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Project Title: **Improved Radiation Dosimetry/Risk Estimates to Facilitate Environmental Management of Plutonium Contaminated Sites**

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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 PuO₂-contaminated sites. Currently available dosimetry/risk models do not apply to exposure scenarios where relatively small numbers of highly radioactive PuO₂ particles are presented for inhalation (stochastic exposure [SE] paradigm). For the SE paradigm, distributions of possible risks are more relevant than point estimates of risk. The main goal of the project is to deliver a computer program that will allow evaluation of the indicated risk distributions for the SE paradigm. However, some of our work also relates to the deterministic exposure [DE] paradigm where large numbers of airborne particles (resuspended dust containing PuO₂) are presented for inhalation to members of the public residing or working at a remediated Department of Energy (DOE) site.

RESEARCH PROGRESS AND IMPLICATIONS

This report summarizes work after 2 years of a 3-year project. To date, research has mainly focused on two areas.

Research Area 1 relates to evaluating, by the Monte Carlo method, the variability in the respiratory tract intake of plutonium dioxide (PuO₂) by DOE workers during decommissioning/decontamination operations. Our present focus is on the variability in radioactivity intake associated with inhaling relatively small numbers of polydisperse (i.e., varying sizes) PuO₂ particles. For polydisperse PuO₂, a single, large, high-specific-activity particle can exceed the annual limit on intake (ALI). Only a few such particles can greatly exceed the ALI. Further, when relatively small numbers of very highly radioactive particles are inhaled, there can be considerable variability in the amount of radioactivity deposited in the respiratory tract. Our research provides tools for characterizing that variability. Workers at the Rocky Flats Environmental Technology Site near Denver are the present at-risk population being considered.

Research Area 2 relates to evaluating possible respiratory tract intake of radioactivity by the public from airborne dust contaminated with PuO₂ arising from the Rocky Flats Site after remediation. The specific activity of the contaminated dust is orders of magnitude lower than for PuO₂ so that large numbers of such particles must be inhaled to lead to significant radiation exposure. Starting from single dust particle intake, we have calculated, via the numerical convolution method, the variability in radioactivity intake by adult males associated with inhaling up to 5,000,000 dust particles (density 2 g/cm³) containing PuO₂. Members of the public who at some future time after site remediation might reside at what is presently the Rocky Flats Environmental Technology Site near Denver are the present at-risk population being considered.

Specific achievements/findings are summarized below.

- A Monte Carlo-based computer program, which we previously developed to calculate the distribution of radioactivity intake via inhalation of ²³⁸PuO₂ by male adults engaged in light exercise, has been improved. Respiratory tract deposition probability is based on the ICRP 66 publication.
- Single-particle and multiple-particle intake distributions were generated for ²⁴⁴PuO₂, ²⁴²PuO₂, ²³⁹PuO₂, ²⁴⁰PuO₂, ²³⁸PuO₂, and ²³⁶PuO₂ (ordered here by increasing specific activity), based on a density of 10 g/cm³, a polydisperse size distribution (truncated lognormal: AMAD= 5 μm; σ_g=2.5; maximum aerodynamic diameter = 26 μm). The intake distributions were conditional on particle deposition in the respiratory tract, and results indicated that considerable variability in intake would be expected for exposure during

decommissioning/decontamination accidents. Multiple particle intake distributions shifted from lognormal toward normal as the number of particle inhaled increased.

- Single-particle and multiple-particle intake distributions were generated for generic PuO₂ inhaled in resuspended Rocky Flats soil. Intake distributions were generated for adult males who inhaled and deposited in the respiratory tract 100, 200, 500, 1000, 2000, 10000, 100000, 1000000, or 5000000 PuO₂-contaminated dust particles. Results were developed for soil specific activity of 1 Bq/g, soil density of 2 g/cm³, and for a polydisperse size distribution (truncated lognormal: AMAD = 1 μm; σ_g = 2.5; maximum aerodynamic diameter = 26 μm). This allows easy scaling to other soil specific activities. However, for large numbers of dust particles inhaled over years, variability in radioactivity intake was not found to be important. We also expect our results for inhaling soil contaminated with PuO₂ to apply for a first approximation to adult females.
- Our results have important implications for establishing radionuclide soil action levels for the Rock Flats site for the following alpha-emitting radionuclides: ²³⁴U, ²³⁵U, ²³⁸U, ²³⁸Pu, ²³⁹Pu, ²⁴⁰Pu, ²⁴²Pu, and ²⁴¹Am. Presently, radionuclide soil action levels developed by others are based on PM-10 concentrations, for which dust particles with aerodynamic diameters > 10 μm in the respirable size range are excluded. For PuO₂ contained in resuspended dust, a particle with an aerodynamic diameter > 10 μm but in the respirable size range can contain more radioactivity than millions of much smaller particles included in the PM-10 concentration. Thus, large-size respirable particles should not be excluded when establishing radionuclide soil action levels for Rocky Flats and other sites.
- Current information associated with alpha radiation-induced lung cancer was updated. Data were acquired related to workers at the Mayak facility in the former Soviet Union who developed lung cancer after inhaling ²³⁹PuO₂. The data support a possible large threshold for lung cancer induction when contributions of cigarette smoking and gamma ray exposure are accounted for. Thresholds for cancer induction would have important cost-saving implications for remediation of Pu-contaminated sites.
- We are maintaining a database on worker exposure to Pu. Information has been placed on the worldwide web. In addition, a radiation glossary was placed on the web for students and others with limited background on radiation terminology and issues. The glossary is currently being used at several universities in the US and by clinicians at the First Institute of Biophysics in Ozyorsk, Russia.

PLANNED ACTIVITIES

Over the next year (year 3), we will continue and complete intended research on radiation dosimetry/risk modeling for inhaling PuO₂ as particles or in resuspended soil. We will deliver stochastic respiratory tract dosimetry/risk computer models applicable to inhalation exposure to Pu aerosols for both the SE and DE exposure paradigms. Key results of the research will be presented in forms easily used by scientists, regulators, legislators, and stakeholders. We will also clarify any cost-saving implications of the research results for cleanup of Pu-contaminated DOE sites. Further, we will publish major results of the research, present them at scientific meetings, and identify needed follow-on research.

INFORMATION ACCESS

A list of publication/presentations fully or partially supported by this project follows. Web resources developed in this project are also listed.

Publications:

Cheng, Y.-S., Zhou, Y., and Chen, B. T. "Particle deposition in a cast of human oral airways," *Aerosol Science & Technology* (in press).

Glissmeyer, J. A., Alvarez, J. L., Blunt, B. C., Frame, P. W., Hoover, M. D., Hull, A. P., Karhnak, J. M., McFarland, A. R., Newton, G. J., and Rodgers, J. C. *American national standard for sampling and monitoring releases of airborne radioactive substances from the stacks and ducts of nuclear facilities*, ANSI/HPS N13.1-1999, Health Physics Society, McLean, VA, 1999.

Guilmette, R. A. and Scott, B. R., "Radiation Toxicology," in *Encyclopedia of Toxicology*, Vol. 3, (Wexler, P., Editor), pp. 5-18, Academic Press, San Diego, 1998.

Hoover, M. D. and Newton, G. J. "Performance testing of continuous air monitors for alpha-emitting radionuclides," *Radiat. Prot. Dosim.* 79 (1-4), 499-504, 1998.

Hoover, M. D., Newton, G. J., Guilmette, R. A., Howard, R. J., Ortiz, R. N., Thomas, J. M., Trotter, S. M., and Ansoborlo, E. "Characterization of enriched uranium dioxide particles from a uranium handling facility," *Radiat. Prot. Dos.* 79 (1-4), 57-62, 1998.

Hoover, M. D., Mewhinney, C. J., and Newton, G. J. "Modular glovebox connector and associated good practices for control of radioactive and chemically toxic materials," *Health Phys.* 76 (1): 66-72, 1999.

Osovet, S. V. and Scott, B. R. "Nonmonotonous character of dose-response relationships." *Viniti* No. ¼, 645, B98, March 6, 1998 (in Russian).

Scott, B. R., Lyzlov, A. F., and Osovet, S. V. "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.

Scott, B. R. "Improved radiation dosimetry/risk estimates to facilitate environmental management of plutonium contaminated sites," in *Environmental Management Science Program Workshop*, U. S. Department of Energy Publication CONF-980736, Washington, DC, pp. 25-26, 1998.

Scott, B. R. and Fencl, A. "Variability in PuO₂ intake by inhalation: Implications for DOE worker protection," *Radiat. Prot. Dosim.* (in press).

Scott, B. R. "Transformation of C3H 10T1/2 cells," Letter to Editor, *J. Radiol. Prot.* (in press).

Presentations:

Cheng, Y.-S., Yeh, H. C., Smith, S. M., Cheng, K. H., and Swift, D. L. "Deposition of ultrafine particles in the nasal and tracheobronchial airways," 1998 International Aerosol Conference, Edinburgh, UK, Sept. 14-18, 1998.

Hoover, M. D., Newton, G. J., and Cox, F. M. "Sampling radioactive aerosols," American Academy of Health Physics Short Course, 31st Midyear Meeting of the Health Physics Society, Mobile, AL, February 7, 1998.

Hoover, M. D. "Workplace air sampling methods and good practices," Technical Workshop on Air Sampling: The Big Picture," Savannah River Chapter, Health Physics Society, Aiken, SC, April 24, 1998.

Hoover, M. D. "Statistical considerations for aerosol sampling, professional enrichment short course," 43rd Annual Meeting of the Health Physics Society, Minneapolis, MN, July 12, 1998.

Hoover, M. D., Newton, G. J., and Cox, F. M. "Flow measurements with rotameters and appropriate corrections," 43rd Annual Meeting of the Health Physics Society, Minneapolis, MN, July 15, 1998.

Hoover, M. D. "Statistical considerations for aerosol sampling," Professional Enrichment Short Course," 32nd Midyear Meeting of the Health Physics Society, Albuquerque, NM, January 24, 1999.

Scott, B. R., Cheng, Y.-S., Diel, J. H., Hoover, M. D., Ménache, M. G., Neft, R. E., Newton, G. J., Snipes, M. B., and Zhou, Y. "Evaluating the intake via inhalation of plutonium oxides for the stochastic exposure paradigm," Poster 13 presented at the *Environmental Management Science Program Workshop*, Chicago, Illinois, July 27-30, 1998.

Smith, S. M., Cheng, Y. S., and Yeh, H. C.: "Diffusional deposition of ultrafine particles in human tracheobronchial airways," 1998 International Aerosol Conference, Edinburgh, UK, Sept. 14-18, 1998.

Zhang, Z., Wang, X., and Cheng, Y.-S. "Flow pattern and aerosol deposition in the human oral airway," 1998 International Aerosol Conference, Edinburgh, UK, Sept. 14-18, 1998.

Web Resources Developed in this Project:

Radiation Glossary for Students: <http://www.lrri.org/radiation/rad.htm>

Plutonium Resources (at our Institute): <http://www.radiation-scott.org/>

Plutonium Related Cases (via hyperlinks): <http://www.radiation-scott.org/Cases.htm>

Plutonium Induced Health Effects (based on publications on Mayak workers):
<http://www.radiation-scott.org/health.htm>

Other Plutonium Related Web Sites: <http://www.radiation-scott.org/other.htm>

Electronic Borders' Dictionary of Health Physics: <http://www.hpinfo.org>