1996_15

EXPERIMENTAL INVESTIGATION OF SOIL WATER CONTENT EFFECTS ON IN-SITU SOIL-GAS RADON TESTING PRIOR TO CONSTRUCTION

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ABSTRACT

Testing of radon concentration in soil gas that is drawn from two to four feet below grade, prior to construction, is becoming increasingly important in order to identify construction sites with potential for elevated indoor radon concentrations. In addition, such testing is increasingly evolving as a practice within other soil testing performed during the design and construction phases of a project. Theoretical considerations suggest that soil water content may significantly affect measurements of radon concentrations in soil gas prior to construction, during soil preparation, and after foundation/slab construction. An experimental assembly has been designed and constructed to investigate soil water content effects on soil gas radon concentration measurements. Soil samples were first weighted and dried using a hot air conventional oven, and then placed inside the assembly's testing chamber. Temperature and relative humidity inside the chamber, pressure differentials between the chamber and the ambient, and radon concentration emanated from the soil samples are simultaneously monitored during the experiments. Time-dependent responses of the measured parameters are continuously collected using a micro data-logging system and retrieved at the conclusion of each experiment. In most samples, analysis of results show no dependence of average radon concentration collected from soil samples on sample water content ranging from dryness to saturation. Less than 10% change in in-situ samples radon levels were observed in most soil samples. Dryness conditions may slightly contribute to produced testing results in the lower range of statistical uncertainty of average radon concentrations.

INTRODUCTION

Radon (Rn) is an odorless, colorless, almost inert, radioactive gas. It is formed directly from the radioactive decay of radium (Ra). Some researchers have indicated that about 55% of the average natural background radiation exposure may come from radon. Soil is the main source of radon entering structures. Radon is generated in the solid grains since Ra is a solid material. It must subsequently be transferred to the outside of the solid soil grain to have a potential for migration (Al-Ahmady 1995). The transition process controlling this transfer is called radon emanation, and it is characterized by the radon emanation coefficient. For most soils, only 10-50 percent of the radon generated actually emanates from the mineral grain and enters the pore volume of the soil (USDOI 1992).

Depending on the relative position of formation and the direction of the recoil, the newly formed radon atom travels from its generation site in the solid grain until it loses its energy to the host materials. The host materials could be the solid grain of the formation, another solid grain, or materials confined in the soil pore, primarily water and air. The transport range in water is approximately 600 times less than the range in air, and this fact suggests that soil water content may have noticeable effect on radon availability in the pore space. In fact, among the factors that influence radon emanation, soil moisture content has been demonstrated to have a significant impact (Strong & Levins 1982). Fluid-filled soil pores contain most of the soil moisture. When the content of water in the pore space increases, the direct emanation coefficient component is increased, since a greater fraction of the recoil radon atoms are trapped in the pore.

Soil moisture content consists of three components: gyroscopic, capillary, and gravitational. Most of the soil moisture effect is developed by the capillary component. This component is responsible for generating water films around solid grains that act as a trap for recoiled radon atoms. The existence of water in excess of the capillary water will have a small effect on the radon emanation since most of the atoms are being stopped by the capillary water films. The gyroscopic component has only a minimal effect on emanation since it represents a very small percentage of soil moisture.

Existence of elevated indoor radon concentration in a structure depend on several factors, including complex interaction among parameters, controlling soil gas entry path, and driving forces from the sub-structure area into the indoor (Al-Ahmady 1995). Testing of radon in the soil pore (soil gas) prior to construction has been increasingly evolving as an important measure upon which potential to elevated indoor radon concentration, after construction, may be predicted. This measure may be used to decide the need for applying radon-resistant construction standards. Furthermore, a continuing increase in such testing can be observed in the requirements for initial environmental assessment of sites prior to construction for different purposes.

In this paper, an experimental assembly was designed and constructed to measure radon emanated from soil samples while samples are subjected to the full range of water content from dryness to saturations. Radon in the assembly's chamber, as well as other environmental parameters, were continuously and simultaneously monitored.

MATERIALS AND METHODS

Figure 1 illustrates the block diagram of the experimental assembly used in this work. Soil samples were placed on a wide open face pan with a soil thickness of approximately 5 cm. This design is utilized to minimize the effect of soil permeability and spatial dependency of radon diffusion coefficient on the transport of radon from the soil sample into the chamber space. This space was flushed with air prior to the start of each experiment. Radon concentrations were then continuously monitored to observe the build-up of radon gas in the chamber until reaching equilibrium inside the chamber. Radon concentration, pressure, temperature, and relative humidity data were simultaneously measured with a sampling time of 10 minutes, utilizing the data-logging system, and data were retrieved from the logging system into a personal computer system.

Air flow mechanisms contributing to the convective transport of radon from the soil sample into the chamber space were minimized by controlling temperature and pressure difference when possible. Temperature inside the chamber was kept the same as the room temperature to minimize temperature-driven air flow between the chamber and the outside. An air leakage control valve was also used to compensate for conditions where convective flow may have occurred. Since soil samples surface area is large compared to the thickness, equilibrium between radon concentration in the soil pore space and the chamber space was considered to be reasonably achieved. The design and conduction of experiments utilized a system approach in which comparative indicators are sought rather than absolute results. Upon such, measurement of radon concentrations in the chamber space can represent, under the same operating conditions, the concentrations of radon in the soil pore space. A change in the overall radon concentration in the soil pores space, therefore, is reflected with observed changes in the radon concentration measured in the assembly's chamber.

Soil samples were collected from three construction sites (representing typical construction soils in Florida) from three depths (2,3, &4 feet) typically representing the usual range where in-situ soil gas radon measurements are performed. Soil samples were collected with enough quantities placed into air tight containers (site container), sealed, labeled, and transported into the testing laboratory. At the lab, contents of site containers were divided into three parts where each was placed in a smaller air tight plastic container (lab container), and soil moisture was measured. Preparation of drying samples were performed using a convectional hot air oven for a minimum period of 48 hours. Dried samples were then placed in the lab containers, sealed, labeled, and left for a minimum of 14 days prior to testing; allowing for radon to reach equilibrium with its parent. Saturated samples were prepared by adding water into soil samples until saturation.

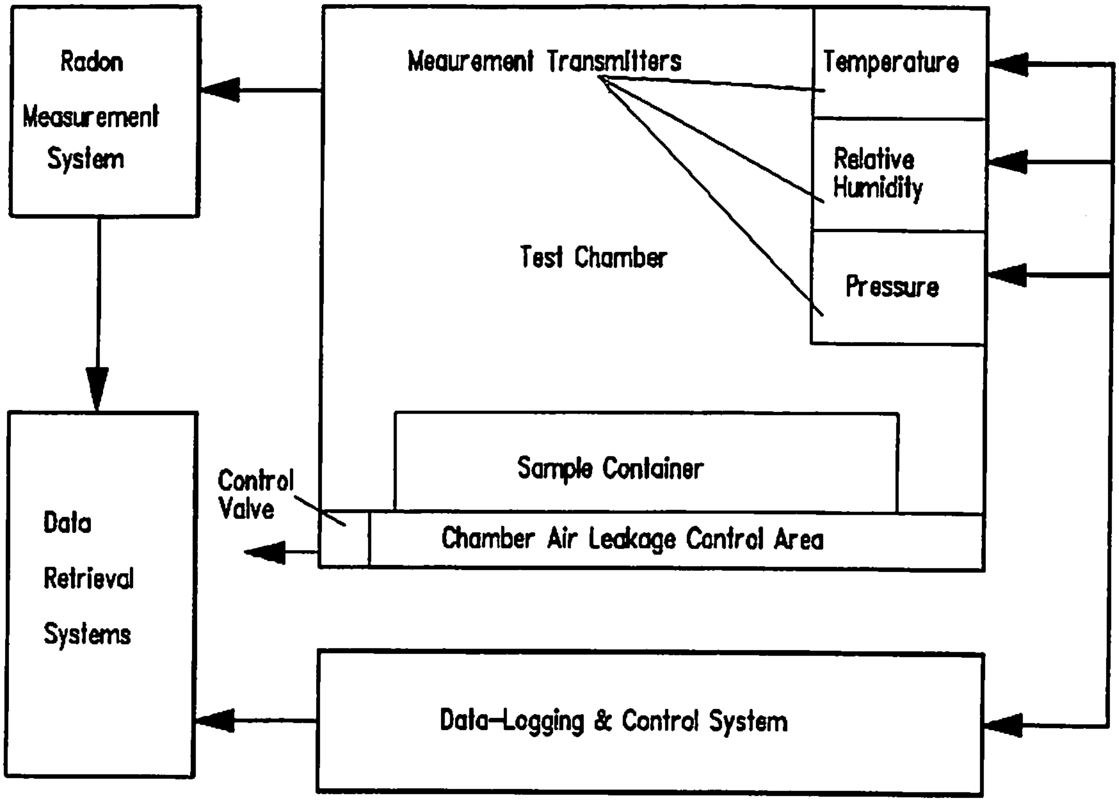

Figure 1: A Block diagram illustrating the experimental assembly used to test the effects of soil water content on in-situ soil gas radon measurements.

RESULTS AND DISCUSSION

Figure 2 shows the distribution of measured soil water contents for the tested samples. The average soil moisture content level from in-situ samples (original soils), designated by S1, S2, and S3, were generally higher for samples collected at the corresponding sites 1, 2, and 3, respectively. Maximum and minimum soil water contents were 25.64 and 6.60 % weight collected at the two foot depth in S3 and S1, respectively. Figure 3 shows the response of average radon concentration, after reaching equilibrium, in the test chamber plotted for original, dried, and saturated soil samples collected at the construction sites from a 2 to 4 feet depth. As seen in the graph, minimal deviation of average radon concentrations was observed between the dried to saturated soil samples and the original soil sample; particularly for sites S1 and S2. Samples collected from site S3 experienced some differences between the dried/saturated samples and the original; however, these differences are small.

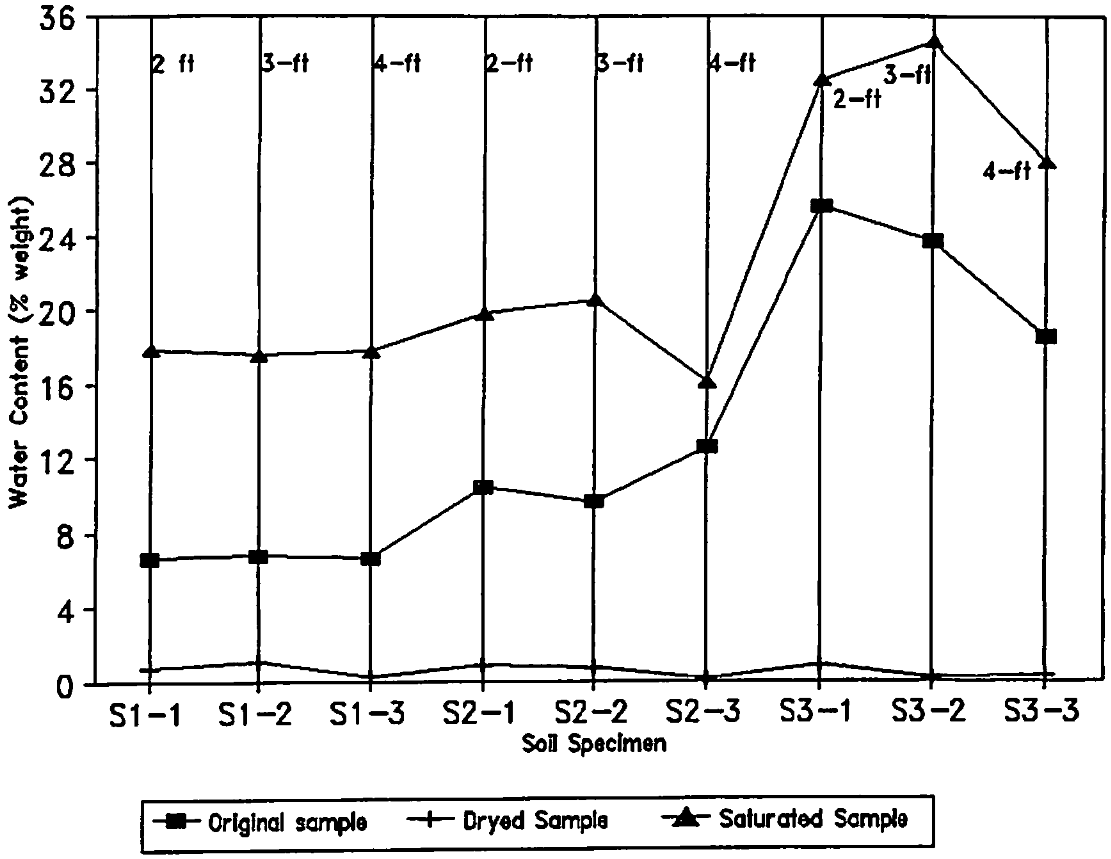

Figure 2: Distribution of soil water content for the tested soil samples collected from 2,3, &4 feet depths at the construction sites.

As seen in Figure 3, the difference between the maximum and the minimum time-averaged radon concentrations (concentration span) measured at the assembly's chamber for all samples were comparable except for the two foot depth in site S1. The latter sample showed concentration span value that significantly differs from the rest of the samples; therefore, it is omitted from consideration. Span of time-average radon concentration is calculated as the following:

$$Rn_{span} = ABS[Rn_{saturated} - Rn_{dried}]$$

where ABS refers to the absolute value of the difference. Rn_{span} (Bq/m^3) represents the range of average radon concentration changes corresponding to the range of soil water content from dryness to saturation. Ignoring the soil sample collected at a 2 foot depth in site S1, the maximum span of the average radon concentration among soil samples was observed at a depth of 4 feet in site S3, and it is approximately 30 Bq/m^3. Such span is very small and is expected to have a minimal effect on the predicted average in-situ radon concentration.

To represent the span of radon concentrations on the concentration measured with original soil samples without alteration to their water content, the following parameter is utilized:

$$Rn_{ratio} = 100 \times (Rn_{span}/Rn_{original}) = 100 \times (ABS[Rn_{saturated} - Rn_{dried}]/Rn_{original})$$

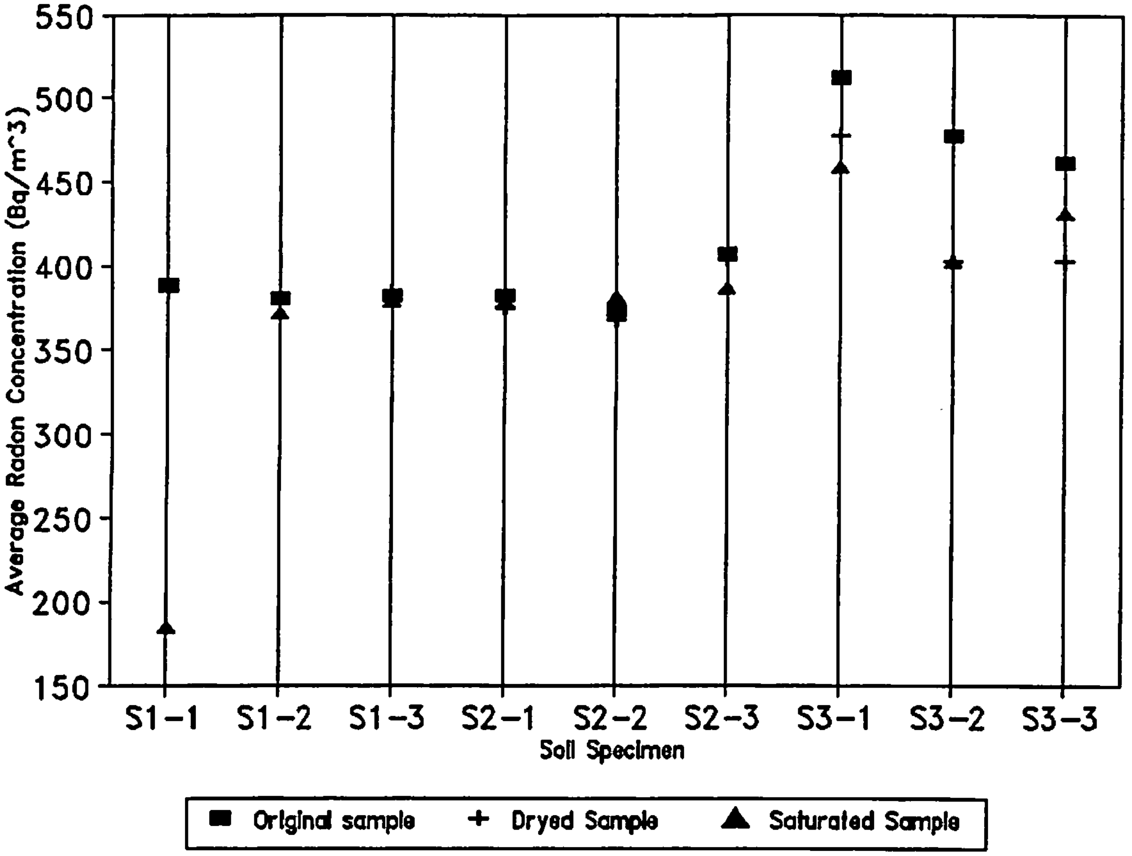

Figure 3: The response of averaged radon concentrations for original, dry, and saturated soil samples

where Rn_{ratio} (%) represents the ratio of time-averaged radon concentration span to the time-averaged radon concentration measured with original soil. This parameter indicates the percent change of averaged radon concentrations measured in the assembly's chamber, with soil water content alteration from dryness to saturation, to the radon concentration measured from the original soil sample without water content alteration. Figure 4 shows the percent change in measured radon concentrations with water content alteration with respect to original soils. A maximum change of approximately 6% was observed at the 4 foot sample collected in site S3. Soil water content alterations for samples collected at S1 and S2 were less than 3% and 5%, respectively, with respect to radon concentrations of original soil samples. These changes in resulted radon concentration due to alteration of soil water content are very small. The scope of such changes indicates that only a minimal effect in the order of less than 10% may be experienced during in-situ soil gas radon measurement.

Large impact of soil moisture on radon emanation from the solid soil grain into the pore space has been demonstrated by several researchers in uranium tailing (Stranden et al. 1984, Strong & Levins 1983). The effect is particularly significant when alteration to soil moisture capillary component occurred. Trapping of recoiled radon atoms, generated from radioactive decay of radium in the pore space, is profoundly reduced when capillary water surrounding solid grain is reduced or eliminated. Alteration to the soil water content in the gravitational water (toward saturation) is expected to have minimal effect on the trapping of recoiled radon atoms transported from the soil solid grain into the pore space, since most atoms trapped in the capillary water films around solid grain.

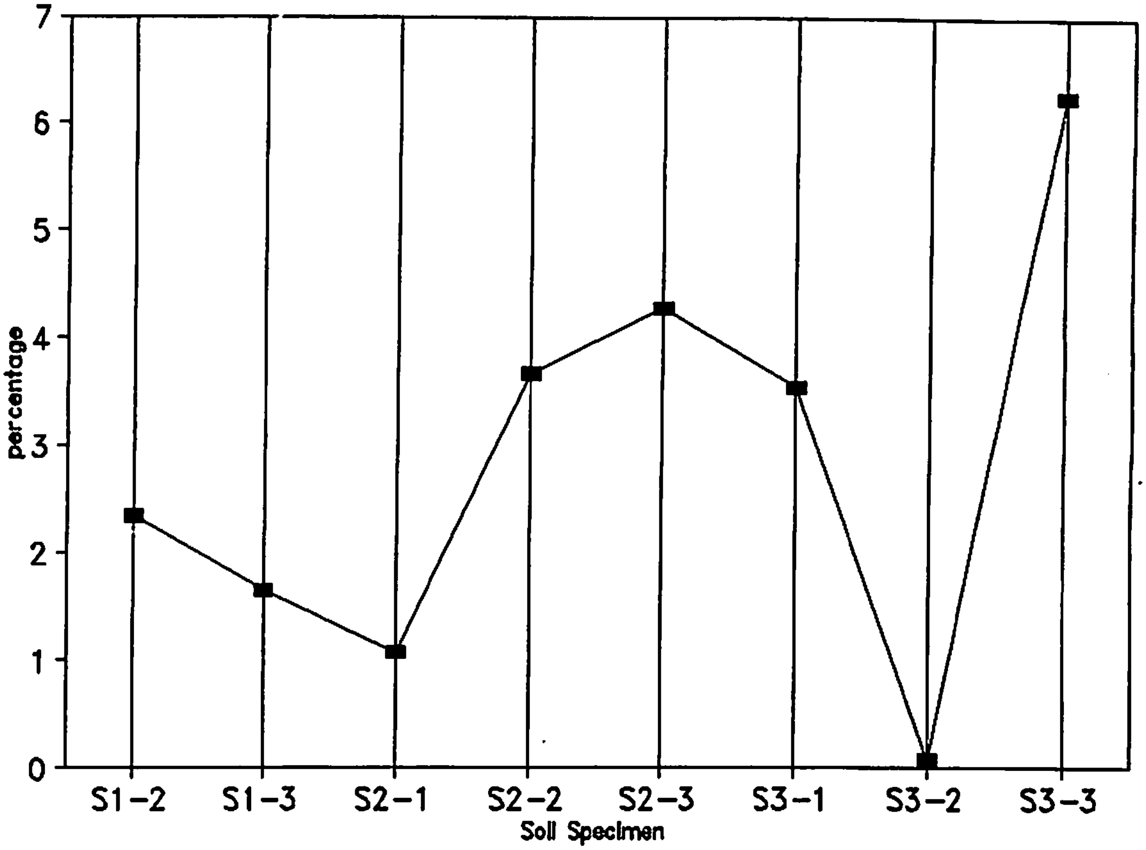

Figure 4: Changes in the measured radon concentration of original in-situ soil samples in response to the range of soil water moisture alterations from dryness to saturation.

In this scope, alterations of water content in tested samples during saturation was expected to have less effect than alterations toward dryness. Except for the sample collected at 2 feet in site S1, where measured radon concentration dropped by over 50% during dried sample testing, samples tested during soil dryness conditions show little alteration to radon measurement performed during original water moisture contents and saturation conditions.

CONCLUSIONS

An experimental assembly designed to measure radon concentration emanated from large surface area, and small thickness soil samples can be used to investigate the effects of soil water content on the exulted radon gas generated from solid soil gain, under controlled environmental conditions. When radon transport between the tested sample and the air phase in the testing chamber is mostly limited to molecular diffusion, evaluations of the effect of soil water content effects on exulted radon can be performed. This tool therefore, can be used to simulate soil water moisture effects on the increasingly expending in-situ testing of soil gas radon measurements prior to construction. Results obtained from this research shows that soil water contents ranging from dryness to saturation may affect radon measurements performed for radon-rich soil gas radon concentration measurements by less than 10% of their values when performed on original soils with in-situ water content.

REFERENCES

Al-Ahmady, K.K. "Measurements and Theoretical Modeling of Radon Driving Forces and Indoor Radon Concentration and The Development of Radon Prevention and Mitigation Technology", Ph.D. Dissertation, University of Florida, Gainesville, Florida; 1995.

Stranden, E.; Kolstad, A.K.; Lind, B. "The Influence of Moisture and Temperature on Radon Exhalation" Radiation Protection Dosimetry, 7, 55; 1984.

Strong, K.P.; Levins, D.M. "Effect of Moisture Content on Radon Emanation from Uranium Ore and Tailings", Health Physics., 42, 27; 1982.

United States Department of Energy (USDOE) "Understanding Radiation", Energy Booklet DOE/NE-0074, 97-105; 1986.

United States Department of Interior (USDOI) "The Geology of Radon" (1992), United States Geological Survey, U.S. Government Printing Office, 0-326-248; 1992.