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INDOOR RADON: SHORT-TERM AND LONG-TERM INFLUENCE OF PROLONGED PRECIPITATION

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Abstract: For long-term indoor radon measurements (91 or more days), home occupants are allowed by the USEPA recommendations to leave their house windows open whenever weather allows. Open windows diminish the partial vacuum normally found in homes (caused by warm air rising through the house), and consequently reduces the inward movement of radon into the house from surrounding soil. However, even under these open-house conditions, indoor radon in our study area increases during rainfall, and long-term radon measurements are higher if taken during a season of above average precipitation. This seasonal effect can result in higher than normal short-term (2-7 day) indoor radon measurements, often taken by home inspectors during the sale of a house.

Key words: Indoor radon, rainfall, soil gases, groundwater transport

1. INTRODUCTION

The United States Environmental Protection Agency and the United States Surgeon General estimate that radon is the second leading cause of lung cancer in the United States. Increased awareness of the health risks posed by elevated concentrations of indoor radon has focused attention on the mechanisms by which radon enters into homes. It is understood that the migration of soil gases is caused by three primary and interacting mechanisms: soil-to-house diffusion, groundwater-to-house transport and house-from-soil convection.

Soil-to-house diffusion is a pushing process by which a gas can migrate from a high concentration as found in soil to an area of low concentration as is normally found in the basement of a house. The following report quantifies the increase in indoor radon that occurs when the radon concentration in the soil around a house is increased by a rising water table below the house foundation and by a falling perched water table just below the surface of the soil around the house.

Groundwater-to-house transport describes the process by which gases dissolved in a fluid migrate through soil as the fluent migrates through the soil. Indoor radon increases when radon dissolved in groundwater enters houses when the groundwater seeps into a home, or when well water is used in house. In either case, waterborne radon diffuses out of the water.

House-from-soil convection is a pulling process, also described as pressure driven gas flow, and is caused by the weak partial vacuum present in a house. Pressure differentials between air pressure inside a dwelling and soil of only a hundredth of a percent can provide a sufficient pressure gradient to facilitate radon entry into a house (Tanner, 1986). This partial vacuum occurs because the upper part of a house is warmer than the lower part, causing air in the house to rise and escape (called “thermal stack effect”). The vacuum can be increased by wind pressures, temperature differentials and changes in barometric pressure. In houses, convection can also be increased by internal mechanical systems (e.g. ceiling fans, forced air heating, air conditioning, etc.) which pulls air out of a house. In
northern Virginia, where many homes have fireplaces, a good example of the thermal stack effect happens when hot gas from burning wood quickly moves up and out a chimney.

Of the three radon-increasing mechanisms, house-to-soil convection is thought to be the major process by which indoor air radon concentrations are increased. Together, diffusion and convection can create extremely high indoor radon concentrations if the radon in soil around a home increases. Our thesis is that if the radon concentration in the soil around a house increases because of rainfall, which causes a rising water table below the house foundation and a falling perched water table just below the surface of the soil around the house, convection and diffusion will cause a greater increase in indoor radon that during times when rainfall is normal or below normal. Possibly there is an upward displacement of radon enriched air from the micro-pores by a rising water table caused by prolonged rainfall. Similarly, development of a perched water table could possibly contribute to the often observed wet-season increase in indoor radon, perhaps by a downward displacement of radon in the pores of the upper few feet of soil around a house.

Intervals of above normal precipitation occur usually in the winter in northern Virginia and southern Maryland, but not consistently. In our study area, the upper portion of the soil around homes is damp and the water table is typically at a depth of 50-100 feet. During prolonged rainfall, the downward moving perched water table (near-surface accumulation of water) can merge with the upward moving water table. Few data are available about the effect of fluctuations in water table depth on the concentration and mobility of soil radon gas. The United States Environmental Protection Agency Manual “Reducing Radon in Structures” states that as water tables rise, it is logical that more soil gas is forced into houses.

In summary, it was the purpose of this study to evaluate the validity of the contention that rainfall differences, as quantified seasonal total precipitation, can be correlated with radon gas concentrations in houses in northern Virginia.

2. METHODOLOGY AND RESULTS

Alpha-track indoor radon monitors were placed in several hundred occupied houses for 3 month intervals that correspond to the seasons. In this study, the detectors were exposed for 91 days, on the first floor, the most lived-in part of the houses (Mose and others, 1991). In the study area, Fairfax County in northcentral Virginia and the adjacent Montgomery County in southcentral Maryland, the weather is monitored daily by about 300 weather stations by volunteers, and the data are compiled and summary reports issued by the National Oceanic and Atmospheric Administration (Cooperative Program Branch W/OSO141X4).

According to the weather summaries, Table 1, the total seasonal rainfall starting from the winter at the end of 1986 through the winter of 1987 ranged from less than 10 inches to more than 15 inches. The median indoor radon measurements from the study homes in northcentral Virginia and southcentral Maryland ranged from 1.6 pCi/L to 2.4 pCi/L. As shown in Table 1, as the rainfall increased, the indoor radon increased.

| Table 1. Seasonal summary of rainfall and indoor radon |
|----------------------------------------------|------------------|-----------------|------------------|
| Season           | Total Average Rainfall | First Floor Median Indoor Radon | Number of Homes |
| Spring of 1987   | 7.4 inches             | 1.6 pCi/L       | 76               |
| Summer of 1987   | 9.9 inches             | 1.6 pCi/L       | 125              |
| Winter of 1987   | 10.1 inches            | 2.1 pCi/L       | 100              |
| Fall of 1987     | 10.8 inches            | 2.2 pCi/L       | 115              |
| Winter of 1986   | 15.1 inches            | 2.4 pCi/L       | 39               |

3. CONCLUSIONS

This research also shows that variations in indoor air radon concentrations in a home built over terrain with a fluctuating water table could be substantial. This suggests that to test a home or
structure built over this type of terrain, the measurement time could be selected based on an understanding of when the water table rises and falls. Since the nature of the water table and groundwater are of concern when evaluating the migration of many environmental contaminants, this research indicates that water table fluctuations could have an effect on the volume of gaseous emanations of these contaminants.

REFERENCES