Maximum Likelihood Analysis of Bioassay Data from Long-term Follow-up of Two Refractory PuO_2 Inhalation Cases

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Abstract – The U.S. Transuranium and Uranium Registries' tissue donors 0202 and 0407 are the two most highly exposed of the 18 registrants who were involved in the 1965 plutonium fire accident at a defense nuclear facility. Material released during the fire was well characterized as "high fired," refractory plutonium dioxide with 0.32 micrometer mass median diameter. The extensive bioassay data from long-term follow-up of these two cases were used to evaluate the applicability of the Human Respiratory Tract Model presented by International Commission on Radiological Protection in Publication 66 and its revision proposed by Gregoratto et al. in order to account for the observed long-term retention of insoluble material in the lungs. The maximum likelihood method was used to calculate the point estimates of intake and tissue doses and to examine the effect of different lung clearance, blood absorption and systemic models on the goodness-of-fit and estimated dose values. With appropriate adjustments, Gregoratto et al. particle transport model coupled with the customized blood absorption parameters yielded a credible fit to the bioassay data for both cases and predicted the Case 0202 liver and skeletal activities measured post-mortem. PuO_2 particles produced by the plutonium fire are extremely insoluble. About 1% of this material is absorbed from the respiratory tract relatively rapidly, at a rate of about 1 to 2 d^{-1} (half-time about 8 to 16 h). The remainder (99%) is absorbed extremely slowly, at a rate of about $5x10^{-6}$ d^{-1} (half-time about 400 y). When considering this situation, it appears that doses to other body organs are negligible in comparison to those to tissues of the respiratory tract. About 96% of the total committed weighted dose equivalent is contributed by the lungs. Doses absorbed by these workers' lungs were high: 3.2 Gy to the alveolar-interstitial region and 6.5 Gy to the thoracic lymph nodes for Case 0202 (18 y post-intake); 3.2 Gy to the alveolar-interstitial region and 55.5 Gy to the thoracic lymph nodes for Case 0407 (43 y post-intake). This evaluation supports the Gregoratto et al. proposed revision to the ICRP 66 model when considering situations of extremely insoluble particles.

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