RADON:

**GAS TRANSPORT IN SOILS AND ITS RELATION
TO RADON AVAILABILITY:**

**HOT SPOT IDENTIFICATION AND FLOW
CHARACTERISTICS NEAR STRUCTURES**

FINAL REPORT

Project Number DE-FG03-96-ER62200

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Key Words: Radon, gas transport, thoron, air quality in homes.

Introduction:

This is the final report for Project Number DE-FG03-96-ER62200, "RADON: Gas Transport in soils and its relation to radon availability and hot spot identification. This project was part of a larger program on radon-related research conducted by the U.S. Department of Energy, Germantown, MD.

Summary of Work:

There were 3 major objectives being addressed in this research.

The first was to coordinate ground-truth quality assurance in the DOE/LBL/EPA cooperative study to determine a methodology to predict the areas where indoor radon concentrations have the highest probability of exceeding 20 pCi/L (750 Bq/m³). The second was to examine 2 common types of homes (basement and non-basement) for yearly radon variation by monitoring specific parameters under normal living conditions. The third task was to develop a rapid field method to determine the thoron (Rn-220) content of soils that would complement the rapid method of Rn-222 content that was earlier developed under this proposal.

Overview of Objectives:

The first objective was accomplished as part of the directed DOE/LBL/EPA cooperative project to develop a methodology to predict the areas of the U.S. where homes are located that have the potential for the highest indoor radon concentrations. The DOE/EPA cooperative project addressed the issue of model development but does not provide specific funding for coordinating ground-truth acquisition. The specific effort for which this project was funded was to provide ground truth for both soil-gas radon and transport-related parameters (diffusion, mass transport, permeability) and indoor radon levels in selected test study areas. This provides a quality assurance measure of the predictive power of the model developed by the DOE/EPA cooperative project.

One of the primary input parameters for the predictive model is the equivalent soil uranium derived from gamma-ray data. A national aerorad data base exists, known as the NURE aeroradiometric survey, which provides equivalent uranium concentrations on a broad scale using flight lines of 3 or 6 mile spacings. This data base is not sufficient for

determining emanated radon is an important component for practical technology transfer and refinement of the predictive model as it can relate to individual site locations. One location described as enigmatic by predictive model developers at Lawrence Berkeley Laboratory (LBL) is Frederick County, Maryland, where one input variable to the model is the complex geology in the county. A soil-gas reconnaissance survey of the county demonstrated that the complex geology could be delineated and the great differences of radon availability from soils derived from various lithologies was revealed; the field ground truth explains the enigma and provides detail that can enhance the working model.

The second objective was to acquire data-base information on the transport of radon into 2 types of typically constructed homes, that is, one with a basement and one without. Studies were conducted to measure the radon migration within the critical zone of migration influence of a specific structure or house. One limitation of tests being conducted at artificial structures designed to develop information on entry rate, is that they may not be representative of the actual nature of the infiltration. Basically, this test is designed to provide information on an "average house" with average living conditions. It is not to be conducted with worst-case scenarios that may be mistakenly interpreted as standard conditions. Rather, it is the observations that are controlled, not the structure or the living style.

The third objective involved the determination of thoron (Rn-220) as could be derived from a single measurement that included radon (Rn-222) concentrations. The theory is based on the fact that radon and thoron have two very distinct half-lives, thoron being 57 seconds and radon being 3.8 days. Typically, field measurements of radon ignore thoron by waiting at least 10 minutes before introducing a sample for alpha counting. With this new calculation method, thoron can be determined if it is injected immediately after collection into a scintillation cell for counting. This method allows the highly portable and inexpensive field alpha-particle counting devices used for radon to be employed for thoron determination.

This specific project was conducted between May 1996 and September 1998. These objectives include completion of a former funded project DE-AI05-87-ER60578 that was initiated between DOE and the U.S. Geological Survey. In 1995, the Geologic Division of the USGS reorganized and terminated all their radionuclide projects, including those that were currently in progress with funding from outside agencies. In addition to the scientific results of this project, at the request of the technical representative of the radon project, a brief synopsis of results and achievements of the Radon Environmental Availability and Transport Section is provided.

QA/QC Activities:

Participated in EML radon intercomparison and utilized the U.S. Bureau of Mines calibrated radon facility to investigate the variation and efficiency in alpha-particle counting for several styles of Lucas-type cells at reduced pressure regimes in the cells. The results indicate for cells where the greatest free internal distance to a phosphor coated surface is less than 2.5 cm, reduced pressure (from 200 mm Hg to 700 mm Hg) has less than a 10 percent effect, which is within the measurement error of standard field analyses. The U.S. Bureau of Mines radon calibration facility is now located at the Colorado School of Mines, Golden, Colorado.

Results discussed through publications:

The results of these current studies appear in peer reviewed publications and copies are attached to this final report.

It should be noted that there are several observations not directly related to the course of these funded investigations that are very important to other issues such as indoor radon mitigation methods. For example, an ancillary observation of this project revealed a very effective method of decreasing radon in a home that has a forced air, gas combustion furnace in the basement. This method is to provide outside air for combustion, not directly to the burners, but rather to the basement itself. This added a quantity of dilution to the basement air as well as providing a pressure balancing port for the structure to decrease the inside negative pressure that draws soil gas into the structure. Under otherwise closed-house conditions, for the brief period of time the air vent was open, the indoor radon concentration dropped by nearly a factor of 2 and required several hours to retain previous levels. This would be a very advantageous mitigation method for reducing radon concentration near the current action level established by the U.S. Environmental Protection Agency.

In addition, the technical representative asked the PI on this project to review program documents and list achievements for the Radon Environmental Availability and Transport Section. Those highlights follow:

Highlights from the "Radon Environmental Availability and Transport Section"

Identification of high radon areas and improvement of indoor radon control strategies was a central theme of the Department of Energy's program on Radon Environmental Availability and Transport of Radon into Buildings. A major new effort was initiated to develop a methodology to identify the information necessary to predict areas of high radon potential. This effort is significant in that it represents a working partnership among the Lawrence Berkeley Laboratory (LBL) and the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the U.S. Geological Survey (USGS). It combines information gathered by EPA on the regional distribution of radon and variations of different indoor radon measurement protocols, the technical expertise of the USGS on the geologic controls of the source and distribution of radon in the natural environment, and the knowledge of LBL on radon migration and entry mechanisms.

Initiated a study to determine what relevant and available data bases are necessary for regional prediction of radon risks. This information is critical for a first approach in identifying radon areas where the conditions exist for exposures greater than occupational limits. Results of this study are available from the LBL radon web-site:
<http://ectd.lbl.gov/cbs/NEWSLETTER/NL12/radon.html>

Determined the geologic factors that characterize radon-source location. This is critical information if any site or regional characterization is to be feasible.

Shattered the fallacy that the coastal plain areas, i.e., the east and gulf coasts, are entirely low risk areas.

Confirmed the hypothesis proposed by a minority of the scientific community that limestone terrains can have high radon potential.

Characterized specific regions for the influence of climate on radon source, transport and soils, essential information to determine the radon risk estimates on a national scale.

Provided techniques important for reconstruction of exposure information when former residences are not available for direct in-home measurements.

Identified home-site factors, such as the judicious location in planting of trees or lawn irrigation practices, that influence the rate of radon entry.

Through an understanding of radon entry mechanisms, evaluated the effectiveness of simple and cost-effective methods, such as caulking, to reduce radon concentration in homes.

Indicated that radon entry rates and indoor concentrations are not necessarily correlated.

Formulated essential understanding of chemical water/rock interactions contributing to understanding the factors limiting the concentration of radon in water.

Developed effective computer simulation programs to study the effects of variable meteorological conditions on radon entry.

Computer studies indicated the importance considering radon mitigation construction techniques as an entire package, because if not integrated properly, radon entry can actually be enhanced.

Developed several techniques that measure soil permeability in-situ, a factor of radon transport studies, and with extended application to transport studies of any toxic materials from any man-made or natural source.

Discovered that the aerial radiation measurements available from a previous nationwide survey (NURE) could not be used without adjustments because of the many different standards used for the initial reduction of flight-line data.

Developed the first comprehensive models of radon generation and transport in soils.

Determined that radon-220 (from thorium-232), in many cases, creates indoor radioactivity equal to or in excess of the radioactivity produced by Rn-222 (from uranium-238).

Developed a field method for determining the radon and thoron concentrations using inexpensive equipment.

Provided the first studies on the effects to radon transport and availability as a function of site modification, as in the case of building a house.

Conducted studies looking at the mechanisms other than molecular diffusion of radon in the soil by studying other isotopes in the uranium decay series. This study is providing the first objective look at long-term integrated radon fluxes.

Devised new techniques for determining the radon emanation from various materials, including the often overlooked materials used in construction of a home.

Project Products published from the beginning of Project

This project is a continuation of work initiated under project number DE-AI05-87-ER60578 and the publications include the earlier studies.

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