DEA EN PHYSIQUE ET CHIMIE DES MATÉRIAUX

Spectroscopie et dosimétrie de traceurs à base d'241Am localisés dans les os du genou à l'aide de simulation Monte Carlo.

Nuttens, Vincent

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Spectroscopy and dosimetry of ^{241}Am-based tracers localized in the knee bones using Monte Carlo simulations

Nuttens Vincent
DEA Thesis

Introduction and purpose:

Manipulating radioactive materials is not without risk. In case of accident where people would have ingested or inhaled radioactive materials, it is important to know how to face it. First the nature of the contamination, i.e. which radionuclide, has to be determined. Radionuclides that emit α-particles are the most dangerous in case of internal contamination. Indeed, α-particles lose their energy on very short distance (few microns), causing lots of damage to the surrounding tissues. Among these α-emitters, americium-241 is worthy of particular attention. In case of internal contamination by inhalation or ingestion, it can prove to be highly noxious. Indeed, once in the human body, it behaves chemically like calcium and fixes itself in the bone, and hence is called "bone-seeker". The bone marrow is then exposed to extremely noxious radiations.

Fortunately, americium-241 also emits γ radiations (notably, at 59.4 keV) that can be detected outside the human body. Consequently, spectroscopic analyses can be considered to quantify the degree of contamination. However, because the energy of the γ rays is low, the detection system has to be as close as possible to the bone in order to reduce the attenuation of radiation by the tissues. Therefore, the knee and the skull are the two most interesting human parts. The detection system has then to be well calibrated. The purpose of this thesis is to calibrate the detection system for the knee geometry using Monte Carlo simulation. This problem is within the framework of an international intercomparison, in which I took part, aimed at investigating and comparing the different Monte Carlo approaches adopted in this field by various Laboratories.

Materials and methods:

MCNPX have been used to simulate the detection system, also called whole body counting system (WBC). It is made up of two Low Energy Germanium detectors (LEGe). The knee is modeled by the voxel phantom developed by Zubal et al. First, the detector efficiency of one detector exposed to an americium-241 point source has been evaluated using the pulse height tally F8. Second, supposing a homogeneous distribution of americium-241 activity in the knee bones, the degradation of the spectrum by the tissue surrounding the knee has been evaluated by looking at the γ flux spectrum with tally F1. The detection efficiency of the WBC system exposed to a contaminated knee is determined. Finally, the total dose deposited in the knee tissues per unit of activity is evaluated by Monte Carlo method for the γ rays. For the α–particles and electron, the delivered dose is computed assuming that they transferred all their energy at the point where they were emitted.

Results:

The intrinsic efficiency of detector for the peak at 59.5 keV is equal to 0.9192±0.0006. The absolute efficiency is depends mainly on the solid angle. Hence the source has to be as close as possible to the detector. The second step of the investigation reveals that the intensity of the 59.5 keV peak is attenuated by a factor of about 3.55 by the surrounding tissues. The absolute detection efficiency of the WBC for the peak at 59.5 keV is $(1.0936 \pm 0.0007) \times 10^{-2}$ counts/photon which corresponds to experimental results. The detection limit is 85 Bq for an acquisition time of 5 minutes. The dosimetry results show that huge contaminations (several MBq) are necessary to have noxious effect on the contaminated patient.

Conclusion:

The MCNPX results for the determination of the detector efficiency are coherent with those from the literature. It also allows to highlight each effect occurring inside the detector. Monte Carlo simulations are also powerful to determine the attenuation of the γ rays by the tissue without introducing any detector function, which is impossible experimentally. The low detection limit of the whole body counting system makes them very powerful for the detection of extremely low degree of contamination. Unfortunately, the dose results are only qualitative because the model does not take into account the americium-241 uptake on the bone, nor its clearance by the body. However, our results are in quite good agreement with the ICRP results.