From Aerosol Deposition to Non-Reference Internal Dose: Integrated Evaluation of Inhalation Exposure and Internal Dosimetry for Military Personnel

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Purpose: Inhalation represents a primary pathway for the intake of airborne particles, including radioactive materials, contributing up to approximately 73% of annual exposure from natural radiation sources. For occupational exposure, inhalation is the dominant route of intake, as documented in the European Commission's radiation protection technical report. The relevance of inhalation exposure is further amplified in military operational environments and occupations involving airborne radioactive particles or toxic metals, such as nuclear weapons testing, accident response and cleanup activities, and the handling of radioactive materials. In response to this need, this work presents a customizable computational tool for estimating particle deposition in the human respiratory tract, designed to balance precision, computational efficiency, and operational practicality. Beyond deposition, the framework is extended to estimate the corresponding radiation dose quantities, enabling evaluation of non-reference equivalent and detriment effective doses associated with inhalation exposure scenarios.

Methods: Aerosol deposition was computed using the International Commission on Radiological Protection (ICRP) Human Respiratory Tract Model (HRTM) (ICRP Publication 66), implemented in the Python-based tool, $\mathrm{REDCAL_{dep}}$ within the REDCAL framework and incorporated updates from ICRP Publication 130. The model allows for physiologically customized deposition estimates consistent with Military Exposure Guidelines (MEGs), along with individualized and sensitivity analyses. REDCAL further integrates deposition framework with radionuclide-specific biokinetic and dosimetric models to estimate non-reference radiation dose quantities for military personnel.

Results: Deposition fractions (DFs) computed using $\mathrm{REDCAL_{dep}}$ for a reference worker showed excellent agreement with ICRP values, with total DF differences below 5% and region-specific differences generally under 3%. Sex-weighted deposition fractions based on a 14-day MEG-defined activity schedule resulted in maximum regional DF deviations of approximately 72% and total DF differences of up to 49.44% relative to ICRP reference worker assumptions. Leveraging these DFs, the non-reference dose quantities were subsequently estimated incorporating non-reference S-values derived from the University of Florida Military Phantom Library.

Conclusion: The MEG-informed deposition fractions reported in this work constitute a novel dataset that strengthens the estimation of internalized uptake and non-reference radiation dose quantities, thereby improving dose reconstruction and risk evaluation for military context exposure scenarios.

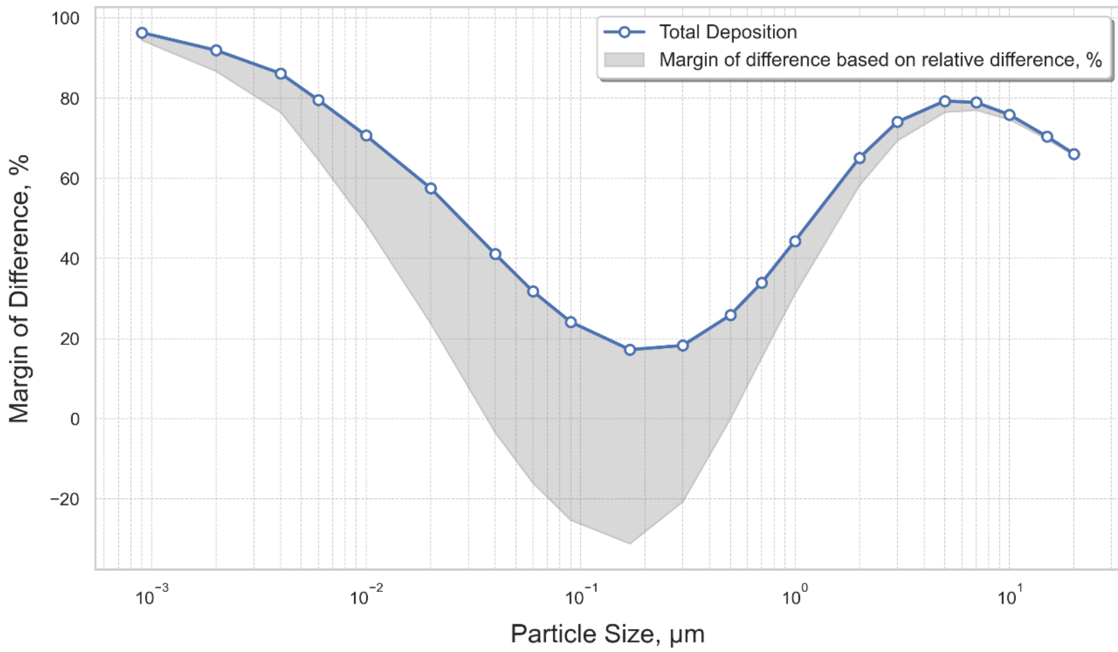

Figure 1. Margin of difference between military-specific and ICRP DFs.