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OUTDOOR RADON CONCENTRATIONS IN THE VICINITY OF AN ACTIVE HOME RADON MITIGATION SYSTEM

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ABSTRACT

When compared to indoor radon concentrations, outdoor radon levels are generally low. Within the vicinity of a radon mitigation system, however, exhausted radon may cause unnaturally high levels of outdoor radon. A study was conducted over a period of three weeks on a home with a subslab depressurization mitigation system measuring outdoor radon concentrations correlated with wind speed. The data demonstrated that wind speeds were inversely related to outdoor radon concentrations. Strong wind speeds during the early morning and late afternoon correlated with low radon levels while low wind speeds in the evening resulted in high radon levels. Though the outdoor radon levels did pool during stable atmospheric conditions, the radon levels never exceeded 3 picoCuries per liter and averaged 0.345 pCi/l. Further study should be conducted over a longer period of time during different seasons, at various distances and directions from the home, and at different heights above the ground.

INTRODUCTION

As a class A carcinogen, it is important to study both outdoor and indoor radon concentrations. Residents in Santa Barbara should be particularly concerned as Santa Barbara County has been declared to be a radon hot spot by the California Department of Health Services (Anonymous, 1993). Carlisle and Azzouz determined that the Rincon Shale Formation in Santa Barbara County was responsible for the high radon levels (Carlisle and Azzouz, 1993). The Environmental Protection Agency (EPA) recommends that radon concentrations within residential homes to be less than 4 pCi/l in order to minimize health risks. However, it has been calculated that approximately 6% of the homes on the Rincon Shale Formation in Santa Barbara exceed the EPA action level (Hobbs and Maeda, 1996).

The adverse health effects of radon and its decay products have been known for many years. Radon decay products are inhaled and stick to the lungs where they decay and release alpha particles. These alpha particles are released at high speeds and may strike the lung cells possibly damaging them. Chronic exposure to radon decay products may eventually lead to lung cancer. Therefore, it is important for persons who have indoor radon levels exceeding the EPA action level to reduce their health risks by implementing radon mitigation systems.

A popular, effective, and durable means to reduce radon concentrations have been the subslab depressurization system. The subslab depressurization system diverts soil gas from entering the home by directing the soil gas into a pipe. The system draws on the soil gas from beneath the home with a fan. The soil gas enters a piping system and is exhausted at the roof. The gas is then dispersed and diluted within the atmosphere. However, this outdoor exhausted radon gas may enter the home at the floor level during times of atmospheric stability. To our knowledge, no previous systematic study has been conducted on this problem.

It was determined that a diurnal pattern exists in both outdoor and indoor radon levels and a regular pattern was found in wind speeds. Radon levels were inversely related to wind speeds. Radon may pool at night due to stable atmospheric conditions; however, we determined that no serious entrainment exists in the home in our study. Further investigation of this phenomena is required as the home owner wants to lower indoor radon levels as much as possible in order to decrease his health risks. We did not measure the rate of entrainment of radon.

EXPERIMENT

Objective

When compared to indoor concentrations, outdoor radon levels are generally low due to dispersal and dilution within the atmosphere. Within the vicinity of a radon mitigation system, however, exhausted radon may cause unnaturally high levels of radon. Therefore, a study was conducted on a home with a subslab depressurization mitigation system measuring outdoor radon concentrations correlated to wind speed to determine if pooling of radon occurred during stable atmospheric conditions.

The home under study is located in Winchester Canyon, an area of exposed Rincon Shale. The home has a basement with two stories existing above it. It was originally built without a mitigation system but was retrofitted with a subslab depressurization system in 1993. Prior to the implementation of the mitigation system, indoor radon levels were as high as 10 pCi/l. With the installation of a mitigation system, indoor radon levels dropped to an average of 1.8 pCi/l, well below the EPA action level of 4.0 pCi/l. The subslab depressurization mitigation system was therefore an effective means to control indoor radon levels. The system primarily consisted of a fan and a 4" diameter polyvinylchloride (PVC) pipe. It produced a depressurization of about 1-inch H_20 (-250 pascals) beneath the basement slab pulling soil gas from beneath and around the home. Although this was a relatively low pressure when compared to atmospheric pressure (about 10^5 pascals), it was more than adequate when dealing with radon mitigation; soil gas was naturally drawn into the home with a pressure of about 10 pascals due the stack effect while the mitigation system had a suction of approximately -250 pascals. Consequently, instead of the soil gas being pulled into the home by the stack effect, it was diverted by the mitigation system. Approximately 160 CFM (75.5 l/s) of air was pulled through the system; the exhaust gas was found to have a relatively constant radon concentration of about 200 pCi/l resulting in about 15,000 pCi/s in the exhaust. The piping system began below the home's basement, extended up through the basement, first story, attic, and exited the home through the roof. The pipe on the roof extended 0.3 m vertically from the roof and was fitted with a vented cap to prevent rain and debris from clogging the system. The mitigation system ran constantly 24 hours a day and had no on/off switch. The negative pressure at which the system pulled in soil gas was monitored in the garage with a gauge indicating the air pressure.

Materials

A *femto*-TECH model RS-410F was used to measure radon levels. The instrument measured radon concentrations by measuring airborne alpha radiation in an ion chamber and measured radon through either active or passive modes. The passive mode was used for long-term monitoring (days), while the active mode was used to measure short time periods (10 to 30 minutes). The counting mode was used in the experiment for the environmental data while the rate mode was used to measure the radioactivity of the exhaust. Accumulated counts were integrated using a time constant of 45 minutes to decrease statistical errors; in the passive mode, it took approximately 45 minutes for the monitor to equilibrate with its environment. Cumulative counts were recorded every half an hour and were converted to pCi/l or Bq/m^3 where 1 Bq is equivalent to 1 decay/sec (1 pCi/l = 37 Bq/m^3).

A wind vane and anemometer were used to measure wind velocity. These instruments were placed 2 meters above ground fixed to a playhouse 3 meters north east of the home. The NRG logger 9000 was used to record the hourly wind velocity measurements. The NRG logger 9000 was connected to the anemometer and wind vane, an EEPROM Reader II serial device, and a data chip. Datalog 2 software was used to read the EEPROM micro-chip. The turbulence and wind rose capabilities of the program were not functioning.

A CFM-88 flow hood by Shortridge instruments was used to determine the exhaust flow of air from the radon mitigation system. Computer programs used to organize and display the collected data include Microsoft EXCEL and Cricket Graph.

RESULTS AND DISCUSSION

At 1 m above ground, average outdoor radon concentrations in Santa Barbara are approximately 0.3 pCi/l (Carlisle and Azzouz, 1993). The nationwide average for the United States is 0.06 to 1.1 pCi/l (Hopper et al., 1991).

Wide variations result from different vertical mixing, various environments, and soil gas concentrations. Turbulent diffusion and variable meteorological patterns are responsible for vertical mixing of radon in the atmosphere where it radioactively decays with a half life of 3.8 days. Due to the presence of the mitigation system, average radon concentrations within this study are 0.345 pCi/l at 2 m above ground. Averages for the month of February (0.482 pCi/l) may be lower those of March (0.168 pCi/l) and April (0.386 pCi/l) due to high moisture content in the soil from rain; water has a tendency to reduce the flow of radon gas from the ground. Radon concentrations at 1 m above ground within the United States average 0.2 pCi/l (J.G. Price et al., 1994). Values for national averages are at levels taken only 1 m above ground, while radon levels from our study exceed national average even when measured at 2 m above ground. Therefore, elevated ambient radon levels are clearly related to the mitigation system.

Diurnal patterns emerging from our data show radon concentrations lowest in the afternoon and highest during the evening. This phenomena is the result of a thermal gradient in the air caused by the sun's energy heating the earth. As the sunlight radiates on the earth, it heats up the ground. In the afternoon, the air adjacent to the ground is heated by conduction causing this air layer to be warmer than the elevated air. Unstable conditions result as this hot layer of air rises due to its low density and high buoyancy. This rising air creates pockets of vertical mixing by convection. As a result of this convective process, pollutants near the earth are mixed upward and diluted.

In the evening, the ground cools as it continues to radiate heat into the air. The sun no longer continues to heat the ground because it has set. As the ground cools, air adjacent to the ground is cooled by conduction. Very stable conditions result as the cool air remains near the earth and does not rise. No convection exists and thus there is no vertical mixing. Rapid changes in the stability of the air occur during sunrise and sunset (Portstendorfer et al., 1994).

Radon concentrations from are data conform to a diurnal pattern and wind patterns were inversely related to radon concentrations. Low wind speeds during the evening through the early morning corresponded to high radon levels. The data from 2/13 to 2/15 demonstrated that low wind speeds of 2 to 4 mph occurring from 8:00 PM to 7:00 AM correlated with relatively high radon levels of approximately 1 pCi/l (see Fig. 1). High wind speeds of 7 mph resulted in radon concentrations below measurement capabilities of the detector. The wind pattern is also related to the heat expelled from the ground and the daily wind current moving out of the canyon to the ocean in the evening and into the canyon in the morning. The excess heat from the ground has already dissipated by the evening resulting in stable atmospheric conditions.

Wind measurements taken from 3/8 to 3/12 also consisted of a regular pattern with peak wind speeds throughout the day and lowest wind speeds during the night. Wind speeds peaked at 9:00 AM to 10:00 AM and again later in the afternoon anywhere from 2:00 PM to 3:00 PM. Wind speeds of under 2 mph occurred from 7:00 PM to 7:00 AM and resulted in radon levels at approximately 0.4 pCi/l while wind speeds of 7 mph in the afternoon correlated with radon levels under 0.2 pCi/l (see Fig. 2).

The last set of data from 4/22 to 4/27 had high wind speeds of 8 mph which occurred during the afternoon and correlated with negligible radon levels (see Fig. 3). High radon levels occurred during the evening to reach above 1 pCi/l during wind speeds of less than 2 mph.

Radon data were taken from 7/18 to 7/25 at the roof near the exhaust pipe (see Fig. 4). At the roof, radon concentrations emitted from the pipe averaged 32.6 pCi/l. The afternoon levels around were the lowest at approximately 6 pCi/l compared to other roof values. The values peaked at 2:00 AM at 60 pCi/l. Indoor radon levels taken from the home also showed a diurnal pattern. Measurements were taken from 10/26 to 11/02 with the average radon concentrations at 1.4 pCi/l. The values peaked regularly anywhere from late in the evening. Lowest radon concentrations occurred during the afternoon. The log graph compares the roof and indoor basement radon levels and exemplifies the difference in the magnitude of the concentrations; the roof concentrations were approximately 25 times higher than the basement levels.

From this data, it can be concluded that radon pooling does occur during the night. Of particular concern is the entrainment of exhausted radon through the basement windows of the home. During stable atmospheric conditions, the exhausted radon may not be dispersed by the wind but instead may sink and enter the home through the floor level and through the basement windows. The amount of entrainment is not known.

If energy consumption or system noise is of concern to the home owner, it may be possible to shut the system down during the afternoon when indoor and outdoor radon concentrations are low. If concerned over increased levels of radon, the home owner may open windows at the lower level of the home to neutralize the indoor depressurization tendency. The home owner could also simply pressurize the home to prevent entrainment of the exhaust gases. The mitigation system runs on a 90 watt powered fan which consumes the energy equivalent to run a light bulb. Therefore from energy considerations, it is not necessary to shut down the system. In the future, however, it may be advantageous to build mitigation systems with on/off switches.

Densely housed areas with general radon problem such as the New Jersey Reading Prong or the Santa Barbara Rincon Shale may present pooling problems. Hypothetically if a large number of homes located side by side were all fitted with mitigation systems and were all exhausting radon, significant pooling of radon in the outdoor air could result. Under the National Emission Standards for Hazardous Air Pollutants, the EPA has listed radionuclides as hazardous air pollutants (42 USC sec 7412(b)(1)(B); 40 CFR part 61. This standard requires that radionuclides be treated with stringent standards and regulations in order to protect the public health; therefore, no person may construct a source which results in the emission of the hazardous air pollutant in excess of the EPA emission standard. Will this affect home owners whose combined outdoor exhaust levels exceed a certain level?

Fig. 1: 2/13 to 2/15
Wind Speed and Radon Concentration
versus Time

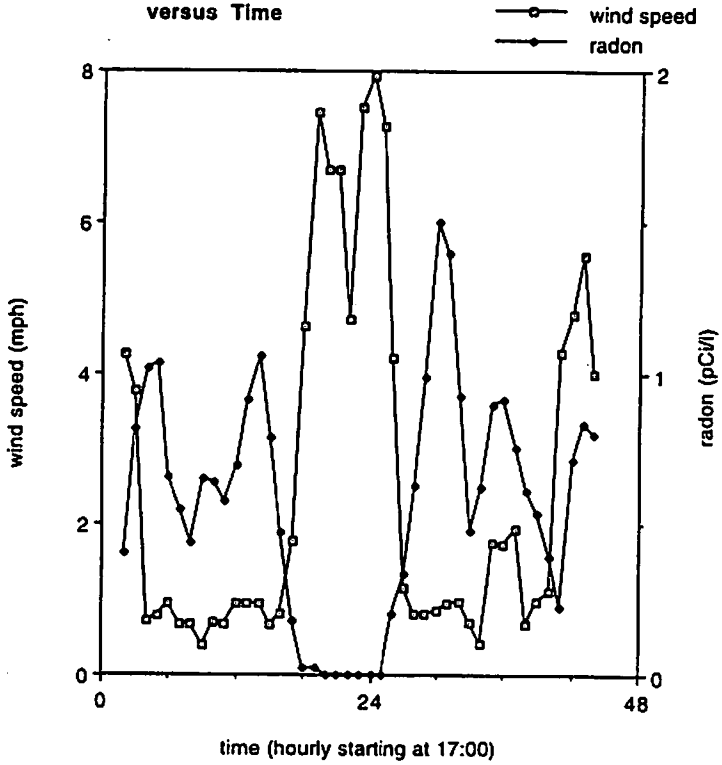


Fig. 2: 3/8 to 3/12
Wind Speed and Radon Concentration
versus Time

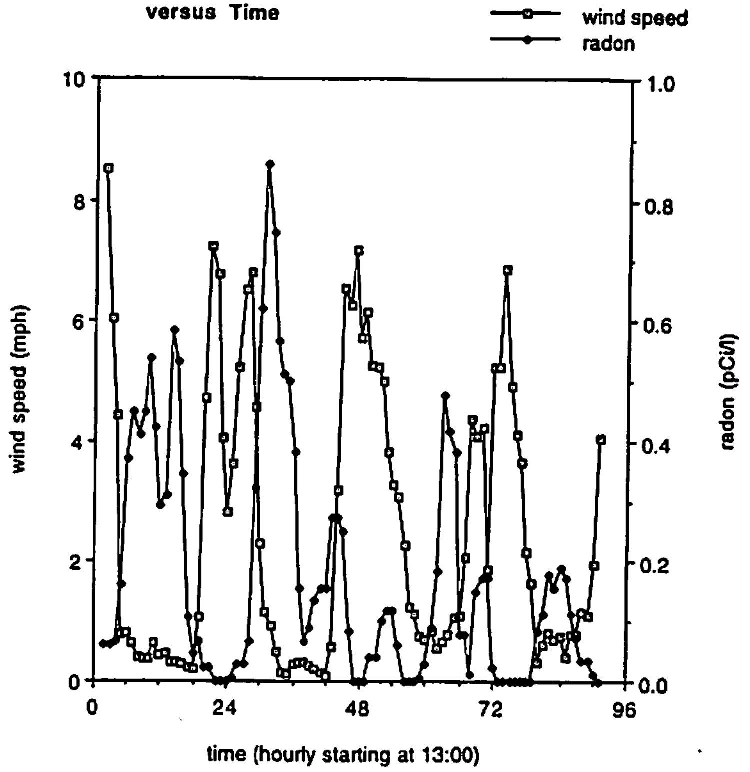


Fig. 3: 4/22 to 4/27
Wind Speed and Radon Concentration
versus Time

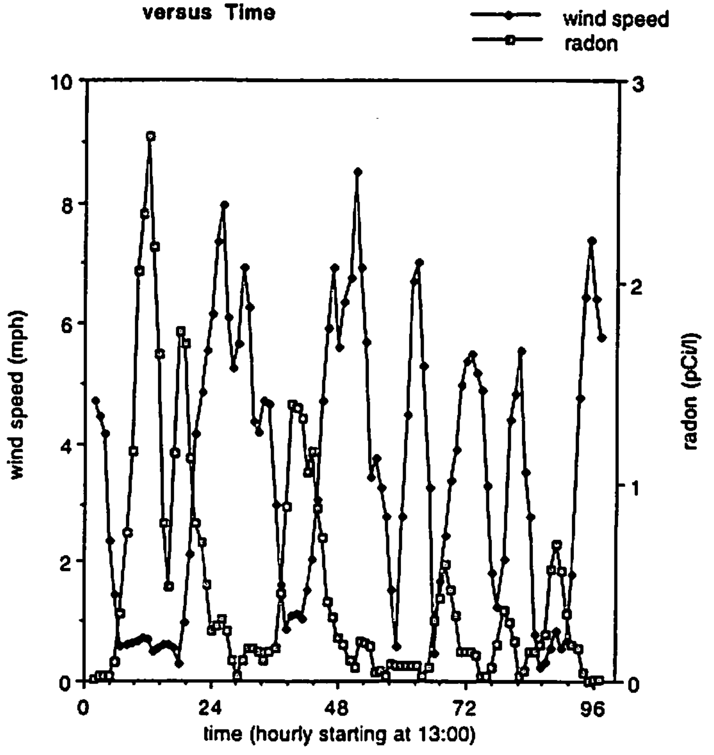
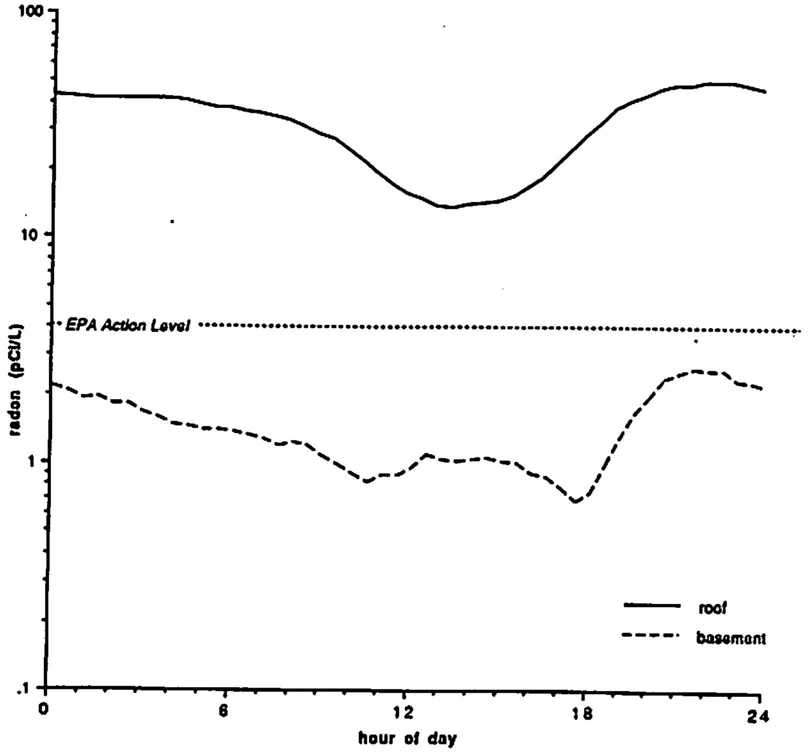


Fig. 4: Roof and Basement Radon Concentrations



SUMMARY AND RECOMMENDATIONS

Our study has demonstrated the possibility of entrainment of exhausted radon gas into basement windows during times of atmospheric stability. This problem is of utmost importance to the home owner who wants the minimum radon risk within his home. Future studies should measure the entrainment levels by collecting data on radon concentrations at basement windows. The addition of a timing mechanism on the radon mitigation system with on/off capabilities should also be investigated such that a home owner may shut off his system if pooling of outdoor radon is determining to be significant.

It may also be advantageous to collect data over a longer period of time to smooth out any anomalous data and to determine if there is significant seasonal variation in radon concentrations and wind velocities. Rain and moisture influencing our data may be offset with a larger data set. Measurements should be taken at different heights and locations around the home to ascertain if particular areas of the home have significant pooling. Data on wind direction and wind rose will also determine pooling areas. Data may also be collected with the mitigation system off to ascertain the influence the system has on radon levels. Studies should be conducted on hypothetical or actual radon gas pooling situations which consist of many homes concentrated in a single area that all exhaust radon through their subslab mitigation systems.

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