Environmental Management Science Program

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Improved Radiation Dosimetry/Risk Estimates to Facilitate Environmental Management of Plutonium Contaminated Sites

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Research Objective

The objective of this research is to evaluate distributions of possible alpha radiation doses to the lung, bone, and liver and associated health-risk distributions for plutonium (Pu) inhalation-exposure scenarios relevant to environmental management of PuO_2-contaminated sites. Currently available dosimetry/risk models do not apply to exposure scenarios where, at most, a small number of highly radioactive PuO_2 particles are inhaled (stochastic exposure [SE] paradigm). For the SE paradigm, risk distributions are more relevant than point estimates of risk. The focus of the research is on the SE paradigm and on high specific activity, alpha-emitting (HSA-aE) particles such as $^{238}PuO_2$. The scientific goal is to develop a stochastic respiratory tract dosimetry/risk computer model for evaluating the desired absorbed dose distributions and associated health-risk distributions, for Department of Energy (DOE) workers and members of the public.

Research Progress and Implications

This report summarizes results after 1 year of a 2-year project. The key research achievements and their implications are as follows:

The respiratory tract dosimetry computer program, LungMod, developed at our Institute for the National Council on Radiation Protection and Measurements was updated to a 32-bit version applicable to both monodisperse and polydisperse aerosols. The program is being used to evaluate Pu-particle regional deposition efficiencies throughout the respiratory tract.

A Monte Carlo (MC)-based computer program (preliminary) was developed for calculating the distribution of radioactivity intake via inhalation of $^{238}PuO_2$ by male adults. The program was applied to a scenario where one person in 100 is expected to have a particle presented for inhalation. The intake distribution obtained was used for an upper-bound, intake distribution for members of the public (infants, children, teenagers, adults) who inhale dust contaminated with $^{238}PuO_2$, when up to one person in 100 inhales one or more contaminated dust particles.

Single-particle radioactivity intake distributions (conditional on particle deposition) were developed for HSA-aE, $^{238}PuO_2$ aerosols for the SE paradigm, for male adults. Evaluations were conducted for a lognormal size distribution with activity median aerodynamic diameter of 5 mm and geometric standard deviation of 2.5.

Single-particle intake distributions were convoluted to obtain multiple-particle intake distributions for up to 10 particles. For $^{238}PuO_2$, radioactivity intake for 10 deposited particles in the respiratory tract spanned a wide range. The 2.5%, 50%, and 97.5% (percentiles) of the intake distribution were 0.28 kBq, 2 kBq, and 7.5 kBq, respectively. Corresponding values for $^{239}PuO_2$ can be obtained by dividing the indicated values for $^{238}PuO_2$ by 280.

The stochastic geometry model of Werner Hofmann and colleagues was acquired and will be used to evaluate variability in deposition of particles in the respiratory tract. The model allows the lung morphometry to vary in a stochastic manner, based on measured distributions.

We are updating information on current knowledge about cancer induction by alpha particles. A key issue being addressed relates to the validity of the linear, no-threshold (LNT) model for cancer induction. Data we acquired, based on a recent case-control analysis of Mayak workers by Russian scientists, indicate that a sizable threshold may exist for alpha radiation-induced lung cancer. Evidence

for thresholds for radiation-induced cancer at other sites in the body is also growing and has cost-saving implications for cleanup of Pu-contaminated, DOE sites.

We are maintaining a database on worker exposure to Pu.

The key implications of the research conducted for the SE paradigm are as follows: (1) single-particle intake should predominate when less than 1 in each 100 members of the public are presented a PuO_2 particle for inhalation; (2) the intake of a single HSA-aE, PuO_2 particle could exceed the annual limit for worker exposure; (3) widely varying amounts of radioactivity can be deposited in the respiratory tract, even for a fixed number of HSA-aE, PuO_2 particles inhaled; (4) use of point estimates of dose and average risk based on the LNT health-risk model could lead to wasting dollars on excessive cleanup of Pu-contaminated sites.

Planned Activities

Over the next year we will: (1) place a database developed in this project on Pu exposure of workers onto the World Wide Web; (2) complete research on characterizing source terms for potential DOE-worker and public exposures; (3) apply the stochastic geometry model of Hofmann and colleagues in variability evaluations related to particle deposition in the respiratory tract; (4) initiate and conclude research on characterizing absorbed radiation dose distribution for key organs, for the SE paradigm; (5) characterize lung, bone, and liver cancer risk distributions for plausible DOE-worker and public-exposure scenarios for the SE paradigm; and (6) deliver a stochastic respiratory tract dosimetry/risk computer model applicable to inhalation exposure to Pu aerosols for the SE paradigm.

Other Access To Information

Bobby R. Scott, Andrey F. Lyzlov and Sergey V. Osovets. “Evaluating the risk of death via the hematopoietic syndrome mode for prolonged exposure of nuclear workers to radiation delivered at very low rates.” Health Physics 74 (5), 545-553, 1998.

Sergey V. Osovets and Bobby R. Scott. “Nonmonotonous character of dose-response relationships.” Viniti No. 1/4, 645-B98, March 6, 1998 (in Russian).