Uncertainties in dose calculations in mixed radiation field using point-like detector option in the MCNPX code

Uncertainties in Dose Calculations in Mixed Radiation Field Using Point-Like Detector Option in the MCNPX Code

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INTRODUCTION

The objective of this work is to analyze the differences between the experimentally measured and calculated doses from particle transport simulation using point-like detector option in the Monte Carlo MCNPX code.

In the radial channel # 3 (BH # 3) at the IEA-R1 nuclear research reactor of Instituto de Pesquisas Energeticas e Nucleares (IPEN) in Brazil, biological samples were irradiated with the reactor in operation [1]. To estimate radiation damage in the sample, it was necessary to determine the deposited dose in the irradiation position.

DESCRIPTION OF THE ACTUAL WORK

The Monte Carlo MCNPX code [2] calculates deposited radiation dose, obtained from the fluence computed with the f5 tally.
We assumed aqueous medium in the polypropylene container (Eppendorf tube, 0.5 ml), since DNA plasmid in aqueous solution was irradiated.

The generated simulation model involves a surface source, mode n p, mode p and aqueous medium.

A variance reduction technique was applied to speed-up calculations, increasing importance of particles in the direction of reduced track. The values of neutron and photon spectrum are obtained from the code DOT 3.5 [3].

Figure 1 presents different views of the simulation performed by the MCNPX code, modeling the experimental facilities, and a photograph of the facility.

RESULTS AND DISCUSSION

Table I lists the tally results with the relative error in the simulation and the associated CPU time.

Table I - Tally results.

Tally	ϕ_n (n/cm^2)	ϕ_γ^s (γ/ cm^2)	ϕ_γ^p (γ/ cm^2)	CPU time
F4	2,07E-08 ±5%	5,59E-09 ±23 %	4,76E-09 ±75%	10 d
F5	1,72E-08 ±5%	7,50E-09 ±4%	6,31E-09 ±5%	6,3 h

The f4 tally results do not converge at all. Finally, we decided to use the tally 5 to accelerate the convergence: this choice is justified since the zone where the simple is placed is not a moderated one.

The experimental method used for the verification of the results of mathematical simulation utilised both TLD-600 and TLD-700 detectors.

Table II shows the comparison between the measured dose and the calculated dose.

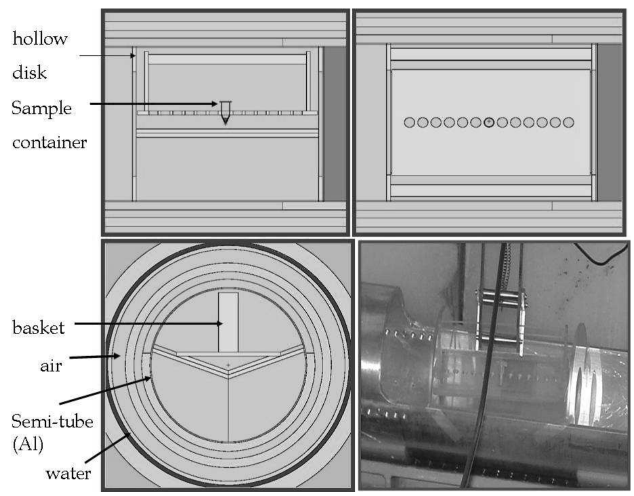

Fig.1-Lateral, top and frontal view of sample support in the interior of the BH # 3 as described in the MCNP-4C input card. Also, a photo of facilities is shown.

Table II – Experimental and computed results

D(Gy/h)	Experiment (TLDs)	Calculated MCNPX	Difference (%)
D_n	2,90±9%	2,75±6%	5
$D\gamma$	1,75 ±22%	1,28±9%	26

There is good agreement (5%) in the neutron dose; this indicates that the methodology used in the simulation is correct. However, a 26% difference was found for photons doses. The main causes are:

1. The detection volume is very small and differs from the phantom used to calculate the fluence-to-dose conversion factors in [4-5].

2. The MCNPX code does not include the transport of photons arising from the delayed fission, from decay of fission products, from decay of activation products (there is Al in channel components).
3. The photon spectrum was obtained from the simulation with the discrete ordinates deterministic DOT3.5 code, instead of the measured spectrum that emerges from the channel.

Another source for the observed discrepancy can be the following: the monoenergetic source of Co-60 is used for the TLD-700 calibration; this is not appropriate for mixed-radiation fields, as the one in our reactor that has a broad spectrum of photons.

CONCLUSIONS

The estimate of neutron dose with the MCNPX presents a good agreement with experimental.

The large discrepancies between the experimentally measured and calculated photons doses in the simulation were explained in detail.

We intend to continue working on finding solutions to reduce those discrepancies in the near future.

Also, we intend to make evaluations with different sample geometries and different irradiation spectra, in order to analyze the influence of these parameters on the calulation uncertainties.

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