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D9.116 – Fluence to dose conversion coefficients for reference phantoms and postures other than standing for photons and neutrons

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Abstract

The goal of the PODIUM project is to develop a software application that allows calculation of the radiation worker doses of interest by combining positioning information from a staff monitoring system and information on the radiation field. The aim is to provide fast dose calculations for workers moving in realistic workplace fields. These calculations will be based on Monte Carlo (MC) methods and need to employ a variety of computational body phantoms, assuming various postures in the radiation field (e.g., standing, bending over something, hands stretched out into the radiation field) and having different body statures (tall, small, broad). One approach is using a library of pre-calculated conversion coefficients as a first approach of the fast online dosimetry application for workers in the realistic workplaces of WP4 (interventional radiology) and WP5 (neutron fields). For this purpose, a database of pre-calculated fluence to organ and effective dose conversion coefficients was established. This database will cover different relevant phantom postures, statures and positions in the field as well as photons and neutrons of different energies and in different irradiation geometries. Deliverable D9.116 present fluence to dose conversion coefficients for phantoms having reference statures and assuming various postures, for photons and neutrons.

CONTENT

I. Introduction: fluence to dose conversion coefficients and their role in PODIUM

The objective of this deliverable of PODIUM WP2 is to provide a library of pre-calculated conversion coefficients as a first approach of the fast online dosimetry application for workers in the realistic workplaces of WP4 (interventional radiology) and WP5 (neutron fields). Especially for neutron dosimetry, it was to be expected that fast (i.e., real-time) Monte Carlo radiation transport would not be feasible within the duration of the PODIUM project. For photons, the database of pre-calculated fluence to dose conversion coefficients can back up the fast Monte Carlo calculations of Task 2.3.

This database covers different relevant phantom positions in the field as well as photons and neutrons of different energies and in different irradiation geometries.

II. Fluence to dose conversion coefficients for photons

The photon conversion coefficients were aimed at serving the needs of the workplaces considered in the frame of the PODIUM project, i.e. interventional radiology. Hence, phantoms with protective lead garment were used for the simulations, and radiation incidence was limited to (a) the upper part of the body and (b) anterior and anteriorly oblique directions of photon incidence. To account for the inhomogeneous radiation incidence on the body, the body was sub-divided into six smaller sections (called “panels”) for which separate conversion coefficients were calculated. There were three panels in height (called “Top”, “Mid”, and “Bottom”), on both sides (left and right). On each of these panels, incidence of parallel mono-energetic photon beams under various angles was considered. Angles in horizontal directions ranged from 60° left-anteriorly oblique (“LAO60”) to 60° right-anteriorly oblique (“RAO60”), in steps of 15°. Anterior radiation incidence corresponds to 0°. The angles in vertical directions ranged from 30° upward (“Up30”) to 30° downward (“Do30”), also in steps of 15°, where horizontal incidence corresponds to 90°. All combinations of horizontally and vertically oblique angles were considered. An illustration of the terminology used for the panels and the incidence angles is shown in Figure 1. The photon energies ranged from 10 keV to 120 keV in steps of 10 keV.

For all six panels, all nine horizontally varying incidence angles were considered, i.e., LAO60, LAO45, LAO30, LAO15, AP, RAO15, RAO30, RAO45, and RAO60. The relevance of the vertically varying incidence angles depended on the location of the panel in height: for the Top panels, only upwards oriented angles were considered; for the Mid panels, upwards and horizontal angles were considered, and downward angles were considered only for the Bottom panels.

Conversion coefficients were calculated for a reference-sized male mesh phantom “RAF” in two different postures – a standing posture with arms stretched away from the body and leaning forward with hands above the patient’s body. Figure 2 shows the voxelized versions of the RAF phantom in the two postures. For details about the phantoms, please see Deliverable D9.104.

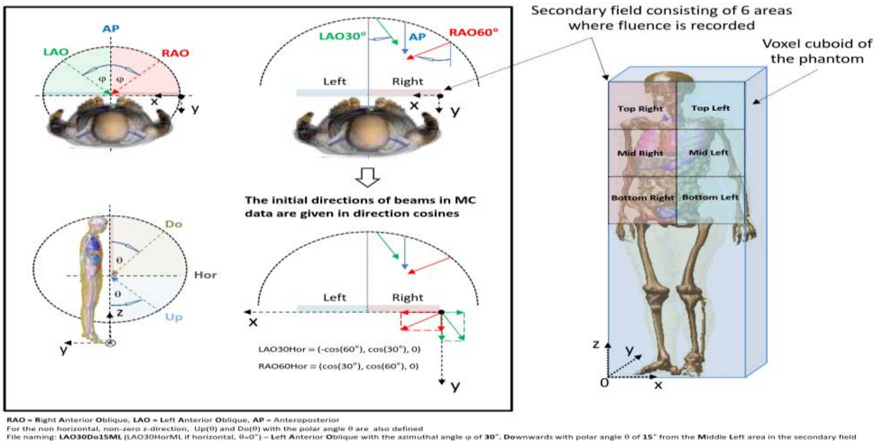

Figure 1: Terminology used for field panels and angles of incidence

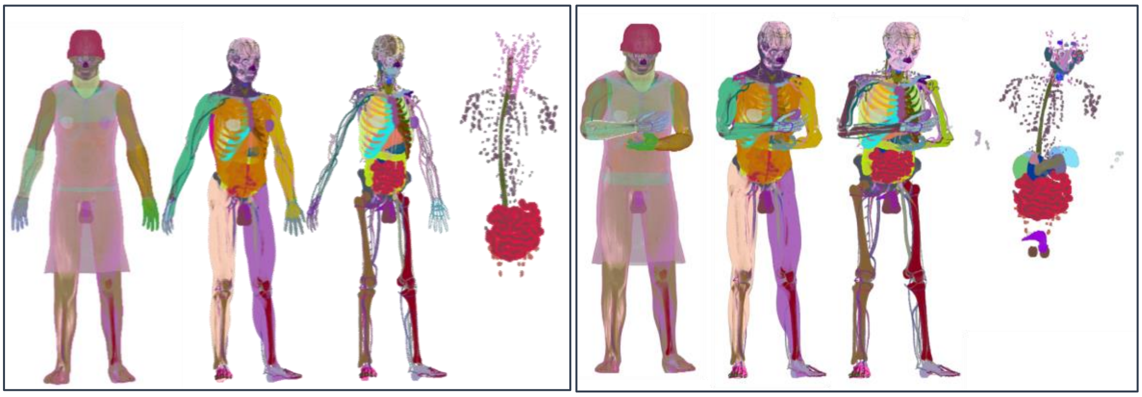

Figure 2: Simulated postures of the RAF phantom

Conversion coefficients were calculated for effective dose [ICRP, 2007] and for all organs contributing to this quantity. Examples of fluence to effective dose conversion coefficients for both postures and for selected panels, incidence angles and photon energies are shown in Figure 3.

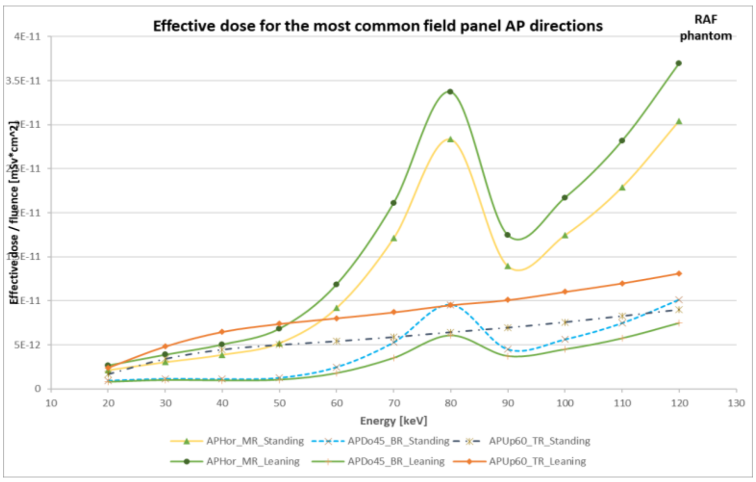

Figure 3: Effective dose per fluence conversion coefficients for the most common AP horizontal radiation incidence of the standing and leaning postures of the RAF phantom. The x-axis is representing photon energy, and each panel is represented by a different curve.

The tables of the RAF phantom show that the forward leaning posture has an impact on all Field Panels. In the great majority of the cases, effective doses for Bottom panels decreases with the leaning posture, while the effective doses for Mid and Top panels increases. In all cases, the lead apron has relatively less attenuating effect below its 88 keV K-edge, which accounts for the fall in the effective dose contributions behind the lead apron, which give minima at 100 keV.

III. Fluence to dose conversion coefficients for neutrons

For neutron workplaces, the fields are much more homogeneous than the photon fields in interventional radiology. Hence, only broad parallel beams incident on the whole body had to be considered. The angles of incidence are horizontal and 45° upwards, along the vertical axis and along the horizontal axis, it is from 0° to 315°, in steps of 45° with 0° being from the right side of the phantom to the left side of the phantom. It is observed that the most extreme neutron dose conversion coefficients will occur in the 45° upwards from right to left direction (lowest effective dose, for most neutron energies) and in the horizontal AP direction (highest effective dose). For the neutrons and the broad parallel beams, the position of the legs and arms is far less important than for instance for photons beams in the interventional radiology / cardiology case. The approximation of using the various angles, especially the 45° upward direction, as being equivalent to a person bending 45° forward with a horizontal beam, and therefore the standing 45° upward beam direction can be used, to approximate this posture with the neutron dose conversion coefficients.

IV. Conclusions

With this deliverable, WP2 provides a library of pre-calculated fluence to dose conversion coefficients for phantoms having reference statures and non-reference postures that can be used as a first approach of the fast, online dosimetry application for workers in realistic workplaces. The numerical data of the conversion coefficients were uploaded in the STORE database and can be found at DOI:10.20348/STOREDB/1156.

V. References

ICRP 2007. The 2007 Recommendations of the International Commission on Radiological Protection. *In:* PROTECTION, *ICRP Publication 103.* Oxford, UK: Elsevier.