Analysis & Monte Carlo Modelling of Radio-Opaque Personal Protective Fabrics

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Michael J. Roeterink graduated from the Royal Military College of Canada in May 2012, receiving a BEng in Chemical Engineering with First Class Honours. The following fall, Michael enrolled in a MASc in Nuclear Engineering under the supervision of Dr. E.G. Dickson, Dr. D.G. Kelly, and Dr. E.C. Corcoran. His research is focused on the application of transport and Monte Carlo simulation to develop a realistic dosimetric model of a human arm protected by a personal protective fabric. This model is the first step in the development of a computational tool to assess the imparted full-body dose in the event of radiological particulate exposure. This simulation resource could be used to optimize the composition of radio-opaque personal protective fabrics and contribute to the development of a set of human protection factors to be used by military commanders and first responders during radiation hazard scenarios. Michael's work has been presented in several national conferences and he has been awarded first prizes in both the Undergraduate category (2012 Canadian Nuclear Society Student Conference) and the Master's category (2013 Canadian Nuclear Society Student Conference). Most notability, Michael is the proud recipient of the 2013 NSERC Alexander Graham Bell Canada Graduate Scholarship.

Abstract

Radiation safety practice aims to limit personnel exposure to harmful sources of radiation by adhering to the theory of As Low As Reasonably Achievable (ALARA). Unfortunately, it can be difficult to extend the ALARA principle to military members and first responders as the dynamic and ambiguous nature of most radiation hazard scenarios may necessitate that these individuals work for extended periods of time in close proximity to a radiation source or within the plume of a dispersed material. Furthermore, the physical nature of many of the required tasks eliminates the use of traditional shielding structures as they are too cumbersome to be carried for protection. Thus, the inclusion of radio-opaque materials in protective fabrics has numerous applications and is deserving of continued research.

Personal protective fabrics (PPF) can be used to reduce wearer exposure to the emitted radiation by either blocking radioactive particulates from reaching the skin or attenuating the radiation itself, but do not offer complete protection. The objective of the present work was three-fold: (i) to characterize the composition of radio-opaque fabrics

and analyze their gamma photon attenuation, (ii) to benchmark a Monte Carlo model using the experimental results from transmittance experiments on the fabrics, and (iii) to extend this Monte Carlo computation model to demonstrate its relevance in designing new fabrics, which may have improved radiation shielding capabilities.

For the characterization analysis, the fabrics were imaged using scanning electron microscopy (SEM), while their elemental compositions were determined using a combination of energy-dispersive X-ray (EDX) spectroscopy, inductively coupled plasma-mass spectrometry (ICP-MS), and instrumental neutron activation analysis (INAA). Reduction in transmittance was evaluated by measuring the attenuation of a multi-radionuclide challenge source through increasing layers (between 0 to 20) of the radio-opaque fabrics.

Experimentally benchmarked models represent powerful tools for the investigation and optimization of radio-opaque fabrics. As such, Monte Carlo simulations, using the Monte Carlo N-Particle Transport Code, Version 5 (MCNP5), were conducted to assess the transmittance of gamma photons for a single layer of each fabric over a range of energies and the results were compared with those obtained experimentally. Finally, MCNP5 was used to predict the attenuation properties of new radio-opaque fabric designs.