Analysis of Regional Retention of Plutonium in the Respiratory Tract of Four Acutely-Exposed Workers Using Scar-tissue Compartments

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Animal studies and autopsies of former plutonium (Pu) workers have demonstrated that a small fraction of inhaled Pu may be retained in the respiratory tract compartments long after an inhalation intake, even when the inhaled material is known to be very soluble. The Human Respiratory Tract Model (HRTM) described in Publication 130 [1] of the International Commission on Radiological Protection (ICRP) provides some mechanisms to account for retention of the material that can be subject to little to no mechanical transport or absorption into the blood. One of these mechanisms is deposition of the material in sequestered compartments, and the other is 'binding'. The latter refers to a process by which a fraction of the dissolved material chemically binds to the airway wall tissue. This fraction (f_b) is taken to be 0.2% for Pu [2], but given the implications of chemical binding for doses to the target tissues in the respiratory tract, it is important that this parameter be further evaluated and studied.

The United States Uranium and Transuranium Registries obtained data on regional retention of Pu in the respiratory tract of four workers who had inhaled materials with solubility ranging from soluble nitrate to very insoluble high-fired oxides. Significantly more Pu was found to be retained in the upper respiratory tract of these workers than was predicted by the current biokinetic models [1, 2]. Modification of the model parameters, including f_b, was unable to explain the data for one individual who inhaled an insoluble form of Pu. Moreover, several studies show evidence of retention of a large amount of Pu in scar tissues of humans and experimental animals, pointing to an alternate mechanism by which Pu can be retained infinitely in the respiratory tract.

This presentation proposes a HRTM that is modified with the addition of scar-tissue compartments to describe the long-term regional retention of Pu in the respiratory tract of all four individuals. The transfer rates to scar-tissue compartments were determined using Markov Chain Monte Carlo analysis of the bioassay and post-mortem regional retention data, taking into account the uncertainties associated with deposition, dissolution, and particle clearance parameters. The estimates obtained from modelling these data showed that a significant amount of plutonium, 20-100%, retained in the respiratory tract was sequestered in the scar tissues, depending on the solubility of the inhaled material. Unlike chemically-bound Pu that irradiates sensitive epithelial cells, Pu in scar tissues may not be dosimetrically significant because the scar tissues absorb most, if not all, of the energy from alpha emissions.

References:

[1] ICRP. Occupational intakes of radionuclides: Part 1. ICRP Publication 130. Ann. ICRP 44(2), 2015

[2] ICRP. Occupational intakes of radionuclides: Part 4. ICRP Publication 141. Ann. ICRP 48(2/3), 2019

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