Uncertainty Evaluation of Skeleton Plutonium Activity Concentration Estimated from a Latent Bone Model

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The recently proposed latent bone model (LBM) for non-osteoporotic individuals applies principal components regression (PCR) to estimate plutonium activity concentration in the human skeleton from measurements of a limited set of bone samples. This study developed a Monte Carlo method to evaluate uncertainty in LBM estimates of skeleton plutonium activity concentration (C_{skel}) using PCR analysis. For this study, the analytical bone dataset was prepared using plutonium concentrations in 18 preselected 'best' bone samples from 14 non-osteoporotic whole-body donors to the United States Transuranium and Uranium Registries. The tissue donors' age ranged from 52 to 87 years and the C_{skel} ranged from 0.9 to 42.0 Bq kg^{-1} of wet weight. The bone set contained 3 samples from each of 6 bone types: skull, long bone end (epiphysis), long bone shaft (diaphysis), cortical bone, trabecular bone, and other bones. The PCRs were used to fit LBMs for 2 to 6 randomly sampled bones, and 10,000 simulations were run for a given number of bone samples. The simulation results indicated that the residuals of plutonium concentrations were normally distributed for each of 14 studied cases. The standard deviation of the residuals (SD) of normal distributions were used to determine the uncertainties associated with the estimated C_{skel}. Linear regression was used to derive a relationship between SD and C_{skel} for each number of sampled bones. The linear regression equations for 2 and 6 sampled bones were: $SD = 0.061 \times C_{skel} + 0.846$ ($r^2 = 0.573$, $p = 0.0011$) and $SD = 0.024 \times C_{skel} + 0.446$ ($r^2 = 0.398$, $p = 0.0098$), respectively. The higher uncertainties were associated with a lower C_{skel} and a smaller number of sampled bones. As C_{skel} increased, the estimated relative standard deviations (SD/C_{skel}) decreased from 100% to 8% for 2 bones and from 52% to 3% for 6 bones.

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