MATSIM: A voxel model for the Astronaut Dosimetric Phantom MATROSHKA


INTRODUCTION
This work shows the improvement of the predictive capacity of numerical methods in space radiation dosimetry. We present a validation study of the previously developed numerical model MATSIM\(^1\) (Table 1.) of the MATROSHKA\(^2\) anthropomorphic phantom. In addition we present investigations with MATSIM and a numerical model of a Tissue Equivalent Proportional Counter (TEPC) both exposed to radiation conditions as present outside the International Space Station (ISS).

EXPERIMENTAL DESIGN & METHODS
The MATROSHKA phantom with a set of thermoluminescent detectors (TLDs) was exposed to \(^{60}\)Co photons\(^3\) and neutrons\(^4\) reference radiation facilities (Fig.1). FLUKA\(^5\) Monte Carlo simulations with MATSIM model resulted in absorbed dose distributions for the TLD positions. The model was validated by a comparison with measurements. The MATSIM model was investigated under space conditions assuming a position outside the ISS at 400 km altitude, inward isotropic incidence of protons, neutrons, helium and iron ions, and maximum of solar activity. Under the same conditions a model of TEPC was studied in order to assess microdosimetric distributions expected in tissue.

RESULTS
On-ground \(^{60}\)Co photon and neutron measurements resulted in absorbed dose (in water) as presented in Fig. 2. A corresponding comparison between measurements and simulations is presented in Fig. 3 for photons (top) and neutrons (bottom). Fig. 4 shows a depth profile of absorbed dose distribution inside the MATROSHKA phantom as simulated for space conditions. Fig. 5 shows microdosimetric distributions as simulated with TEPC under space conditions.

CONCLUSIONS
- MATSIM model was successfully validated within 7% and 19% of uncertainty for photons and neutrons respectively.
- Depth dose distributions for phantom’s inner organs (50 mGy/h) and skin (2 mGy/h) were calculated for solar maximum, outside ISS at 400km altitude.
- Numerical simulations with TEPC provided microdosimetric distributions expected on board the ISS. The resulting mean quality factor is \(\Phi = 2.0\).

OUTLOOK
- Validations with protons and heavy ions.
- Analyses for mission specific scenarios taking into account various shielding aspects.

REFERENCES
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