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PROGRESS REPORT AND CONTINUATION APPLICATION

"Transport of Radon and Thoron at the Earth's Surface"

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1. Introduction

This report covers progress under the current funding period 1 Jan 1992 to 1 Jan 1993 and presents the continuation proposal for 1 Jan 1993 to 1 Jan 1994. The previous progress report was submitted in June 1991, so activities during the last half of 1991 will also be included.

Our major activities over the last year have continued to focus on measurements and modeling of the disequilibrium of radon and thoron progeny outdoors, and analysis of data on indoor thoron and thoron progeny.

A master's thesis on the modeling of the disequilibrium of outdoor radon was completed by Rong Wang (Wang,91). A paper on this subject has been accepted for publication in the proceedings of NRE-V to appear in the Journal of Radiation Protection Dosimetry (Schery et al., 92). A computer code by Dr. Schery for calculating outdoor progeny has appeared as an Australian Nuclear Science and Technology Organization (ANSTO) Report (Schery,90). Under Dr. P. Wasiolek's supervision we have obtained extensive new data at an outdoor field site west of campus. In light of the US congressional mandate that a goal for indoors levels of radon is that they be comparable to outdoor levels, Dr. Wasiolek has been estimating outdoor doses using some of the most recent dosimetry models and data from our field site. Outdoor doses vary considerably, depending on meteorological and terrain characteristics, but provide average values that are comparable to the doses from medical exposure and usually exceed average doses from occupational exposure. A paper by Wasiolek and Schery has been submitted to Radiation Protection Dosimetry (Wasiolek and Schery,92).

We have obtained data on thoron in two new houses (including one with a basement) so that there are now nine houses in our study of indoor thoron and its progeny. These houses are representative of construction in the southwestern US. One major conclusion at this point is that soil is the major source of thoron in such houses. A paper on this subject by Li, Schery, and Turk was recently published in Health Physics (Li et al.,92).

For the coming year of the project we plan to get more outdoor data for different terrains and meteorological conditions. Suitable outdoor data for radon and thoron progeny in the attached and unattached states at varied locations is quite limited, but important for making representative dose estimates and rigorous tests of our disequilibrium models. We would like to get more indoor thoron data from a few houses with basements in the east coast of the US, but our primary focus will be analysis of the exiting data. We hope to improve models of indoor thoron and enable better projections of indoor thoron doses in conditions different from that of our study houses. We have need of simpler, more portable devices for measuring thoron gas and as an instrumentation project we have several designs for thoron detectors we would like to investigate.

Further details of our research activities over the last year, and plans for the next year, follow.

2. Radon and Thoron Progeny Outdoors

This project focuses on modeling and measurements of the disequilibrium between radon, thoron, and their progeny near the earth's surface. In addition to advancing basic environmental science knowledge of dry deposition and turbulent transport, models developed should be useful in health physics applications for estimating radiation dose from radon and thoron progeny at ground level under varying atmospheric conditions.

With the help of our collaborator Dr. Stewart Whittlestone, we have developed instrumentation for sensitive measurement of radon and thoron progeny in the attached and unattached states outdoors. We use high volume air samplers and sandwiches of glass filters and 400 mesh screens. Simultaneous data can be taken at two heights and are logged into two notebook computers for later analysis using algorithms developed at EML. We also take supporting meteorological and atmospheric data including temperature, wind speed, wind direction at several heights as well as insolation and aerosol concentration. Extensive data has been taken at our field site about one mile west of campus. We have obtained statistically significant information on the F factor (equilibrium factor) and unattached fraction. One of the surprising results is the typically small variation (less than ±3%) of the F factor and unattached fraction over a height of 20 cm to 2 m. This suggests more rapid mixing of air in this zone than implied by many of the conventional models. We have been developing improved models. One version is covered in the master's thesis of Rong Wang that was completed in July 1991: "Numerical Model and Experimental Study of Rn 222 and its Short-Lived Daughters near the Earth's Surface", (Wang, 91). Further discussion of disequilibrium of radon progeny near the earth's surface can be found in Schery et al, "New Models for Radon Progeny near the Earth's Surface", which has been accepted for publication in Radiation Protection Dosimetry (Schery et al., 92) and a computer code recently released as a report by ANSTO (Schery,90). Our campus field site has moderately rough terrain (roughness parameter about 0.5 m) and tends to have neutral to unstable conditions. For studies next year we would like to obtain more data for different conditions, particularly for smoother terrains and stable conditions. We lack some of the sophisticated instrumentation now available for micrometeorological and pollution studies (such as sonic anemometers). For these reasons we are trying to team up with other groups involved with outdoor breathing level measurements of atmospheric pollutants. We are exploring collaborations with the ASTER program at NCAR (Boulder, Co), a NOAA group associated with Oak Ridge National Laboratory, and Monique Leclerc at the University of Quebec at Montreal. We anticipate travel for cooperative measurements with groups such as these at field sites external to New Mexico.

One of the applications of our outdoor measurements and modeling is improved understanding of delivered dose. Although historically there have been extensive measurements of outdoor radon, what is needed for dosimetry estimates is information on progeny and size distributions. This type of information is generally not available and has been another object of our outdoor measurements. Analysis of the data from our field site at Socorro has resulted in a paper on outdoor doses submitted for publication (Wasiolek and Schery, 92). Under certain conditions outdoor doses can exceed average indoor doses for the US, but in any case average outdoor doses are comparable to the average radiation from medical procedures and exceeds the average dose for occupational exposure. Hence, outdoor progeny doses warrant study. Future measurements will focus on varied geographical locations and meteorological conditions to come up with estimates of dose that are less site specific. In terms of activity, the concentration of outdoor thoron at the breathing level typically exceeds that of radon. Hence, another focus of future dosimetry studies will be measurements and modeling of outdoor thoron progeny.

2. Indoor Thoron

This project focuses on studying the sources of thoron in indoor air and modeling thoron and its progeny in indoor air. We now have data on nine occupied houses in New Mexico including one house with a basement. These data include radon, thoron, their progeny, aerosol concentration, ventilation rates, meteorological information, pressure information, and soil data. These houses all have mitigation systems for radon, which should be equally effective for stopping entry of thoron to the extent that it comes from soil. We have found that in the majority of houses the indoor thoron concentration is significantly reduced by the mitigation systems indicating that soil is the most significant source of thoron. A paper by Li et al, "Soil as a Source of Indoor Thoron", (Li et al.,92) was recently published in Health Physics based on data for the first seven of these nine houses. A review chapter on environmental thoron by Schery and Grumm (Schery and Grumm, 92) has recently been published.

Next year's work will focus on more detailed analysis of our indoor data, and perhaps on obtaining additional data in houses with basements. We need to model the disequilibrium between thoron and its progeny since this information is important for dosimetry calculations. Equilibrium factors for thoron are poorly known. We are also modeling the transport of thoron from soil through a crack in a slab, or through a crawl space, so that we can better understand under what conditions we can expect significant transport from soil for this short-lived isotope. Due to its short life, thoron will not be as well mixed in a house, or even a room, so our experimental measurements and modeling are also addressing the issue of mixing. This project on indoor thoron is the subject of Yanxia Li's Ph. D. dissertation research. We are discussing with the Princeton group (Socolow et al.) the possibility of collaborating with them on measurements in some houses in their area so that we can obtain data for construction representative of the northeast, particularly houses with full basements. We expect that thoron entry into basements will often be strong, but it is less clear how effective will be transport to stories above. The most desirable measurements would be simultaneous measurements of thoron and thoron progeny at several levels of the house in houses that have mitigation systems that can be cycled on and off.

The workhorse of our thoron measurements is our 76L two-filter system ("Fatman") that can take unattended measurements of thoron and radon at two hour intervals down to levels below 0.1 pCi/L. Unfortunately, this system is bulky and somewhat noisy. We have been searching for alternate systems that may not be as versatile and sensitive but that would be more convenient to operate for certain applications. One idea we have been pursuing is the use of flow-through scintillation cells with coincidence counting of the Rn220/Po216 doublet. This approach was suggested by recent work of Falk el al. in Sweden as a technique to separate the thoron signal from the radon signal. In our design we have built a coincidence circuit that tags double pulses that occur within 0.6s of one another for a 3/4L cell with a flow of about 5 LPM. Preliminary comparisons of this system with "Fatman" indicate the cell is working well at low levels of thoron and radon (less than 5 pCi/L of either isotope). We would like to continue testing of this system and see to what extent we can monitor thoron in mixtures containing higher levels of radon by improving our analysis of the count data to correct for accidental coincidences due to decay of the radon progeny present. A second approach we would like to experiment with is use of a flow-through charcoal canister preceded by a filter. This system would be left in place for say one day and then the charcoal would be gamma counted for progeny of thoron to deduce average thoron over the sampling period. Issues to investigate are what would be the sensitivity of such as system and how reliable would be its calibration. It has the possibility of being a simpler system that perhaps could even be sent through the mail. John Peggie of the Australian Radiation Laboratory has asked to visit our lab next year and we are discussing collaboration on such a measurement technique.

4. Additional Information

As of 1 July 1992 the personnel receiving direct support from this grant were Dr. Stephen D. Schery, Principal Investigator, Dr. Piotr Wasiolek, environmental physicist, Dr. Maryla Wasiolek, lab manager, and Yanxia Li, graduate student. Dr. Piotr Wasiolek receives full academic year salary from the project and some summer salary; the remaining personnel are all part-time. Over the last year several undergraduate students have received some support from the project including Cat O'Conner, Henry McCracken, and Jackie Onsurez. Graduate student Rong Wang was supported by our grant but graduated in 1991 after receiving her M.S. Degree. We also provide occasional short-term support for visiting scientists and consultants, especially for help in specialty areas like electronics and computer programming.

Dr. Stewart Whittlestone, Australian Nuclear Science and Technology Organisation (ANSTO), continues to collaborate on the project. In connection with the NRE-V meeting Dr. Schery visited Vladimir Balek in Prague, author of "Emanation Thermal Analysis and Other Radiometric Emanation Methods." We are exploring collaboration with him aimed at more sophisticated studies of the mechanisms of radon emanation. There is a slight chance of travel to Prague to help set up equipment for emanation analysis of soil samples supplied by our lab, although outdoor field studies in Canada are a higher priority and there is not enough money in the budget for both foreign trips. We have received a small amount of matching support through the National Science Foundation REU (research experience for undergraduates) program which pays the summer salary for students selected to join our program. During the summer of 1991 Ken Eack received support from this program and helped collect outdoor data at our field site near campus. He is a co-author of a paper presented at NRE-V (Schery et al.,1992).

There have been a number of visitors to our laboratory over the last year. They include Dr. Phil Hopke, Clarkson University, Dr. James McLauglin, University College Dublin, Dr. Art Rose, Pennsylvania State University, Dr. Allan Tanner, USGS retired, Dr. Isabel Fisenne, EML, Dr. Carl Gogolak, EML, Dr. Jack Kay, Drexel University, Dr. Mike Zarcone, Brookhaven National Laboratory, Dr. Frederic Guerin, BRGM Dept. of Water (France), Dr. Paul Barretto, IAEA, Dr. Jeffre Gaffney, Argonne National Laboratory, Dr. Jerzy Niewodniczanski, Institute of Physics and Nuclear Techniques (Poland), Dr. Alex Montwill, University College Dublin, and Dr. Immo Wendt, Federal Institute of Geosciences and Raw Materials (Germany).

Dr. Schery gave a paper at the NRE-V conference in Salzburg and participated in the DOE contractors meeting in Albuquerque, NM. Our lab participated in the 13 April 1992 radon intercomparison organized by EML and did well, with our value for radon concentration within 3% of the value given by EML's pulsed ionization chambers.

Copies of the abstracts or title pages of recent papers and reports are given in appendix B.

6. References

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