

Maximum Likelihood Analysis of Refractory PuO₂ 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 and blood absorption 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. PuO₂ 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 5 × 10⁻⁶ 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. Up to about 97% of the total committed weighted dose equivalent is contributed by the lungs. Application of the ICRP recommended dose coefficient for absorption type S will significantly underestimate the lung doses for this type of material. This evaluation supports the Gregoratto et al. proposed revision to the ICRP 66 model when considering situations of highly insoluble particles.

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