Evaluation of Radiation Levels at Ipen´s Cyclotron Accelerator Facility in Brazil

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Abstract. This survey aims the evaluation of the exposure to ionizing radiation at the Cyclotron Accelerator Facility located at São Paulo city-Brazil, through the analysis of the workers effective dose and the dose rates obtained by the area monitoring when the Fluorine-18 is being produced. The accelerator cyclotron Cyclone 18 used to produce Fluorine-18 is the focus of this study. The sample was composed by three groups of workers, such as: operation and maintenance; targets and radioprotection. The data analysis was based on the individual monitoring records during the period from 2007 to 2011 and the area monitoring reports from August to December 2011 when the Fluorine-18 was being produced. Measurements were carried out to determine the dose rate in various predetermined spots. The results of occupational radiation exposures were analyzed and compared with the values established in national standards and international recommendations.

1 Introduction

The *Instituto de Pesquisas Energéticas e Nucleares* (Nuclear and Energy Research Institute), IPEN, is located in São Paulo city-Brazil, and its main purpose is research and development in the fields of nuclear energy and its applications. The Cyclotron Accelerator Facility is one of the research and development centers of IPEN where the production of short lived radioisotopes is carried out by particle acceleration for use in diagnostic medicine. In this facility there are two cyclotrons, the Cyclone-30 and the Cyclone-18 for radionuclide production, mainly of F-18 and I-123 in small amount.

According to the literature the main cause of the radiation exposure of accelerator workers arises from operations on and maintenance of radioactivated components, handling and moving of activated items, radiation surveys and radioactive waste handling [1, 2].

Due to the radioactive facility, it is necessary to establish a radiation protection program and the execution of a number of measures aimed to protect the individual that is exposed to ionizing radiation against possible unwanted health effects and also to protect the environment [3].

The implementation of the area monitoring and the use of individual dosimeters are essentials measures of this program for allowing preliminary assessment of the dose rates in the position to be occupied by the worker and the confirmation of which dose the worker accumulated, respectively.

In order to provide data for decision making about operational measures and the protection of the workers and the environment, an annual activity report is evaluated to prevent high doses and to continuously support the improvement that are suggested for the facility in concern to radiological safety [4]. To carry out this survey it was necessary to analyze the facility database and also to verify the reports provided by the radiological protection supervisor.

This survey aims the evaluation of the exposure to ionizing radiation at the Facility through the analysis of the effective dose received by workers and the dose rates obtained by the area monitoring when Fluorine-18 is being produced.

2 Methodology

The study was based on the occupational exposure analysis from 2007 to 2011 at IPEN's Cyclotron Accelerator facility. The data analysis involved the effective dose received by workers from 2007 to 2011 and the measurements of the dose rates during a short period of five months, from August to December 2011.

The individual dosimetry was evaluated with thermoluminescent dosimeters, TLD, to measure the photon energy and the results were recorded according to the facility radioprotection plan.

The Radioprotection Service database was used in this study, and the dose received by the workforce, during the studied period, was distributed in intervals according to the national standards [4] and international recommendations [5].

The sample was composed by three groups of workers according to their tasks, such as: operation and maintenance; targets and radioprotection.

To determine the dose rate, data were collected from the area monitoring reports from August to December 2011 and gamma and neutron detectors were used. Measurements were performed at 07 predetermined spots by the radioprotection team, totalizing 163 measurements at each spot.

The spots are identified in Fig. 1 by the letters A to G and Table 1 presents a description about them. At the first 5 spots (A-E) there is the operating cyclotron influence, then because of the ^{18}O (p,n)^{18}F reaction, both gamma and neutron radiations are monitored. At the last 2 spots, there is only the influence of gamma radiation due to the produced radioisotope Fluorine-18.

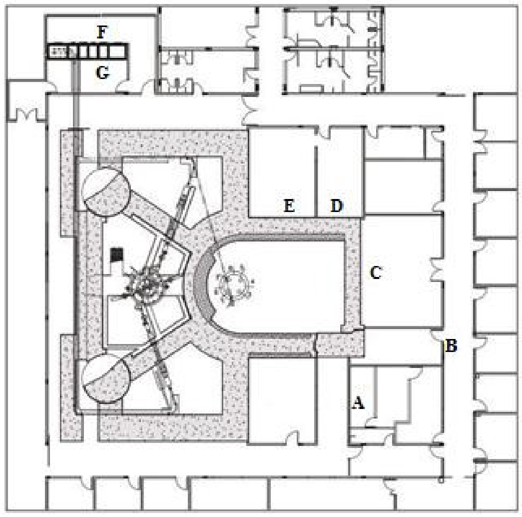

Fig. 1. Plant of the facility and the location of the monitored spots from A to E both gamma and neutron radiation are monitored. At F and G Spots, only gamma radiation is monitored

Table 1. Description of the monitored spots in the vicinity of cyclone-18

Spot	Description
A	Cyclone-18 refrigeration system room
B	Gateway to the facility upper floor - circulation corridor
C	Engine room – Cyclone-18 cave external wall
D	Cyclone-30 control room – Cyclone-18 cave external wall
E	Cyclone-30 sources room – Cyclone-18 cave external wall
F	Irradiated target handling laboratory – In front of the hot cells
G	Hot cell area maintenance

3 Results and discussion

By analyzing the average effective doses for each work group, as shown in Fig. 2, it was noticed that the target group presented the highest average individual doses per year, ranging 8.9-15.7 mSv. This group is responsible by the maintenance, preparation and switch of targets, and also by intervention on cyclotron beam lines, which happens when it is mandatorily turned off so eventual flaws can be repaired.

The operation and maintenance group had the lowest average individual doses for each year, ranging 2.5-5.7 mSv. This group executes all the activities that involve the cyclotron operation safe conduction, so they are not directly exposed to ionizing radiation; the occupational exposure comes from activated components or from produced radioisotopes. However, they could perform maintenance on the machines when necessary.

The radioprotection group received the second highest average dose. The workers of this group always accompany the tasks performed by the other workers; they perform both routine and operational monitoring; and they assist in the expedition of the produced radioisotope. So the result is in accordance with the tasks performed by the group.

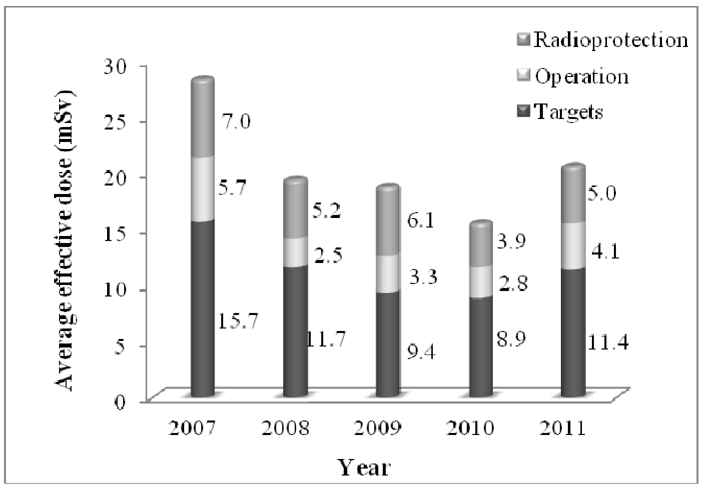

Fig. 2. Average effective dose for each work group per year

The results of the monitored spots are shown in Fig. 3 and the dose rate values are specified in Table 2.

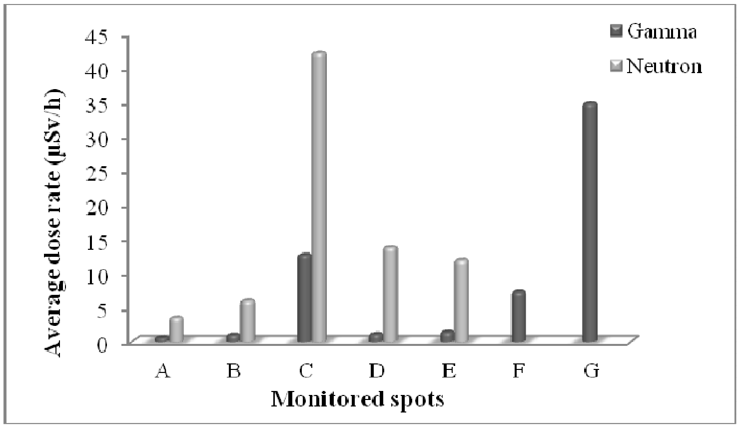

Fig. 3. Average dose rate for gamma and neutron radiation for each monitored spot

Table 2. Average dose rate for gamma and neutron radiations from August to December, 2011

Spot	Dose rate (µSv/h)					
	Gamma radiation			**Neutron radiation***		
	Minimum	**Average**	**Maximum**	**Minimum**	**Average**	**Maximum**
A	0.4	0.6	1.2	3.1	3.5	9.4
B	0.5	1.0	1.9	3.1	6.0	15.6
C	1.6	12.7	14.3	9.4	42.2	62.4
D	0.5	1.1	11.0	6.2	13.8	18.7
E	0.3	1.4	2.7	6.2	11.9	15.6
F	0.1	7.3	49.8	-	-	-
G	0.2	34.8	155.0	-	-	-

*There is no neutron monitoring in the F and G spots.

The highest dose rate for gama radiation was obtained when the cyclotron was turned off at the hot cell area maintenance (G spot) because of the influence of the produced Fluorine-18. This spot showed a significant variation between the minimum and the maximum values, as well as the F spot. In general, the number of Fluorine-18 production carried out over the day, the irradiation time, the irradiated material activity and the yield of the synthesis contribute tor the dose rates to vary greatly in these two spots.

The highest neutron dose rate was inside the engine room and it was related to the radiation beam direction and a thin wall compared to the other spots, which can lead to higher dose rates at this location. However, it is not an effective place for people to remain, i.e., occupation factor ¼ [4].

4 Conclusion

In the studied period, it was observed that the measurements showed almost constant values at all spots for the area monitoring. The reason for this tendency is due to the intensity of the current remaining practically the same and the use of the same stripper most part of the time when measurements were carried out.

The obtained values of the average dose rate for gamma and neutron radiation suit criteria based on operational experience. Values outside the band presented in the results are easily detected by the radiation protection team, which will determine whether or not there is a need for intervention. Therefore, it is important that the monitoring occurs whenever the cyclotron is operating in order to have proper control of occupational exposure.

The effective dose values, during the studied period, showed that no worker received dose higher than the limit of 50 mSv in a single year.

The study showed that he group that presented the highest average individual dose was the target group. The main cause of the radiation exposure for this group arises from operations and maintenance of radioactivated components; handling and moving of activated items; radiation surveys and radioactive waste handling. This result is in agreement with the literature.

The radioprotection group is being really effective by satisfying the radiological safety regulations and by preserving the worker health and welfare.

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