STATISTICAL CONSIDERATIONS AND COMPARATIVE STUDIES OF VARIOUS SCREENING MEASUREMENTS FOR INDOOR RADON

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Abstract - Short term sampling methods for Rn analyses have been considered by many to be unreliable for use in real estate transactions. This opinion has been based upon the recognized fact that Rn may vary with fairly short time periods and that some of these variations may be quite large. However, many of the published data regarding variation of concentration were not taken within the complete confines of the U.S. Environmental Protection Agency (EPA) protocol for screening tests.

This paper presents an analysis of data from alpha track detectors, continuous Rn monitors, passive activated charcoal canisters, passive electret detectors, and one hour air samples collected on activated charcoal in two homes where the EPA protocols were strictly followed. These data were used to describe the mean concentration over the period of the test, the variance of the mean, the confidence intervals and the probability of shorter term samples being within an acceptable range of the mean.

Field data using one hour active collections of radon on charcoal

and two day passive charcoal canisters are compared with integrated samples of three or more days to show their correlation.

INTRODUCTION

At the beginning of 1991, the Mid-Atlantic Chapter of the American Association of Radon Scientists and Techologists (MAC-AARST) began a program of comparative Rn measurements in two houses in the Germantown/Gaithersburg area of Maryland. Both of these houses consist of two stories with basement and are heated and air conditioned by heat pumps. Only one house, referred to as Scottsbury, was sampled consistantly because of its accessability. The two houses are of comparable size but vary in two ways. The Scottsbury has a passive sub-slab ventilation system that appears to make the radon concentrations more variable and more like a house with a furnace chimney. The second house, referred to as Brink, is custom built and is highly insulated and sealed; however, there is a two foot diameter galvanized pipe which penetrates the basement wall and extends for approximately 15 feet into the surrounding earth. Whether this penetration increases the susceptibility of the house to changes due to outside environmental conditions was not determined.

The objectives of the program included the use of comparative sampling as an interim quality assurance method to test precision of measurement with duplicate sampling and to compare results of a given method against the mean of several methods under field

conditions. By samplimg with both short-term and long- term methods, seasonal and weather variations in indoor Rn air concentrations can be described and the accuracy of the screening methods can be compared for their predictive power.

The program was made available for participation by any National AARST member and three companies from other regions have participated coninuously or when feasible. A total of eleven companies have participated so far.

This report presents interim results covering the first six months of the comparative measurement program and some of the comparisons may change when a full year of data is available. However, some of the results regarding correlations with sample means will probably remain at similar magnitudes.

METHODS

Sampling occurred biweekly as far as possible although there were interruptions in the schedule due to the press of business. The usual cause of an interruption was the unavailability of a continuous radon monitor (CRM). Four different CRM's were used throughout the period. These had been recently calibrated and reproduced values that coincided with the means of the passive detector results. There were two exceptions during widely varying concentrations at the beginning and ending of sampling periods. The main purpose of the CRM was to document the variation of concentration with time rather than to be a secondary standard of the Rn concentration.

Several passive sampling methods have been used in the experiments including two to four day open face activated charcoal canisters (ACC), four to seven day diffusion barrier ACC's, liquid scintillation vials, electret detectors, and one hour air samples on activated charcoal. The core experiment collected data in the four day period from Monday at 13:00 hours to Friday at 13:00 hours. Sampling for longer periods was started prior to the core experiment.

The EPA sampling protocol was followed as closely as possible. Detectors were placed three to five feet above the floor, two feet away from outside walls, and away from heating and cooling vents. The houses were closed for 12 hours prior to testing and generally closed throughout the test period. We asked the occupants to note unusual conditions including prolonged opening of doors and windows and two such events were recorded. Overall conditions were similar to what might be expected in a cooperative household. We did not shut down tests during high wind conditions and after evaluation of the results could not see a major effect due to windy episodes

Sampling was in duplicate or multiple replicates with the exception of CRM measurements and results were reduced to arithmetic means for each company's measurements. A grand mean was generated from the results of the 3 and 4 day sample collections. Results from shorter sampling periods were compared to this mean. The statistical significance of the comparisons

was determined with the zM Test (Langley 1970).

RESULTS

The Scottsbury results for the six month period provided most of the data for this report since the Brink data were limited because the house was not always available. Figure 1 shows how the indoor radon concentrations for the basement and first floor of Scottsbury varied over the time period. As might be expected, the concentrations decreased from winter to summer. During this period the rainfall was abnormally light which may be a cause for the reduction of basement concentrations from 10 pCi L^{-1} in the winter to 2.5 pCi L^{-1} at the end of spring.

An interesting phenomenon that has been noticeable during the six months has been the sensitivity of indoor radon to rainfalls that have visibly soaked the ground. This has been especially evident during the the spring to summer drought and is illustrated by CRM results for the end of July that are presented in Fig. 2. Rain occurred the evening of the first day of sampling and into the morning of the second resulting in elevated indoor Rn concentrations which decreased through the rest of the sampling period. Figure 2 also illustrates the cyclic nature of the indoor Rn concentrations on a daily basis with concentrations rising in the early morning and generally subsiding from late morning until midnight.

The probability of a one hour sample exceeding the mean by greater or less than 25% was calculated in two ways. First by

calculating the ratio of the number of results that are outside of the limits to the total number of one hour results and then by determining the ratio of the number of hours that the CRM data are outside the limits to the number of working hours represented by the sampling period. This latter approach also is illustrated in Figure 2 which indicates the eight hour working days by the vertical lines and the number of hours that the CRM records Rn concentrations above or below the 25% limits for each working day.

Table 1 presents the probabilities of a one hour measurement falling outside of the limits for the first two quarters of the year. Although the graphically generated probability indicates equal probability, the actual one hour measurements indicate an increase from spring to midsummer. An increased one hour sampling program covering as many as three of the four days of a sampling period and lower Rn concentrations may have caused a bias toward increasing the frequency of samples that were outside of the limits during the second quarter.

Table 2 shows a comparison of the results of two day and one hour samples relative to the three to four day means. These are expressed as the fraction of each population that is significantly different than the means amd the fraction of measurements that exceed the upper and lower 25% limit. Data from Brink are included in this table for comparison.

Table 3 compares the sampling durations with regard to their

abiltity to predict the six month average concentration as determined by the fraction of measurements that fall outside of the 25% limit of the mean.

DISCUSSION

The results obtained so far in the MAC-AARST Comparative Measurement Program indicate strongly that the shorter term samples have limited predictive power under the conditions encountered at Scottsbury. Some of the variability may be due to the unusual condition of testing a house that has a passive sub-slab ventilation system in place, but this variability may not be that much more than in a house with a combustion furnace and chimney. Comparison with the limited data from Brink, where 28% of the the measurements fell outside of the range, does not add to the confidence in the sampling method.

Comparison of all of the methods for predicting the long term average concentration may be premature with only the six month average concentration. The drought conditions in Maryland could cause abnormally high exhalation of Rn from the soil to the atmosphere leading to an unusual reduction in indoor Rn levels this spring and summer period. Further data are needed to analyze what has been observed so far.

SUMMARY

MAC-AARST has established a comparative Rn measurement program to provide a secondary quality check for radon testing companies. This program provides an additional method for checking the

precision of test devices and a semi-quantitative check on accuracy through comparison with the mean of the sampling results. Additional goals of the program are to evaluate the uncertainties in short term sampling methods relative to screening samples of three to four days passive collection and to longer term averages. Data in the first six months indicate poor predictive power for samples of an hour length.

References

Langley, R. Practical statistics, simply explained. Revised edition. New York: Dover Publications; 1971

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FIGURES

Figure 1. Plot of the average concentrations of Rn verus showing the general downward trend fromwinter to summer.

Figure 2. An example of results from a four day continuous radon monitor that illustrates (1) the periodicity of the early morning increase in concentration, (2) the apparent effect of the drying of the soil on indoor Rn air concetrations, and (3) the method used to determine the probability of measuring a Rn concentration 25% greater or less than the mean.

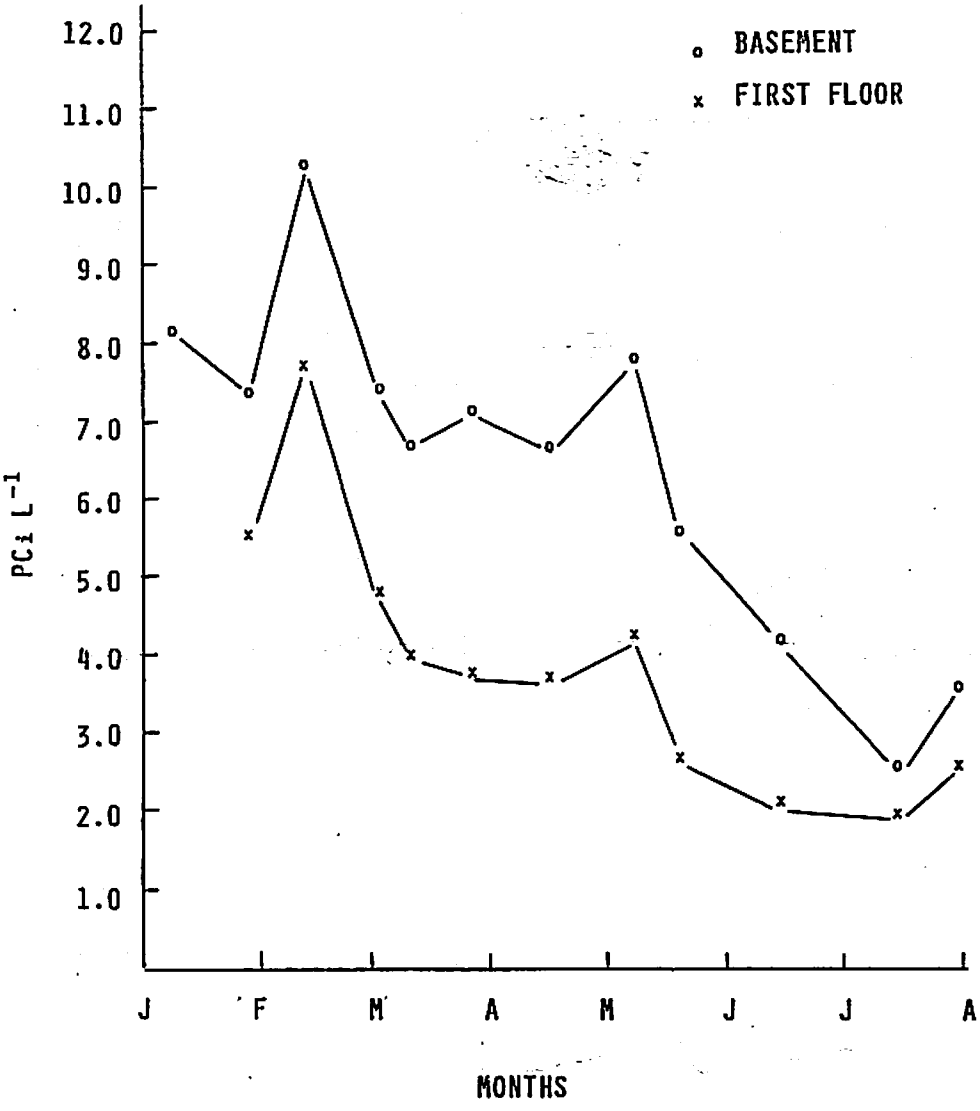
TABLES

Table 1. Probability of making a one hour measurement that is 25% greater or less than the mean.

Table 2. Comparison of the frequencies of results of shorter term collection methods falling outside of the 95% confidence intervals for the three and four day mean concentration and the 25% upper and lower bounds defined by the EPA.

Table 3. Comparison of the detection methods to six month alpha track measurements.

FIGURE 1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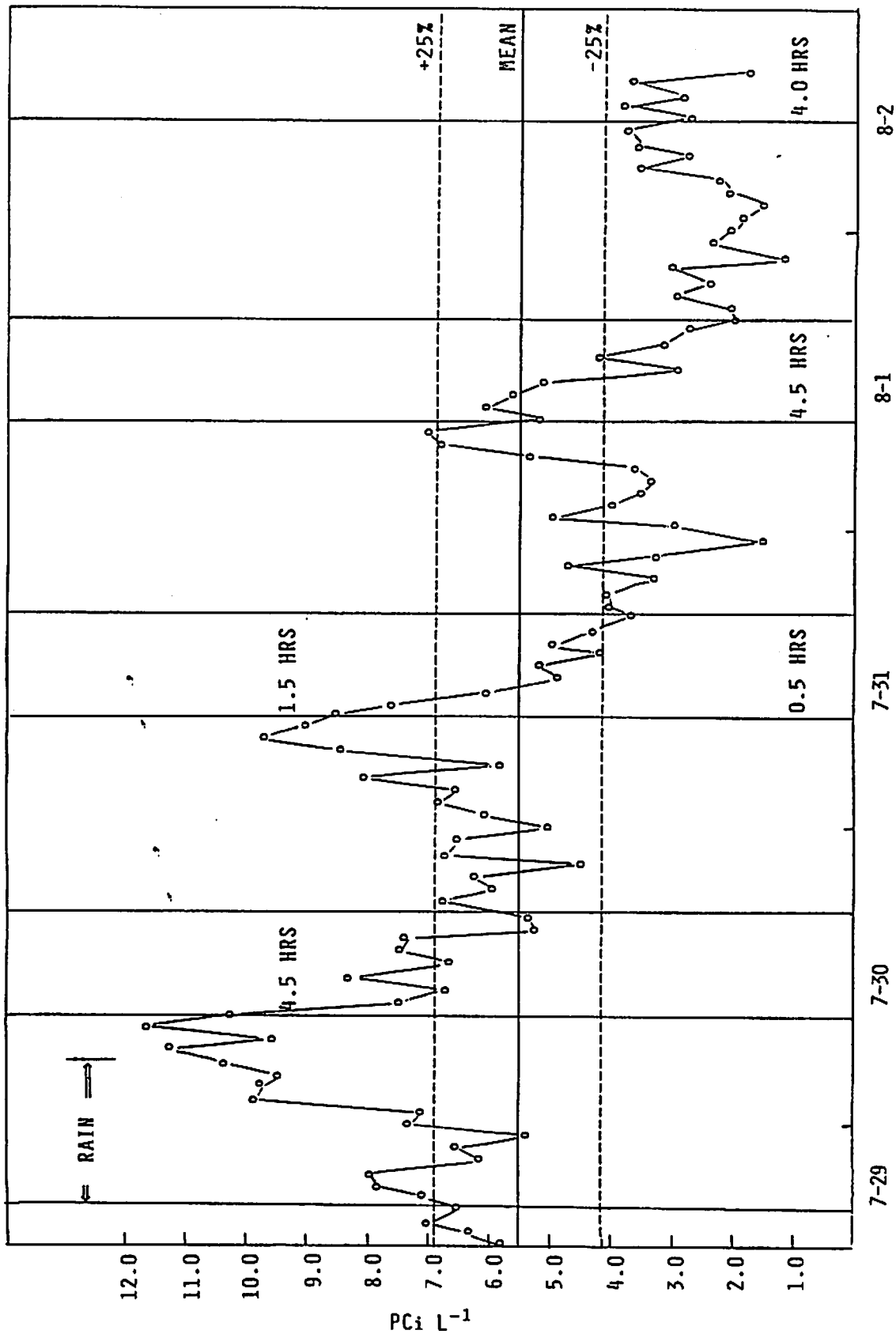
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DAYS

FIGURE 2

TABLE 1

Time	CRM Data	One Hour Sample Data
First Quarter	0.43	0.28
Second Quarter	0.43	0.62

TABLE 2

Collection Method	Fraction Significantly Different from Mean	Fraction Outside of +0.25	-0.25
Scottsbury			
2 Day	0.47	0.31	0.03
1 Hour	0.53	0.21	0.25
Brink			
2 Day	0.11	0.00	0.00
1 Hour	0.61	0.06	0.22

TABLE 3

Method	Number of Duplicates	Fraction outside of +0.25	-0.25	Total Fraction
		Basement		
4 Day	17	0.12	0.29	0.41
3 Day	26	0.19	0.23	0.42
2 Day	16	0.31	0.19	0.50
1 Hour	24	0.29	0.33	0.62
		First Floor		
4 Day	17	0.00	0.71	0.71
3 Day	19	0.26	0.42	0.68
2 Day	14	0.00	0.64	0.64
1 Hour	23	0.00	0.65	0.65