Design of 3-D Printed, Highly Tissue-Equivalent Rodent Phantoms, and Use for Valid Comparison of Cs-137 and X-ray Irradiators

Maddison Heine[1], Mark Murphy[1]

[1]*Pacific Northwest National Laboratory, P.O. Box 999, Richland, WA 99354;*

Recently there has been new security requirements for high-activity gamma-ray sources, and incentives to replace these sources with X-ray technologies. This has led to increased need for accurate comparisons of the depth-dose profiles between gamma-ray and X-ray irradiators to determine equivalency for particular applications. This study investigates the design and testing required in order to produce rodent phantoms of high tissue equivalency, and how to use these phantoms to obtain accurate and valid dosemetric comparisons between these irradiators.

The use of PLA (polylactic acid) filament and Prusa i3 Model MK3S+ 3D printer were investigated in this study. The printing parameters (temperature, layer height, infill pattern and density) were adjusted until the best tissue-equivalency was achieved. The tissue-equivalency is directly related to the equivalency of the photon radiation cross-sections across the photon energy range expected to be encountered.

To test the tissue-equivalency of the phantom material, the photon beam attenuation was measured for small, solid PLA blocks versus PLA thin-walled shells filled with a common meat product consisting of a mixture of soft tissue and adipose tissue (fat) of ~0.99 g/cm^3 density. Both PLA and meat product blocks were irradiated to five photon fields ranging from 50 keV to 1250 keV. This required the use of Cobalt-60 and Cesium-137 gamma-ray irradiators, and a 324 kVp X-ray irradiator with four filtered beams of effective energies ranging from 50-251 keV . All radiation fields used are accredited fields traceable to the National Institute of Standards and Technology (NIST).

The second phase of the study was to design rodent phantoms of various sizes that would provide depth-dose data very similar to live specimens. The design included multiple horizontal layers that could be disassembled and re-assembled – these layers containing microcavities to accommodate radiochromic dosimetry film. The third phase of the study involved using these phantoms to measure depth-dose differences between various models of Cs-137 and X-ray irradiators.

In addition to the required 3D printer parameter settings and PLA block and meat product block comparison data, depth-dose data involving various Cs-137 and X-ray irradiator models are also presented that utilized the 3D-printed PLA rodent phantoms.