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Comparative study of thermal neutron flux from gold foil activation.

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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].

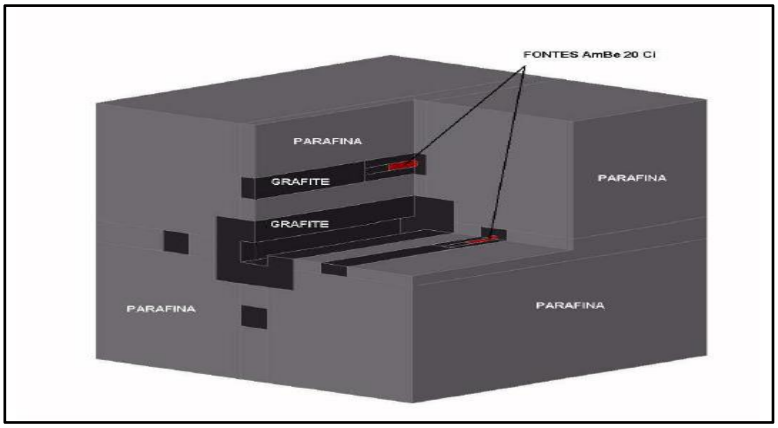

Figure 1: Schematic diagram of the LNMRI/IRD thermal neutron irradiation facility.

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

Bare gold sheets (^{197}Au) 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.

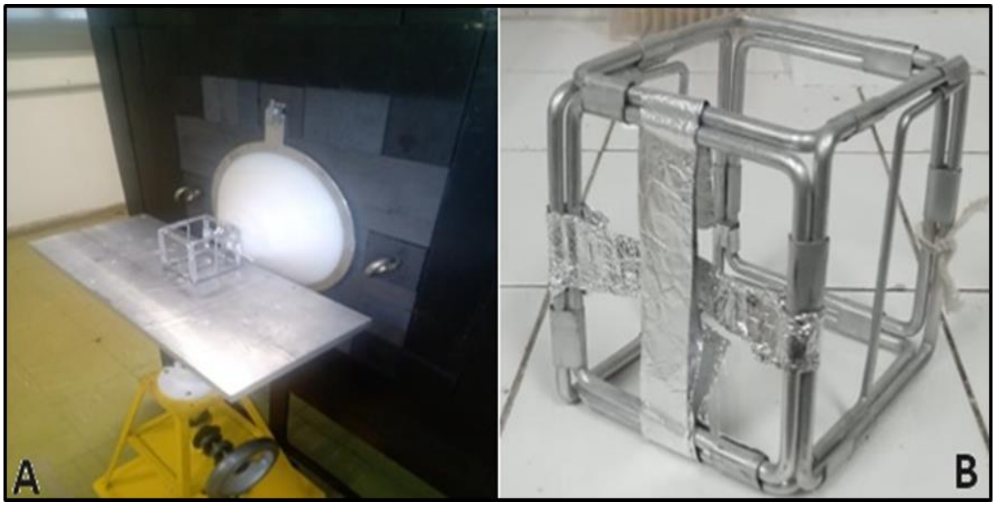

Figure 3: (A) Experiment and (B) detail of the cube where the gold leaves were fixed.

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.

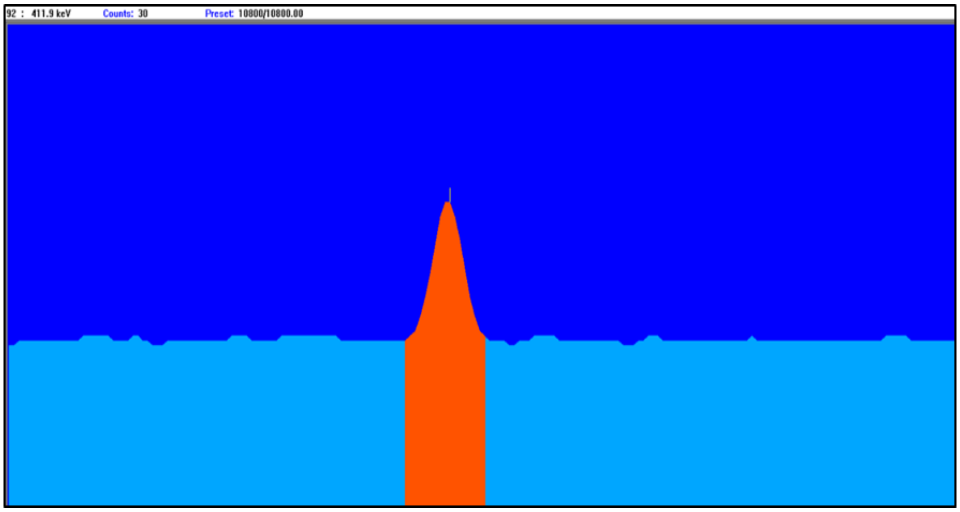

Figure 4: Gamma emission spectrum of ^{198}Au, photopic at 411 keV, in the Genie 2000 software.

Genie 2000 software is a commonly used tool for analyzing radiation spectra, including gamma spectra like this one. It allows detailed visualization and analysis of gamma spectroscopy data, including peak identification, background adjustment and determination of radioisotope activity or concentration.

The photopic peak around 411 keV is particularly important for gold-198, as it represents the specific energy associated with the gamma emission of this isotope. Analysis of this peak allows the presence of gold-198 in a sample to be identified and quantified, and is useful in various applications, such as radiochemistry, nuclear medicine and quality control in industrial processes.

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

Table: 2 - Shock section: 98.4 (4) Au-197.

4. Conclusion

The experiment achieved satisfactory results that could contribute to the development of personal monitors. Gold proved to be sensitive enough to detect neutron fluence. It is necessary to develop mechanisms for using gold in personal dosimetry.

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