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BETA AND GAMMA-RAY PERSONNEL MONITORING AT THE CYCLOTRON OF THE INSTITUTO DE ENGENHARIA NUCLEAR (IEN) BRAZIL

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ABSTRACT

Beta particle and gamma ray individual dose assessment was carried out at the cyclotron of the Instituto de Engenharia Nuclear (IEN), Brazil, using thermoluminescent dosimeters. The meassurements were performed during the maintenance of activated components of the cyclotron and at the radioisotope production laboratory. All individual dose measurements were lower than the ICRP recommended limits for the skin and lens of the eyes.

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MONITORAÇÃO PESSOAL BETA E GAMA NO CICLOTRON DO INSTITUTO DE ENGENHARIA NUCLEAR (IEN) BRASIL

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RESUMO

A determinação da dose individual devida a partículas beta e radiação gama foi executada no cíclotron do Instituto de Engenharia Nuclear (IEN), Brasil, usando dosímetros termoluminescentes. As medidas foram efetuadas durante a manutenção dos componentes ativados do cíclotron e no Laboratório de Produção de Radioisótopos. Todas as doses individuais determinadas estão abaixo dos limites recomendados pelo ICRP para a pele e o cristalino.

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1. INTRODUCTION

The Cyclotron of the Instituto de Engenharia Nuclear (IEN), Brazil, operates mainly for radioisotope production, as a neutron source and for irradiation damage analysis. The radiological risks associated with these activities result from exposure to γ rays, β particles and neutrons and due to contamination from induced radioactivity. Beta and γ ray exposure occurs during the maintenance of activated components of the cyclotron, due to ^{65}Zn produced by the activation of copper components. Other activities that involve the exposure to β and γ rays arise during radioisotope production, mainly from ^{67}Ga, which has ^{65}Zn as an undesirable subproduct. In this work, thermoluminescent (TL) dosimeters were used to assess β and γ ray individual doses received by IEN technicians, who were involved in the cyclotron maintenance and work at the radioisotope production laboratory. These dosimeters were specially developed for ^{137}Cs β and γ ray dose evaluation by Comissão Nacional de Energia Nuclear (CNEN), Brazil, during the radiological accident at Goiânia, Brazil [1]. Consequently, a new calibration and modifications to the measureament algorithm were necessary in order to determine the β and γ ray doses in the present circumstances.

2. DESCRIPTION OF THE DOSIMETER

Four $CaSO_4$:Dy.PTFE pellets 0.20 mm thick,produced at the Instituto de Pesquisas Energéticas e Nucleares (IPEN) [2], Brazil,are sealed in a black plastic film 16.5 $mg.cm^{-2}$ thick and two pellets are shielded with PTFE filters 315 $mg.cm^{-2}$ thick. These filters guarantee electronic equilibrium for ^{60}Co γ rays. The two remaining pellets are unshielded. The shielded pellets are used for γ ray dose assessment, while the unshielded pellets are used to assess the β particle dose.

3. DOSIMETER CALIBRATION

3.1 Beta Particle Calibration

Three dosimeters were irradiated using the Beta Secondary Standard System of the Calibration Laboratory at IPEN, with $^{90}Sr-^{90}Y$(1.5 GBq), ^{204}TL (5.1 MBq) and ^{147}Pm(81 MBq) sources. Compensation plastic filters provide field homogeneity within a diameter of 110mm at the calibration distances. The sources were calibrated in terms of absorbed dose rates, in air, at the Physikalisch Technische Bundesanstalt (PTB), Federal Republic of Germany, with a Primary Standard using an extrapolation chamber.

The energy response curve was determined for unshielded pellets (Fig. 1) and from this curve the calibration factor (absorved dose in air/TL response) of the unshielded detector for the desirable β particle mean energy was evaluated. The relation between the TL responses of the shielded and unshielded pellets as a function of the mean energy of the β radiation was also determined and is presented in Fig. 2.

3.2 X-ray and Gamma ray Calibration

The X and γ ray radiation energy responses of the shielded and unshielded pellets were determined from 20 to 1250 keV and normalized to the ^{60}Co radiation response of the shielded pellets. X ray irradiation experimental conditions are given in Table 1. The energy

TABLE 1

Experimental Conditions for Irradiation by X-Rays.

EFFECTIVE ENERGY (keV)	ADDED FILTRATION (mm)	HVL (mm)
25	2.0 Al	0.75 Al
[illegible]	2.0 Al	1.62 Al
34	2.0 Al	2.86 Al
45	4.0 Al	5.49 Al
55	0.2 Cu	0.35 Al
66	0.5 Cu	0.57 Al
70	0.5 Cu	0.7 Al
74	0.5 Cu	0.76 Al
96	1.0 Cu	1.42 Al
116	Th II	2.07 Cu
126	Th I	2.4 Cu
155	Th III	4.0 Cu

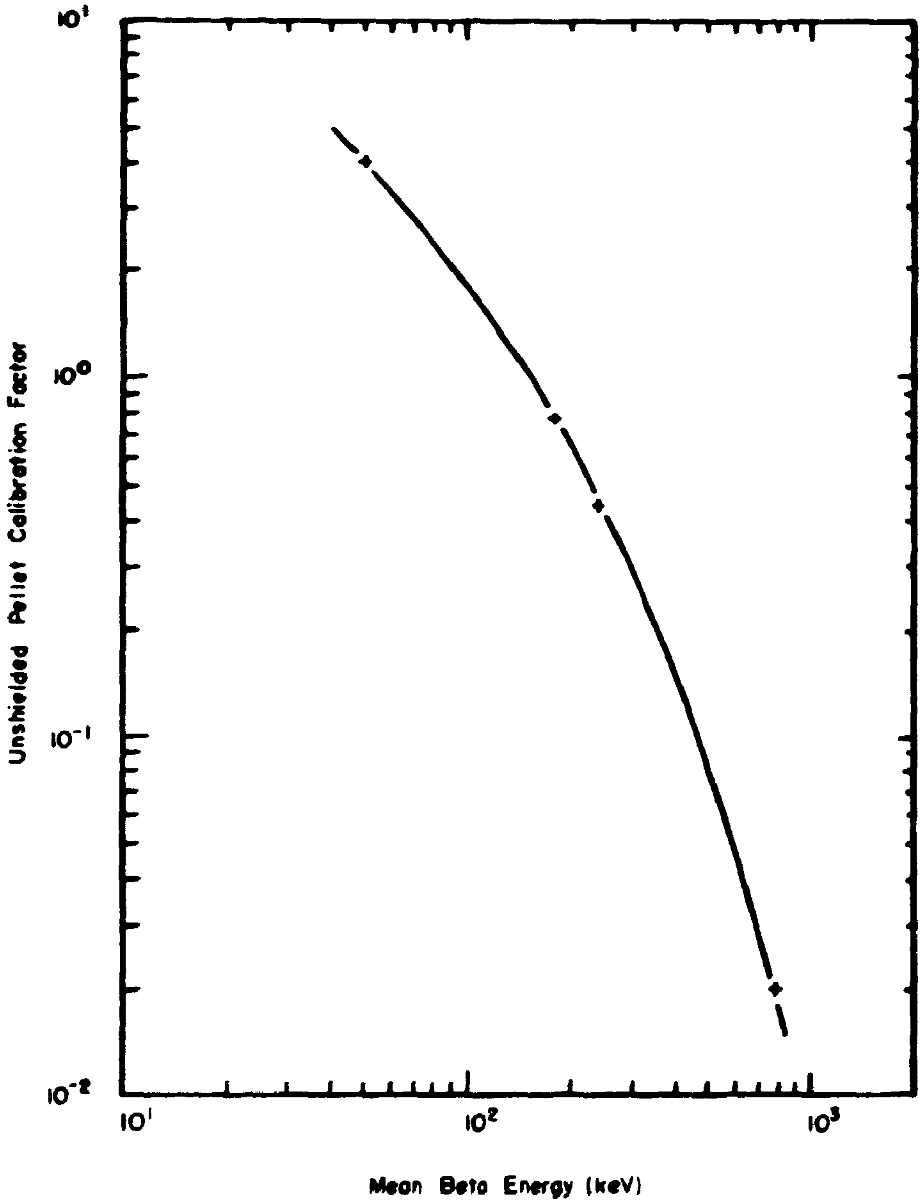

Fig. 1 - Unshielded Pellet Calibration Curve as a Function of the Beta Radiation Mean Energy.

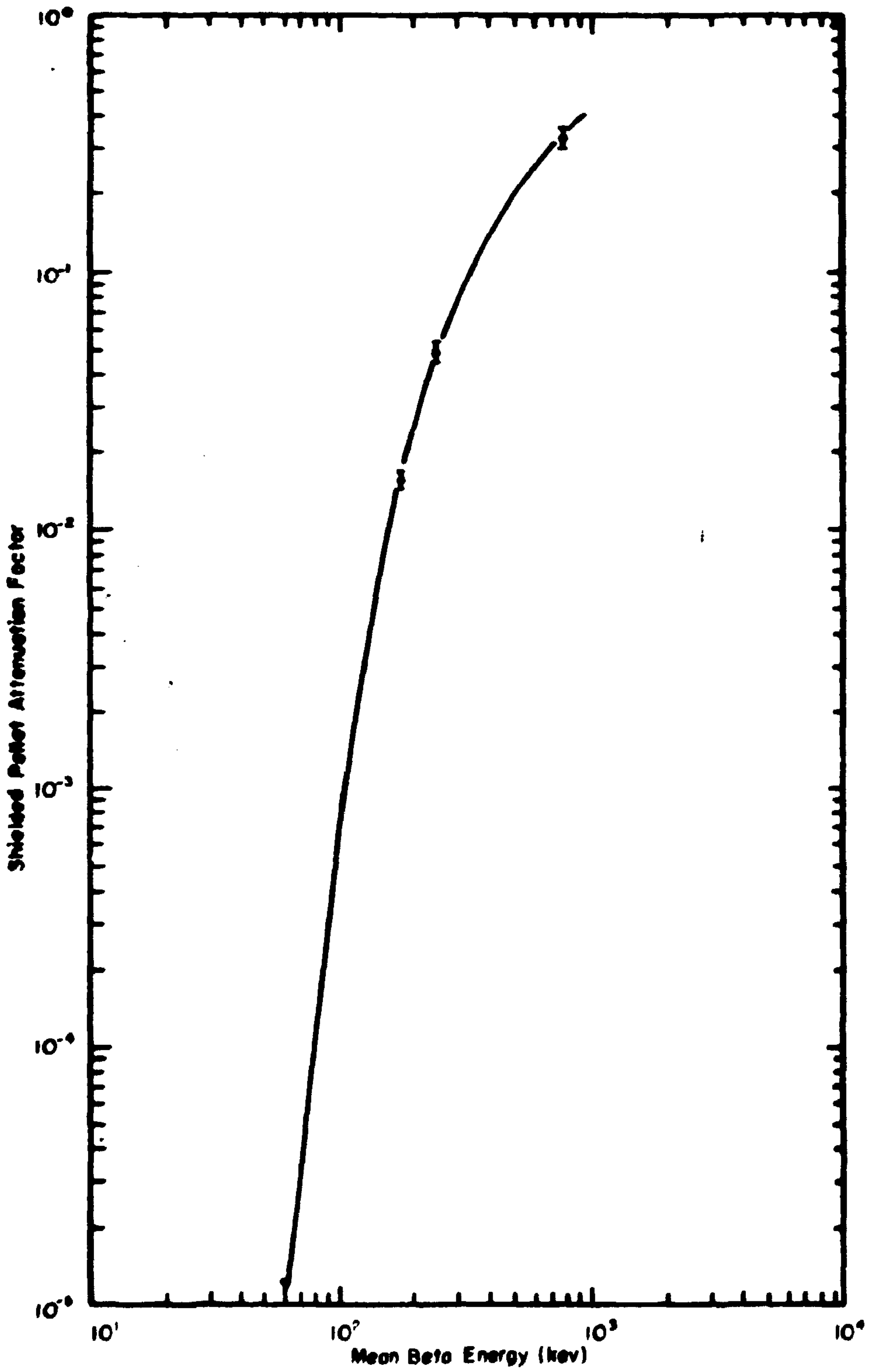

Fig. 2 - Shielded Pellet Attenuation Factor as a Function of the Beta Radiation Mean Energy.

responses for shielded and unshielded pellets are in Fig. 3.

3.3 Algorithm for Evaluating Beta and Gamma ray Doses

The algorithm for evaluating the β and γ ray doses has the form

$$L_\beta + \alpha_1 L_\gamma = L_\mu$$
$$\alpha_2 L_\beta + L_\gamma = L_s \qquad (1)$$

where

L_β is the response of the unshielded TL pellet for β particles (nC);

L_γ is the response of the shielded TL pellet for γ rays (nC);

α_1 is the ratio of the responses of the unshielded and shielded TL pellets for γ rays;

α_2 is the ratio of the responses of the shielded and unshielded TL pellets for β particles;

$\alpha_1 L_\gamma$ is the response of the unshielded TL pellet for γ rays (nC);

$\alpha_2 L_\beta$ is the response of the shielded TL pellet for β particles (nC);

L_μ is the total TL response of the unshielded pellet after irradiation with a β and γ ray source;

L_s is the total TL response of the shielded pellet after irradiation with a β and γ ray source.

The α_1 energy dependence is the ratio of the energy response of the unshielded and shielded pellets for photons (Fig. 3). α_2 is obtained from Fig. 2.

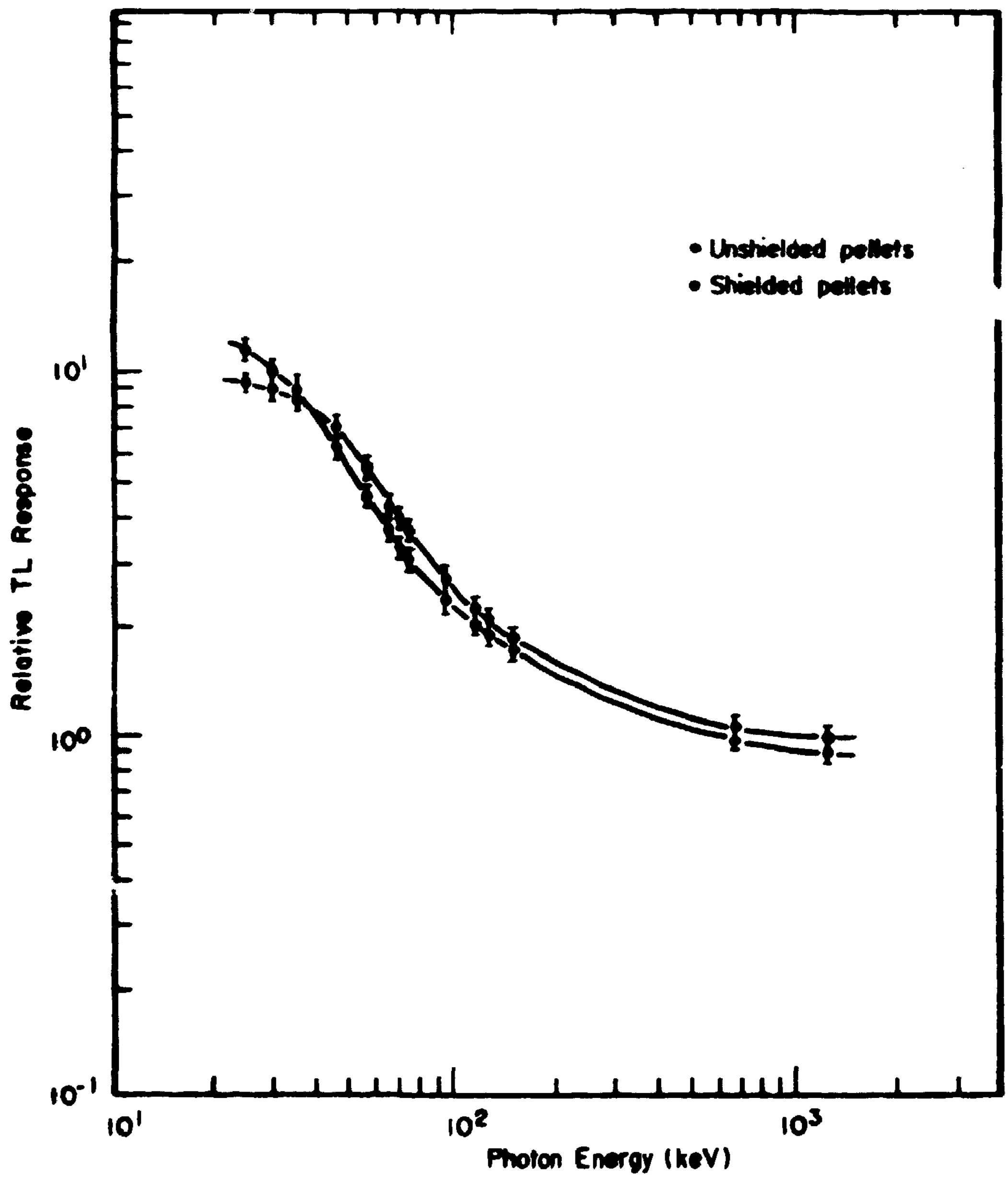

Fig. 3 - Shielded and Unshielded Pellets as a Function of the X-Rays Effective Energy.

The β dose, D_β(Gy), and the γ ray dose, D_γ(Gy), may be evaluated using the relations

$$D_\beta = L_\beta \cdot f_{c\beta} \qquad (2)$$

and

$$D_\gamma = L_\gamma \cdot f_{c\gamma} \qquad (3)$$

where $f_{c\beta}$ and $f_{c\gamma}$ are, respectively, the β particle calibration factor ($Gy \cdot nC^{-1}$) of the unshielded pellets and the γ ray calibration factor ($Gy \cdot nC^{-1}$) of the shielded pellets. $f_{c\beta}$ is obtained from Fig. 1 and $f_{c\gamma}$ is the shielded pellet ^{60}Co γ ray calibration factor, 28.85×10^{-5} $Gy \cdot nC^{-1}$, corrected by the energy response curve of the shielded pellet (Fig. 3).

^{65}Zn decays emitting a β particle with a mean energy of 143 keV and a γ ray of 1115,5 keV. Therefore, from the curves of Fig. 2 and Fig. 3, the values of α_2 and α_1 may be obtained. The algorithm for this isotope has the form:

$$\begin{aligned} L_\beta + L_\gamma &= L_\mu \\ 0.0065\, L_\beta + L_\gamma &= L_s \end{aligned} \qquad (5)$$

This is the algorithm used for β and γ ray dose assessment during Cyclotron maintenance. $f_{c\beta}$ and $f_{c\gamma}$ are, respectively, 12×10^{-4} $Gy \cdot nC^{-1}$ and 28.85×10^{-5} $Gy \cdot nC^{-1}$.

When processing ^{67}Ga, the subproduct ^{65}Zn has also to be considered. ^{67}Ga emits only γ rays with several energies and intensities. Considering both ^{67}Ga and ^{65}Zn γ rays and ^{65}Zn β particles, the following algorithm was obtained:

$$L_\beta + 0.88\ L_\gamma = L_\mu$$
$$0.0065\ L_\beta + L_\gamma = L_s \qquad (5)$$

$f_{c\gamma}$ and $f_{c\gamma}$ are, respectively, 12×10^{-4} Gy.nC $^{-1}$ and 18.80×10^{-5} Gy.nC $^{-1}$.

4. MEASUREMENT PROCEDURES

The TL dosimeters were worn by IEN technicians, for 60 days, on the wrist and forehead. The wrist dosimeter was used to evaluate the dose to the hand and the forehead dosimeter for dose to the lens of the eyes. The average monthly doses for γ rays and β particles were evaluated for cyclotron maintenance and ^{67}Ga chemical processing, 1.85×10^{9} Bq of ^{67}Ga was processed during the 60 days of monitoring.

5. RESULTS AND CONCLUSIONS

Table 2 presents the mean monthly β and γ radiation doses obtained during cyclotron maintenance. Table 3 presents the β and γ radiation monthly mean doses obtained during ^{67}Ga chemical processing. As observed, all values are lower than the ICRP[3] maxima for the skin and for the lens of the eyes. These results illustrate the adequate sensitivity of the dosimeters which were used and the adequate radiation protection procedures during maintenance of the IEN cyclotron and ^{67}Ga processing.

TABLE 2

Beta and Gamma Radiation Month Mean Doses Evaluated During IEN Cyclotron Maintenance.

	Wristlet Dosimeter	Forehead Dosimeter
Gamma Dose (Gy)	2.29×10^{-4}	2.02×10^{-4}
Beta Dose (Gy)	5.75×10^{-4}	2.64×10^{-4}

TABLE 3

Beta and Gamma Radiation Month Mean Doses Evaluated During ^{67}Ga Chemical Processment.

	Wristlet Dosimeter	Forehead Dosimeter
Gamma Dose (Gy)	6.96×10^{-5}	5.26×10^{-5}
Beta Dose (Gy)	4.68×10^{-4}	1.08×10^{-4}

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