Uncertainties in bone (knee region) in vivo monitoring

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Abstract

The bones in the knee region are among the possible choices to estimate radionuclide deposit in the skeleton. Finding the optimum measurement conditions requires the determination of the uncertainties and their relationship with the detector arrangement in the available space, variations in bone anatomy, and non-uniformity in radionuclide deposit.

In this work, geometric models for the bones in the knee region and Monte Carlo simulation of the measurement efficiency were used to estimate uncertainties in the in vivo monitoring in the 46 – 186 keV gamma-ray energy range. The bone models are based on geometrical figures such as ellipsoids and cylinders and have already been published elsewhere. Their parameters are diameters, axis orientations, lengths, and relative positions determined from a survey on real pieces. A 1.70 m tall person was used as a reference; bone model parameters for 1.50 m and 1.90 m tall persons were deduced from the previously published data, to evaluate the uncertainties related to bone size.

The simulated experimental arrangement consisted of four HPGe detectors measuring radiation from the knees in the bed geometry; uncertainties from radionuclide deposit distribution, compact bone density and bone size were also included. The detectors were placed at 22 cm height from the bed and it was assumed that the part of the bones seen by the detectors consists in the first 25 cm from the patella, both in feet and hip directions. The cover tissue was not taken as an uncertainty source, but its effect on the final detection efficiency was taken into account.

The calculations consider the main interaction types between radiation and the detector crystal, and the radiation attenuation in the bones and the layers of materials between bones and detectors.

It was found that the uncertainties depend strongly on the hypotheses made. For example, for 46 keV gamma-rays, a 1.70 m tall person with normal bone density and radionuclide deposit in the compact bone, a loss of 20% in the compact bone density causes an increase of 12% in the efficiency, while a homogenous deposit in the entire bones (instead of only in the compact bone) reduces the efficiency in 24%.

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