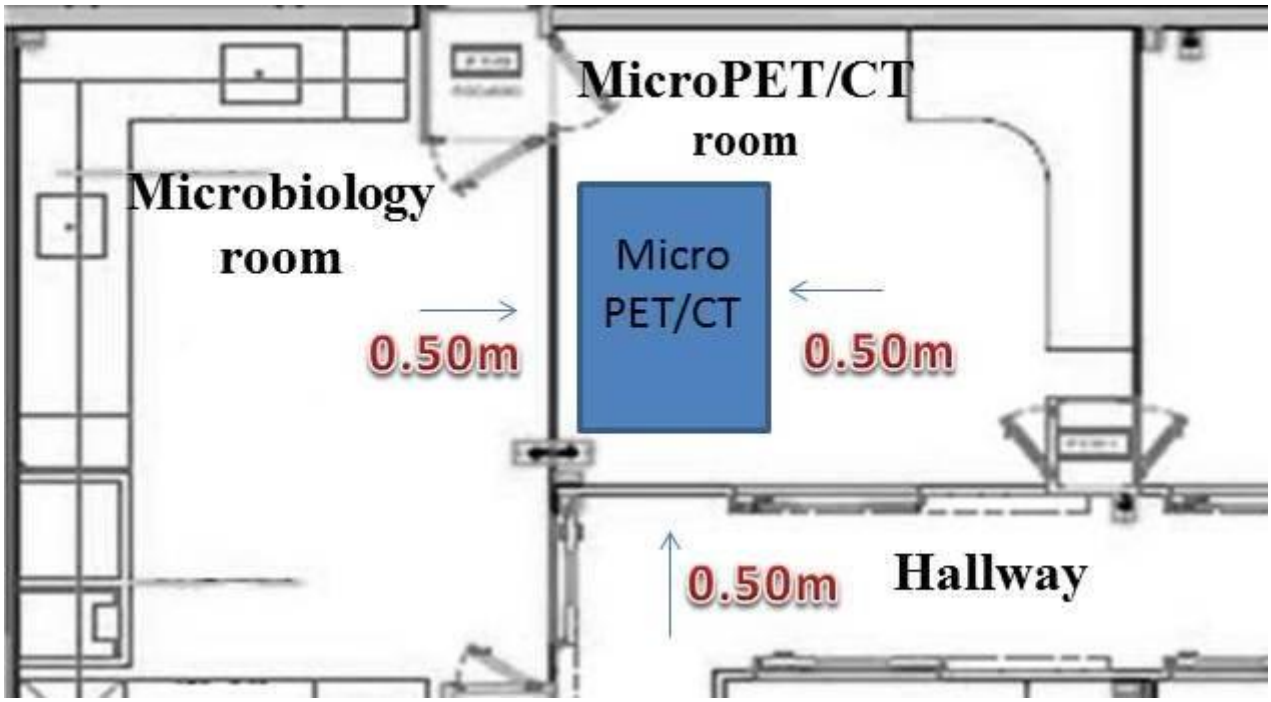

Figure 3: Distance measurements performed using the PET/CT function.

After being converted into dose rate [7], the values of exposure rate are presented in Tab. 2.

Table 2: Average dose rate due to exposure using PET/CT function

	Average dose rate μSv/h	S
MicroPET/CT room	0.286	0.018
Hallway	0.174	0.002
Microbiology room	0.141	0.020

S. Standard deviation.

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 29μSv/h (Tab.1), so the IOE working with lower time handling the small animal, lower will be the effective dose received by IOE.

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

3.1.3 Ambient Dose Equivalent

Tab. 3 shows the results obtained of the ambient dose equivalent of the nine points monitored during the period studied. The ambient dose equivalent values (mSv) were subtracted from the dosimeter control [3, 7].

Table 3: Ambient dose equivalent results (in 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; * .Standard deviation greater than 25%.

The results of the average equivalent dose environment (mSv) are shown in Tab. 4.

Table 4: Average ambient dose equivalent (mSv)

Dosimeter	Average ambient dose equivalent (mSv)	S
1	**0.22**	0.07
2	0.12	0.03
3	0.11	0.03
4	0.10	0.04
5	**0.42**	0.26
6	0.17	0.04
7	0.08	0.03
8	0.13	0.03
9	0.11	0.03

S. Standard deviation.

The area classification system is proposed to control the occupational exposures. According to national standards the workplaces are classified in two types of areas: supervised and controlled [3, 7]. The microPET/CT facilities are classified as supervised area. Although the monitoring results obtained from selected points showed low doses, there is potential for contamination. In this case, the area classification should be supervised.

3.2. Individual Monitoring

The IOE's of CR IPEN-CNEN / SP who are directly involved in the studies or research related to processes involving the facilities of microPET/CT follow the recommendations according to programme of the Radiation Protection.

The results of the effective doses received by IOE´s during the period studied are showed in Tab. 5.

The doses values are considered as recording level which is equal to 2.4 mSv/year [10].

Table 5: Effective dose received by IOE´s during the years 2013 and 2014

IOE´s	Effective dose (mSv) 2013	Effective dose (mSv) 2014
A	2.24	2.46
B	2.40	2.20
C	*	2.20

*No data.

4. CONCLUSIONS

The microPET/CT laboratory have no a daily routine, but this work has shown that in relation to occupational exposure due to the use of the equipment, self-shielding is effective, there is no need for change in laboratory physical structure, since at no point were exceeded the limit specified in the regulations.

The average background radiation obtained of was about 0.33 µSv/h and the exposure rates measurements during the operation of microPET/CT were lower than 5 µSv/h, considering the distance of 1m. It is important to continue monitoring the laboratory, mainly the preparation/administration of radiopharmaceuticals room. On July 2015, the value obtained of the ambient dose equivalent H*(10) was 1.52 mSv/month, which led to a concern about the time that the IOEs are handling the radiopharmaceuticals products (radioactive unsealed sources). The average annual effective dose of the monitored workers no exceeded the recording level, equal to 2.4 mSv/year.

Currently the SPECT role was installed, increasing the number of radiopharmaceuticals products that can be used in the laboratory and the number of people involved in activities beyond the time that the IOEs may be exposed during the radiation levels emitted by the microPET/CT/SPECT.

ACKNOWLEDGMENTS

The authors thank to Radiopharmacy Center of IPEN by the carrying out the measures and the TLD Laboratory by the evaluation of the dosimeters.

REFERENCES

1. N. J. S. Pereira, “MicroPET Scanner Characterisation”, Instituto Superior Técnico, *Universidade Técnica de Lisboa*, Lisboa, Portugal (2008).
2. Comissão Nacional de Energia Nuclear, “Diretrizes Básicas de Proteção Radiológica”, **CNEN-NN-3.01**, Rio de Janeiro, Brasil (2011).
3. International Atomic Energy Agency. “Occupational Radiation Protection”, **Safety Standards Series, Nº. RS.G-1.1**, Vienna (1999).
4. Agência Nacional de Vigilância Sanitária, “Dispõe Sobre os Procedimentos Administrativos para Concessão da Certificação de Boas Práticas de Fabricação e da Certificação de Boas Práticas de Distribuição e/ou Armazenagem”, **Resolução-RDC Nº 39**, Brasil (2013).
5. Agência Nacional de Vigilância Sanitária, “Diretrizes de Proteção Radiológica em Radiodiagnóstico Médico e Ondontológico”, **Portaria da Secretaria de Vigilância Sanitária Nº 453**, Brasil (1998).
6. Bruker Corporation. “Bruker Albira Imaging System User Manual”, **IB543851**, Rev. C 12/12 (2012).
7. Comissão Nacional de Energia Nuclear, “Fatores de Ponderação para as Grandezas de Proteção Radiológica”, **Posição Regulatória 3.01/002:2011**, Rio de Janeiro, Brasil (2011).
8. International Atomic Energy Agency, “Assessment of Occupational Exposure Due to External Sources of Radiation”, **Safety Standards Series, Nº. RS-G-1.3**, Vienna (1999).
9. Comissão Nacional de Energia Nuclear, “Critérios para Cálculo de Dose Efetiva, A Partir da Monitoração Individual”, **Posição regulatória 3.01/005:2011**, Rio de Janeiro, Brasil (2011).
10. Comissão Nacional de Energia Nuclear. “Restrição de Dose, Níveis de Referência Ocupacionais E Classificação de Áreas”, **Posição Regulatória 3.01/004:2011,** Rio de Janeiro, (2011).