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FINAL REPORT

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INVESTIGATION OF RADON, THORON, AND THEIR PROGENY NEAR THE EARTH'S SURFACE

DOE GRANT DE-FG03-94ER6178| (NMIMT ID 29D-9HF010)

1 January 1994 through 31 December 1997

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1. Introduction

This is the final report for DOE Grant DE-FG03-94ER6178, covering a performance period of 1 January 1994 through 31 December 1997. The DOE award amount for this period was $547,495. The objective of the project as stated in its proposal was "to improve our understanding of the physical processes controlling the concentration of radon, thoron, and their progeny in the atmospheric environment." The original project was directed at developing underlying science that would help with evaluation of the health hazard from indoor radon in the United States and implementation of corrective measures that might be employed to reduce the health hazard. As priorities within the Office of Health and Environment (OHER) changed, and the radon research program was phased out, emphasis of the project was shifted somewhat to be also relevant to other interests of the OHER, namely global pollution and climate change and pollution resulting from energy production.

This final report is brief, since by reference it can direct the reader to the comprehensive research publications that have been generated by the project. In section 2, we summarize the main accomplishments of the project and reference the primary publications. There were seven students who received support from the project and their names are listed in section 3. One of these students (Fred Yarger, Ph. D. candidate) continues to work on research initiated through this project. No post-docs received support from the project, although one of the co-principal investigators (Dr. Piotr Wasiolek) received the majority of his salary from the project. The project also provided part-time support for a laboratory manager (Dr. Maryla Wasiolek). Section 4 lists chronologically the reports and publications resulting from the project (references 1 through 12), and the Appendix provides abstracts of major publications and reports.

2. Summary of Accomplishments

The research activity fell into three general categories: 1) development of experimental methods suitable for study of low concentrations of atmospheric radon progeny and assessment of dose due to their inhalation, 2) study of atmospheric radon and thoron progeny, particularly in the unattached aerosol state, and the dose from their inhalation, and 3) study of the exhalation of radon and thoron from soils, and the meteorological and soil factors controlling their release to the atmosphere. We had significant achievements in all three areas.

Prior to our work, the sensitivity of measurements for unattached radon and thoron progeny were generally inadequate for assessment of dose under low levels such as occur outdoors at the breathing level. We refined the diffusion screen technique using larger screens and larger air sampling flow rates so as to make careful assessment of outdoor dose possible (references 1, 2, 3, 5, and 8). We measured and modeled dose due to both radon and thoron progeny in the attached-to-aerosol and unattached-to-aerosol states (references 3 and 5). The outdoor dose rate was found to be generally low (though not negligible) compared with typical indoor dose rates. Nevertheless, it is important to document naturally-occurring outdoor dose rates, even when small, since they are used as a point of reference in setting regulations and evaluating dose due to anthropogenic sources.

Our most significant technological achievement was the development of a relaxed eddy accumulator system for measurement of atmospheric flux densities of ultrafine radon progeny (references 10 and 11). This is a one-of-a-kind system, and one of few approaches able to measure deposition velocities outdoors for nanometer-size particles. Preliminary results with this technique and others (reference 4, 10, and 11) indicated higher-than-expected deposition velocities for nanometer-size radon progeny to the earth's surface, although most of these measurements occurred at the final stages of the project and need confirmation by further measurements. If confirmed, the results might be important for use in atmospheric transport models predicting pollutant dispersion. The removal rates for certain small-sized pollutants to the earth's surface might be significantly affected (generally increased).

In the study of radon and thoron flux from the earth's surface, our most significant achievement was generation of global maps predicting radon flux density over the earth's surface for each month of the year (reference 12). By studying experimental data for flux density, we identified important correlations with radium concentration in soil, soil temperature, and soil moisture. We quantified these dependences with the help of porous media transport theory and used them to generate the global maps (Figure 1 shows the annually-averaged result). The maps were limited by sufficient global data for soil radium, and must be refined in the future. However, they were the first such maps of their kind and should be of value in predicting locations and seasons with a high potential of supplying radon to houses. The maps indicate strong regional and seasonal variations in radon flux (a factor of three is not uncommon). This information will be important for modelers validating global chemistry and transport models using measurements of atmospheric radon gas and requiring estimates of the radon source term (soil on the earth's surface).

Although perhaps not central achievements in the sense of those items listed above, we had several other sound achievements worthy of mention. In collaboration with Dr. Stewart Whittlestone of the Australian Nuclear Science and Technology Organisation, we participated in studies at Mauna Loa Observatory aimed at developing chemical tracers (radon, ^{212}Pb, and others) that can be used to evaluate the history and purity of background air samples (references 4, 6, and 7). In particular, we found

Predicted Annual Averaged Radon Flux Density

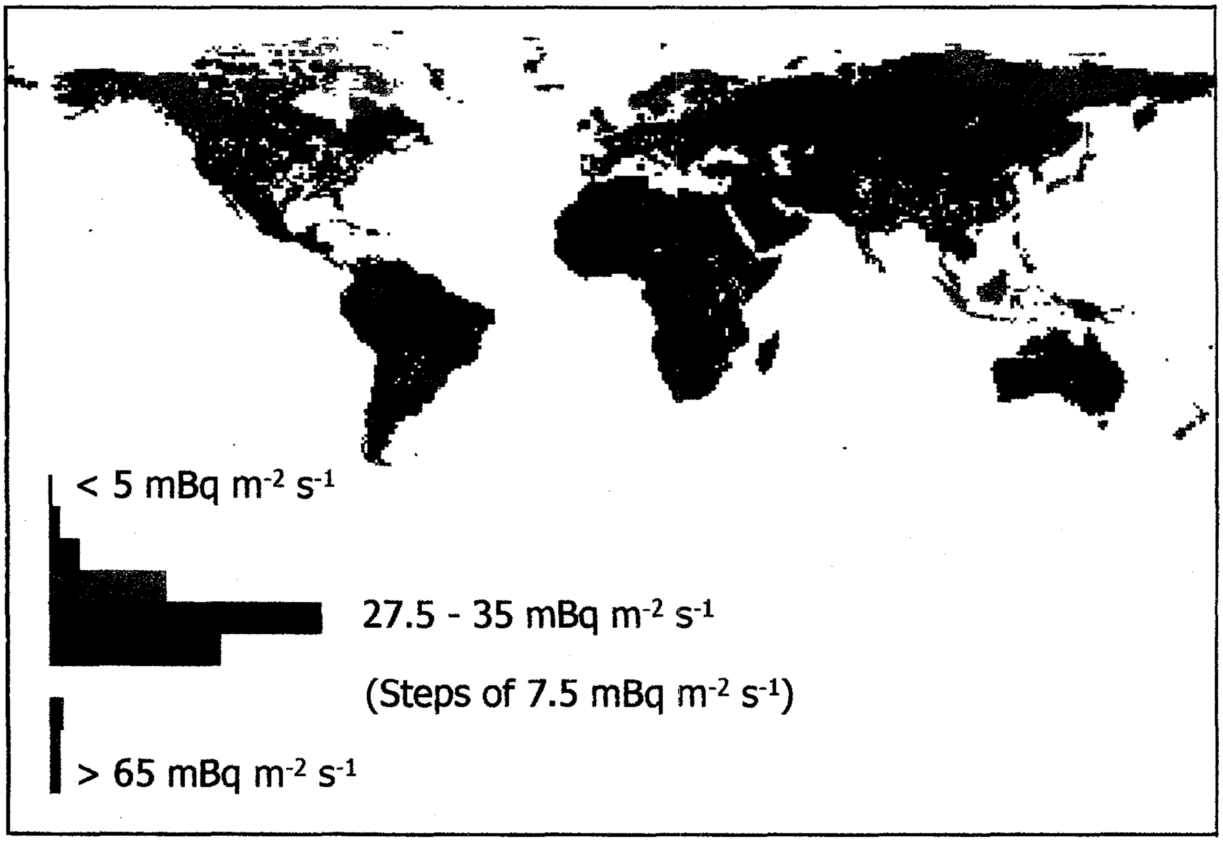

FIGURE 1

that a combination of radon and ^{212}Pb measurements can be used to tag air masses that have come from long range transport on trajectories that entail minimum contact with (and contamination from) local land masses on the island of Hawaii. In collaboration with Dr. Yung-Sung Cheng of Lovelace Inhalation and Toxicology Institute, we participated in studies at Carlsbad Caverns designed to estimate the dose rate due to radon and thoron progeny. This study found that dose was primarily from radon progeny, and enhanced by an unusually large unattached-to-aerosol fraction. The estimated dose rates were insignificant for short-term public visitors to the caverns, but might warrant more detailed study in connection with any occupational exposure for workers spending long periods of time at underground locations.

3. Students Receiving Financial Support from the Project

Undergraduates
- Jeremy Broestl
- Nathan Dale

Graduate Students
- James Mathis
- Zeji Gu
- Bruce Nemetz (M. S. in Physics, 1997)
- Tamara Hernandez
- Fred Yarger

4.Publications and Reports (listed approximately chronologically)

1. P. T. Wasiolek, 1994, Experimental evaluation of wire mesh screen counting parameters for measurements of the unattached fraction of radon progeny, Health Physics 66, 458-462.

2. P. T. Wasiolek and Yung-Sung Cheng, 1995, Measurements of the activity-weighted size distributions of radon decay products outdoors in central New Mexico with parallel and serial screen diffusion batteries, Aerosol Science and Technology 23, 401-410.

3. P. T. Wasiolek and A. C. James, 1995, Outdoor radon dose conversion coefficient in southwestern and southeastern United States, Radiation Protection Dosimetry 59, 269 - 278.

4. S. D. Schery and S. Whittlestone, 1995, Evidence of high deposition of ultrafine particles at Mauna Loa Observatory, Atmospheric Environment 29, 3319 - 3324.

5. P. T. Wasiolek, S. D. Schery, J. E. Broestl, and A. C. James, 1996, Experimental and modeling studies of ^{220}Rn decay products in outdoor air near the ground surface, Environmental International 22, Suppl. 1, S193- S204

6. S. Whittlestone, S. D. Schery, and Y. Li, 1996, Pb-212 as a tracer for local influence on air samples at Mauna Loa Observatory, Hawaii, Journal of Geophysical Research 101, 14,777 - 14,785.

7. S. Whittlestone, S. D. Schery, and Y. Li, 1996, Thoron and radon fluxes from the island of Hawaii, Journal of Geophysical Research 101, 14,787 - 14,794.

8. P. T. Wasiolek, A. C. James, and F. D. Yarger, 1996, Measurements of unattached fraction of radon progeny with two different methods, Journal of Aerosol Science 27, Supplement 1, S465 - S466.

9. Yung-Sung Cheng, Tou-Rong Chen, P. T. Wasiolek, A. Van Engen, 1997, Radon and radon progeny in the Carlsbad Caverns, Aerosol Science and Technology 26, 74 - 92.

10. B. M. Nemetz, 1997, The design and operation of a relaxed eddy accumulator to determine ultrafine particle flux densities using radon progeny as a tracer, M. S. Thesis, Department of Physics, New Mexico Institute of Mining and Technology, Socorro, New Mexico.

11. S. D. Schery, P. T. Wasiolek, B. M. Nemetz, and F. D. Yarger, 1997, Relaxed eddy accumulator for flux measurement of nanometer-size particles, preprint and accepted for publication in Aerosol Science and Technology.

12. S. D. Schery and M. A. Wasiolek, 1997, Modeling radon flux from the earth's surface, preprint and submitted for publication (World Publishing Company) in the proceedings of The 7th Tohwa University International Symposium, 23-25 October 1997, Fukuoka, Japan.

APPENDIX

Abstracts of major papers and reports

Reprints — removed
for separate processing