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Comparative study of thermal neutron flux from gold foil activation.

Silva, W.L. [1], Ramos, M.S. [2], Gomes, R.S. [3], Astuto A. [4], Pereira, W.W.[5]

[1] watila.lins.silva@gmail.com, Instituto de Radioproteção e Dosimetria, Brasil
[2] msxramos@gmail.com, Instituto de Radioproteção e Dosimetria, Brasil
[3] regiogomes@gmail.com, Instituto de Radioproteção e Dosimetria, Brasil
[4] achilebr@gmail.com, Universidade Federal do Rio de Janeiro, COPPER/UFRJ, Brasil
[5] walsan.pereira@ird.gov.br, Instituto de Radioproteção e Dosimetria, Brasil

1. Introduction

The Thermal Neutron Flux TNF2 built in the Neutron Metrology Laboratory (LN) of the Ionizing Radiation Metrology Division (DIMET) of the Institute of Radioprotection and Dosimetry (IRD) was designed to provide uniform thermal neutron fluence in an area for the primary calibration of neutron detectors and personal dosimeters.

The main objective of the work is to determine the neutron fluence after the homogenizing filter, through a study carried out using Monte Carlo simulations and subsequent measurement using gamma spectrometry with the hyper pure germanium detector (HPGe).

2. Methodology

This work was carried out using experiments and simulations to demonstrate neutron fluence through the activation of gold foil. The irradiator (figure 1) used was the LMNRI/IRD thermal neutron irradiator. The fluence is obtained by the moderation and reflection, by the paraffin and graphite blocks that make up the cube, of four 241Am-Be sources, positioned equidistant from the center of this cube, with an activity of 0.6 TBq each and a total emission rate of 1.554 (59) x 108 neutrons/s [1]. Mechanisms were also built to homogenize the neutron flux coming from the central channel. A filter with concentric conical polyethylene layers was developed, similar to the collimator filter built at the ENEA Radiological Protection Institute [2]. The TNF2 irradiation system was previously calibrated for thermal neutron fluence using the Bonner multisphere detector [3].

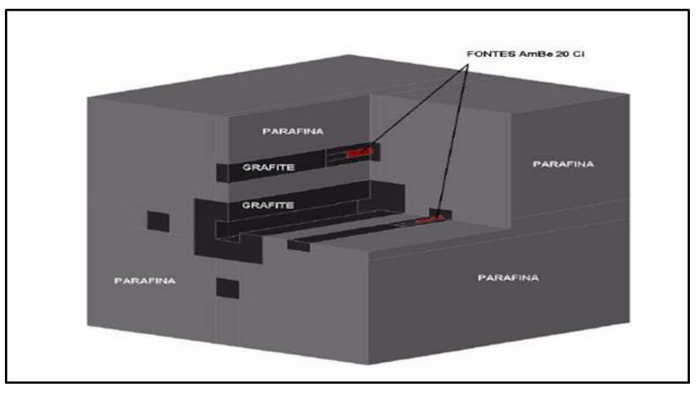

Figure 1: Schematic diagram of the LNMRI/IRD thermal neutron irradiation facility.

Figure 2: Filter with concentric conical polyethylene layers developed at LNMRI/IRD.

Bare gold sheets (197Au) covered in cadmium (Cd) (figure 3 A and B) were positioned externally to be activated. The gold sheets receive a fraction of this neutron fluency. The gold sheets were wrapped in aluminum foil to help position the samples. Aluminum does not interfere with the fluency, as it has a low neutron absorption shock section [4]. During the gold foil activation process, various simulations were carried out using the Monte Carlo MCNP-5 code for the geometries and materials used in order to validate the system studied.

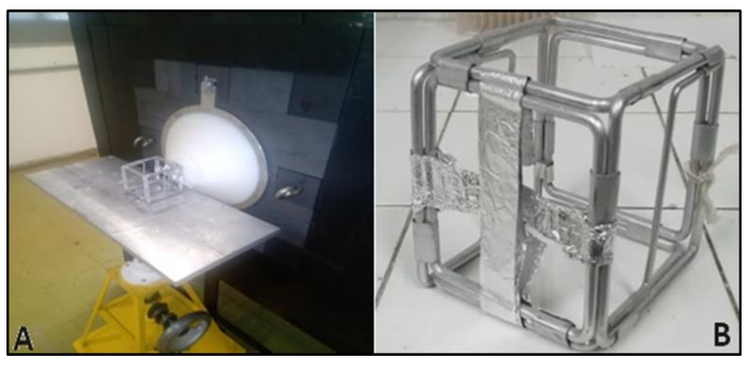

Figure 3: (A) Experiment and (B) detail of the cube where the gold leaves were fixed.

3. Results and Discussion

Six simultaneous simulation runs were carried out with 400,000,000 (four hundred million) events each, totaling 2,400,000,000 (two billion, four hundred million) and the computational processing time was 5,745 minutes, i.e. approximately four days. A spreadsheet was used to calculate the average of the 6 (six) results and their uncertainties presented. The discrepancy of 29.12% in Tally 214 indicates that there is a greater variation in the results in relation to the average, compared to the other Tallys. This suggests that the results of Tally 214 are more dispersed, i.e. there is greater uncertainty associated with these results. This high uncertainty may be due to various factors, such as the complexity of the geometry or materials present in this particular simulation configuration. In table 1.

Tally 15		Tally 214		Tally 224	
Average	Uncertainty (%)	Average	Uncertainty (%)	Average	Uncertainty (%)
0,00133	6,14	0,158	29,12	1,917	0,91

Table: 1 - Results of the MCNP-5 Monte Carlo simulation.

The spectrum of the irradiated gold foil can be seen in figure 4 and the results of the gamma spectrometry measurements can be seen in table 2.

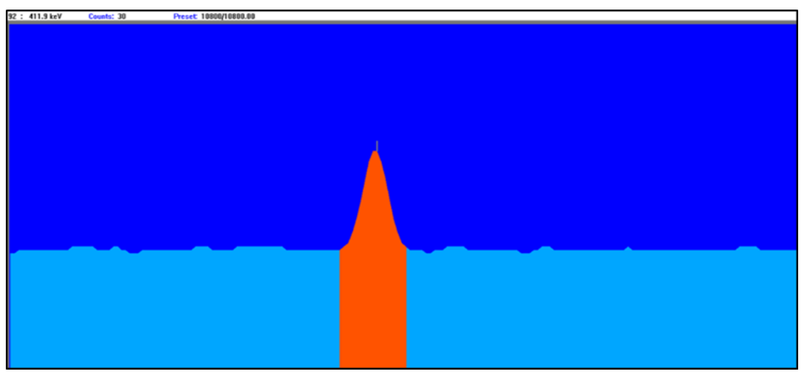

Figure 4: Gamma emission spectrum of 198Au, photopic at 411 keV, in the Genie 2000 software.

Sample	Cd/Naked	Mass (kg)	Measurement start date (UTC -3)	Activity (kBq/kg)	Activity (A_0) on the reference date (kBq/kg)	u (k=1)
01	Nua	7,363 x 10^{-3}	16/08/2023 13:38:04	578,70	604,922	24,25
02	Cd	7,426 x 10^{-3}	16/08/2023 09:57:23	37,54	37,724	3,776
03	Nua	3,378 x 10^{-3}	18/08/2023 12:32:00	487,20	840,981	25,58
04	Cd	3,127 x 10^{-3}	18/08/2023 12:30:32	70,38	121,594	8,292

Tabele2: Shock section: 98.4 (4) Au-197.

4. Conclusion

The first tests were satisfactory, and new measurements will be carried out to validate the measurement, subsequently representing the reproducibility of the results, which could contribute to the development of personal monitors. Gold has proved to be sensitive enough to detect neutron fluency. Mechanisms for using gold in personal dosimetry need to be developed.

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