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Radiation protection aspects of the operation in a cyclotron facility

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HIGHLIGHTS

- ▸ The paper focuses on the radiation protection aspects at accelerators facility.
- ▸ The activated cyclotron components may impact on the personnel radiation exposure.
- ▸ The greater emphasis was given generally to ALARA programmes at accelerators.
- ▸ Exposures at accelerators occur during the repair, maintenance, and any modification.
- ▸ In this study, the target workers group received the highest average effective dose.

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ABSTRACT

The activated accelerator cyclotron components and the radioisotope production may impact on the personnel radiation exposure of the workers during the routine maintenance and emergency repair procedures and any modification of the equipment. Since the adherence of the principle of ALARA (as low as reasonable achievable) constitutes a major objective of the cyclotron management, it has become imperative to investigate the radiation levels at the workplace and the probable health effects to the worker caused by radiation exposure. The data analysis in this study was based on the individual monitoring records during the period from 2007 to 2011. Monitoring of the workplace was also performed using gamma and neutron detectors to determine the dose rate in various predetermined spots. The results of occupational radiation exposures were analysed and compared with the values established in national standards and international recommendations. Important guidelines have been developed to reduce the individual dose.

1. Introduction

The cyclotron accelerator facility is one of the research and development centres of Nuclear and Energy Research Institute, located in São Paulo city, Brazil, where the production of short lived radioisotopes is carried out by particle acceleration for the 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 (NCRP-144, 2003; UNSCEAR 2008, 2010).

In order to provide data for decision making about operational measurements for the protection of the workers and the environment, an annual activity report was evaluated to prevent high doses and to continuously support the suggested improvements for the facility concerning radiological safety.

2. Methodology

The study was based on the effective dose analysis of the workers from 2007 to 2011 at Accelerator Cyclotron Facility in Brazil. The individual dosimetry was evaluated with thermoluminescent dosimeters, TLD, to measure the photon energy and the results were recorded according to the facility radioprotection programme. A total of 66 individual records were analysed and the dose distribution was carried out and compared with the established values in national standards (CNEN-NN-3.01, 2011) and international recommendations (ICRP 103, 2007).

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

In addition, the workplace monitoring reports were evaluated from August to December 2011 and the dose rate arising from the gamma and neutron radiations was measured. The gamma

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radiation was measured with a Geiger Mueller detector, Automess, model 6150 AD5-Teletector. For neutron monitoring two proportional neutron detectors were used: a Ludlum with BF_3, model 15 and a Canberra with ^3He, Dineutron, model 0.5NH1/1KD.

All detectors were calibrated at *Instituto de Radioproteção e Dosimetria*, Rio de Janeiro, RJ-Brazil, with traceability of the calibration to the Brazilian Secondary Standard Dosimetry Laboratory, SSDL.

The measurements were performed at seven predetermined spots by the radioprotection team, being 163 measurements in total 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 five 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 two spots, there is only the influence of gamma radiation due to the produced radioisotope Fluorine-18.

3. Results and discussions

By analysing the mean effective dose for each work group, as shown in Fig. 2, the target group received the highest mean annual effective dose, ranging from (7.4 ± 2.1) to (15.7 ± 4.3) mSv. This group is responsible for the maintenance, preparation and switching of the targets, and also by the intervention on cyclotron beam lines, which happens when it must be turned off so eventual flaws can be repaired. The radioprotection group received the second highest mean doses from about (3.9 ± 1.6) to (7.0 ± 1.7) mSv. The dose result of this group is in accordance with the tasks performed by the group, including both routine and operational monitoring and to assist in the expedition of the produced radioisotope.

The third group involved in operation and maintenance had the lowest mean effective dose for each year, ranging from (1.86 ± 0.85) to (5.7 ± 1.4) mSv. This group carries out all the activities that comprehend the cyclotron operation safe conduction and maintenance.

The results of the monitored spots, as presented in Fig. 3, show the highest dose rate for gamma radiation (G spot), obtained when the cyclotron is turned off at the irradiated target manipulation laboratory due to the influence of the produced Fluorine-18. The highest neutron dose rate was found inside the engine room (C spot). The radiation beam direction and a thin wall compared to the other spots can conduct higher dose rates at this location. However, it is not a place that people work all day long (occupation factor ¼).

In the period of study, it was observed that the measurements presented almost constant values for all spots at the workplace 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 in most part of the time when the measurements were carried out.

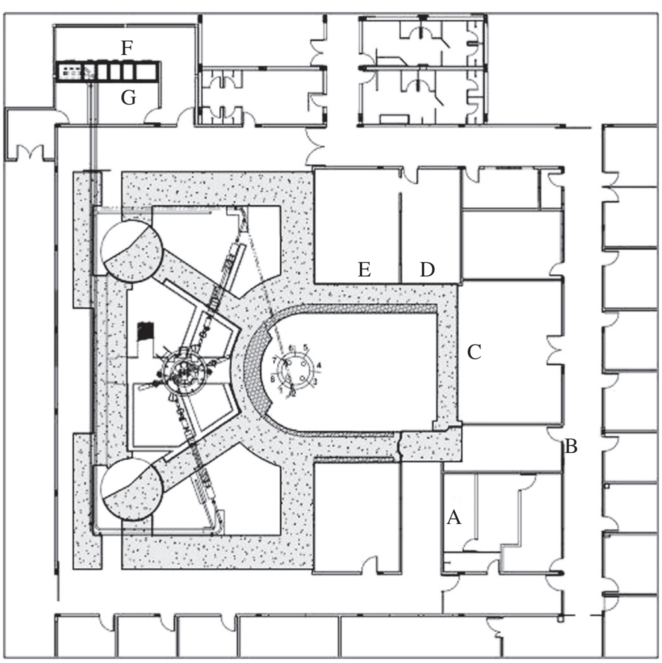

Fig. 1. Facility plant and the monitored spots for gamma and neutron radiations.

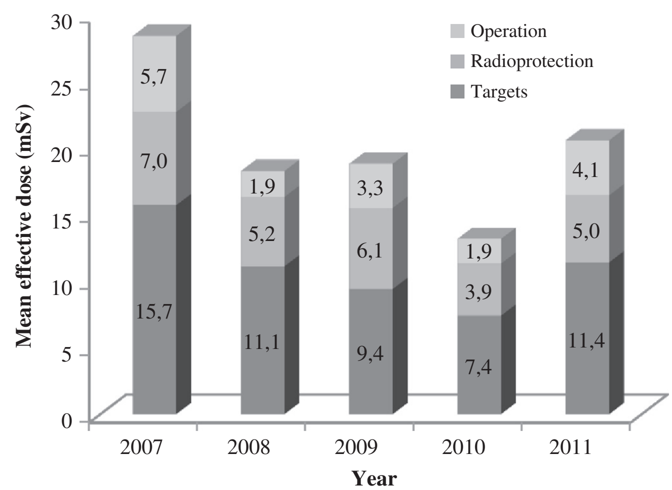

Fig. 2. Mean effective doses for each work group over the years.

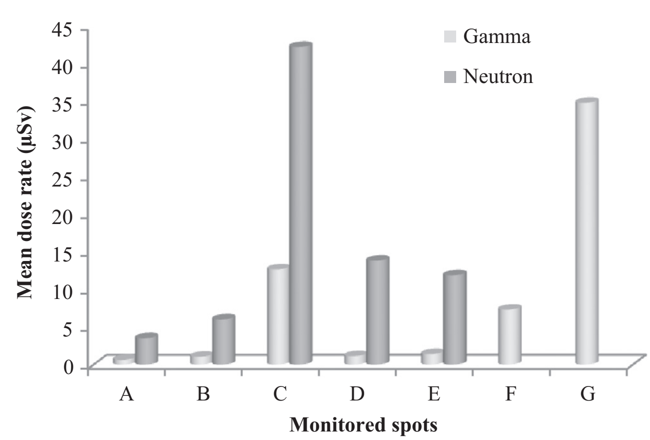

Fig. 3. Mean dose rates for gamma and neutron radiations.

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-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

The obtained values of the mean dose rate for gamma and neutron radiation suit criteria based on operational experience.

The group that presented the highest average of individual dose was the target group. This result is in agreement with the literature available. Therefore, no workers received doses higher than the limit of 50 mSv in a single year.

The radioprotection group is being really effective by satisfying the radiological safety standards and by preserving the workers' health and welfare.

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