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FACTORS ASSOCIATED WITH HOME RADON CONCENTRATIONS IN ILLINOIS

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ABSTRACT

The Illinois Department of Nuclear Safety has performed short-term alpha-track radon testing in over 3000 homes throughout Illinois. Data were also collected on a wide array of household characteristics and test conditions. Analysis of these data revealed a number of interesting patterns.

Contrary to many investigations, the highest average concentrations were not obtained in homes monitored in winter. Though a number of models were explored in the analysis, few could explain more than 10% of the variation in radon concentrations and no model could explain more than 20%. This suggests that other factors, such as local geology, may be largely responsible for inter-house variations.

Among houses with a crawlspace elevated radon was associated with having an indoor entrance and not ventilating or insulating the crawlspace. In houses with basements, the foundation construction materials were important explanatory variables. Surprisingly, common entry routes, such as sump pits, cracks, drains, and exposed earth, were not associated with radon concentration. Also contrary to other studies, energy efficiency was positively associated with radon concentration.

Results suggest that factors governing radon concentrations in the Midwest are poorly understood.

INTRODUCTION

The primary factors governing the entrance of radon into the home are well known: 1) the soil radon gas concentration and soil permeability, 2) the existence of entry routes between soil and home interior, and 3) a pressure difference between home and soil to provide a driving force for radon entry. However, specific conditions that influence these factors are not well understood, and other factors, such as the distribution of radon in the home and the infiltration of outside air, can influence the concentration of radon in various parts of a home.

Though a number of studies have been performed to examine the relationships between local conditions and indoor radon concentrations, considerable uncertainty remains. In addition, relatively little work has been conducted on factors influencing home radon concentrations in the Midwest.

This study was performed using data collected on approximately 3,000 homes in Illinois that were tested for radon as a part of the Illinois Department of Nuclear Safety's Radon Program. In addition to radon testing, data were collected on a number of household and monitoring conditions. The purpose of this analysis is to build a predictive model for indoor radon concentrations in Illinois. Such a model could not only help identify homes with a higher risk of elevated radon, but could also assist in directing mitigation efforts.

A PRIORI MODEL SPECIFICATION

Data on a number of household and monitoring variables were collected during monitoring (see the following section for details). An *a priori* model was developed to guide analysis of these variables and their relationships to indoor radon. The model is also useful in identifying gaps in the array of variables included on the questionnaire.

Table 1 presents the household and monitoring variables evaluated in this analysis. Indicated in the table are expected relationships between each variable and monitored radon concentration. These expectations are based upon relationships reported by others in the literature and on the authors' own field experience. Table 1 lists the basic references used in creating the table. A detailed discussion of the current literature and *a priori* model is not presented here due to space limitations. The reader is referred to reviews such as references (1-3). However, a few comments should be made to clarify subsequent modeling.

Air infiltration may be associated with an increase or decrease home radon concentrations. Increases may occur if infiltration occurs due to house depressurization, which can increase infiltration of soil gas. Similarly, the mixing of air within a house can increase or decrease monitored radon depending upon the location of the monitor. For example, basement radon levels may decrease and first floor radon levels may increase as basement air is distributed through a forced-air heating system. Therefore, variables related to air infiltration and air distribution may demonstrate either a positive or negative relationship to radon in modeling results.

No information on local geology, weather conditions, or other radon sources (other than basement wall construction material and exterior brick) was collected. Thus, the contribution of these factors to radon concentrations cannot be assessed with this data.

METHODS

In the Fall of 1986 the Illinois Department of Nuclear Safety began a systematic home radon testing program in Illinois. Testing was performed on a county-by-county basis using local assistance from county health departments, Cooperative Extension Service personnel, or other organizations. The program continued through the Spring of 1990, though no testing was performed from the Summer of 1988 to the Fall of 1989.

An alpha-track detector was typically placed in the lowest livable area of the home. After approximately one month of exposure detectors were returned to the contract laboratory (Tech/Ops Landaur, Inc.) for evaluation.

In addition to placement of detectors, surveyors completed a questionnaire with the assistance of a head-of-household. The questionnaire included a number of questions on house characteristics and on the household occupants.

Though houses were not selected randomly, selection procedures, typically involving identification of houses from county highway maps, were intended to avoid any systematic bias. Due to the complex interaction of factors influencing radon concentrations, such selection processes may be relatively free of bias (1). At least 20 houses were tested in each county. The number of houses tested in a county increased with increasing population. The 3,021 monitored houses analyzed in this study were drawn from 73 of 102 Illinois counties. These 73 counties contain approximately 88% of the Illinois population.

All data were evaluated for distributional characteristics and coding errors or ambiguities. For many quantitative variables demonstrating non-normal distributions, transformations were performed to enhance normality. In most cases, natural logarithm transformations were sufficient. For other non-normal quantitative variables, however, no useful distributions could be derived from transformation. Some variables demonstrated bi- or tri-modal distributions. Such variables were typically transformed to artificial categorical variables using either theoretically or empirically based cut-points. All final variables and their coding schemes are presented in Table 1. For quantitative variables, scatter plots were assessed for evidence of heteroskidasticity and non-linearity. No problems were identified.

Multiple linear regression was used to explore models of monitored radon concentration. A series of theory and non-theory based models were explored. These are explained in more detail in the following section.

RESULTS

OVERALL

Radon concentrations were approximately log-normally distributed with a geometric mean of 2.84 pCi/l and a standard geometric deviation of 2.30. All subsequent modeling and statistical analyses used the natural log transform of radon concentration.

It was anticipated, prior to analysis, that substructure type, monitor location, and season of monitoring would be the primary explanatory variables across all types of homes, but that the effects of monitor location and season of monitoring could vary by substructure type. Table 2 presents the ANOVA results for radon concentration across the four basic substructure types encountered. Results confirm that substructure is a critical explanatory variable, with crawlspace/no basement producing the lowest concentrations and basement/crawlspace combination producing the highest concentration.

Some of the difference in means, however, may be due to monitor location rather than a direct effect of substructure type. A small percentage of houses with basements were monitored on the first floor, presumably because the basements were not considered "livable". Table 2 presents ANOVA results using first floor measurements only. Though significant differences are still noted, slab-on-grade, rather than basement/crawlspace combination represents the substructure associated with the highest average monitored concentrations

No analysis was conducted on the joint effect of monitor location and substructure type since interaction is an artifact of the survey method: a monitor was placed in the basement only if the home had a basement. The joint effect of substructure and season are presented in Table 3. Both independent variables are significantly associated with the dependent variable, and there appears to be an interaction effect. In basement homes without a crawlspace, fall monitoring produced the highest concentrations. For slab-on-grade homes, fall monitoring produced the lowest concentrations.

Due to the apparent interaction between substructure type and monitoring location and season, as well as probable interactions with other explanatory variables, subsequent analyses were conducted separately for each of the four substructure types.

Before leaving Table 3, however, it is important to note that, contrary to many research findings, winter was not the season of highest radon concentrations. Summer produced the highest or second highest concentrations in each substructure type.

A number of regression models were explored for each substructure type. These are presented in Tables 4 through 7. Model A in all tables represents the results from a series of simple linear regressions using the variable listed as the only independent variable. Interpretation of statistical significance under multiple comparisons is an obvious problem. Consistency with theory and the findings of other studies, as well as consistency across substructure types, should be used in evaluating the results. This point will be explored further in the discussion section.

Models B through D reflect models built upon theory and the results of other models. In Model B, only the monitor location variables were used. In Model C included the addition of monitoring location. Model D represents the best attempt at a complete, theory-based model. Beginning with a base of Model C, additional variables were added for which a good theoretic foundation exists, and which demonstrated results consistent with theory in Models A and E (explained below). Model D should be considered the best model for prediction in Illinois houses.

Models E through G represent non-theoretical modeling. Model E includes all variables simultaneously in the model. Because many of the independent variables are correlated, multicolinearity is a significant problem in Model E. However, by comparing the regression coefficients and p-values to those obtained in other models, one can use Model E to identify those variable that are relatively sensitive or relatively insensitive to the inclusion of other variables in the model. Model F uses Model C plus a forward selection procedure, and Model G used a stepwise selection procedure without any forced variables. Variables included through such non-theoretic methods should only be considered curious possibilities as true explanatory factors for indoor radon. Considerable support from other studies would be needed to enhance the reliability of such models.

The most immediate observation from the regression analyses is the relatively low explanatory power of the models. The percentage of variation in radon explained by the models was generally under 10%. Only for homes with both a basement and crawlspace does theoretical modeling achieve an r-square greater than 0.2. (Note: although Model E can produce a greater R-square, non-theoretic models are likely to have far less predictive power than explanatory power.)

Specific variables of interest include monitoring location and season. For homes with basements, knowing whether the monitor had been located in the basement or not was an important predictor of monitored radon in all models. Knowing whether the monitor was located in a first-floor bedroom or elsewhere on the first was not, generally, a good explanatory variable. This changed in the non-theoretic models for homes with basement/ no crawlspace, possibly due to the addition of the energy efficiency or central air conditioning variables. For homes without basements, bedroom location was important only for homes with a crawlspace, and then, only when monitoring season was included in the model.

Monitoring season was important in nearly all models though the effects were not consistent across substructure types (supporting the previous ANOVA results). Only for slab-on-grade homes, where sample size was small, did the season variables generally have p-values greater than 0.1 and not produce a significant r-square change from Model B to Model C.

BASEMENT/CRAWLSPACE SUBSTRUCTURE

For homes with a basement/crawlspace combination, an entrance from the interior of the home (most likely the basement) to the crawlspace produced a consistent increase in monitored radon. Because the dependent variable is logarithmic, coefficients represent the multiplicative effects of an independent variable on the radon concentration. The coefficient of 0.26 in Model D indicates that a crawlspace entrance increases home radon about 30%. Similar ly, venting a crawlspace demonstrated a consistent decrease in radon, with Model D indicating approximately 20% higher radon levels for homes with unvented crawlspaces. Coefficients for crawlspace insulation and the presence of exposed earth in the crawlspace were both in the correct direction but did not demonstrate consistent statistical significance.

Basement foundation construction material also appeared to be important. Construction materials, from lowest to highest in their apparent contribution to home radon levels are poured concrete, block, "other material", stone and mortar, and brick. From Model D, brick is associated with an average increase in radon levels of greater than 50% over poured concrete. (It is interesting to note that brick reverses signs in Model E. This is apparently an artifact due to multicollinearity.)

Energy efficiency demonstrated a consistent positive relationship with radon. The greater the occupant-assessed energy efficiency, the greater the radon. Perhaps for similar reasons, the number of people in the house was negatively related to radon. Both variables may be related to the amount of air exchange and the size of the house.

Among the most significant findings is that the standard entry routes in a basement (cracks, sump pit, exposed earth, etc.) were not important explanatory variables. Some even had coefficients with a sign opposite that predicted by theory. Also contrary to theory, the presence of a woodstove or fireplace had a negative coefficient and large p-value.

There are a number of interesting curiosities in the regressions of houses with basement/crawlspace combinations. In Model A having room air conditioning or an electric space heater were associated with lower radon concentrations. These did not retain their significance in Model E and may reflect the effects of energy efficiency. Another interesting point is the importance of a brick exterior appearing only in the non-theoretic models. Having an interior entrance to the basement was associated with higher radon levels in Model A, though this association lessened dramatically in Model E. A test for an interaction effect between basement monitor location and basement entry was negative (results not presented here).

BASEMENT NO CRAWLSPACE SUBSTRUCTURE

For basement homes without a crawlspace, a similar pattern appears. Basement construction materials, in the order of their apparent contribution to radon, are: poured concrete, block, brick, and stone and mortar. This order, and magnitude of effect, are roughly consistent with the findings of basement/crawlspace homes.

Standard basement entry routes were, again, not significant, though the presence of cracks had a marginal p value and correctly signed coefficient in Model A. The presence of a woodstove or fireplace also was not an important explanatory factor.

An interaction term between basement monitor location and B_FINISH (using the basement as a bedroom or living area) was found to be significant in a separate test. The inclusion of this term in Model D resulted in a dramatic change in the effect of B_FINISH. Together, these variables would appear to have a substantial effect on radon. For a home with a basement used as a bedroom or living area, basement levels averaged nearly 5 times higher than in homes without finished basements.

Energy efficiency demonstrated the same relationship with radon as in basement/crawlspace homes.

Among the curiosities, the presence of central air conditioning or central forced-air heat, which may be inversely related to energy efficiency, demonstrated significance in Model A. Brick exterior was negatively related to radon, the opposite effect of that in basement/crawlspace homes.

CRAWLSPACE/NO BASEMENT SUBSTRUCTURE

In homes with a crawlspace but no basement, having an entrance to the crawlspace from the home interior was an important predictor of radon in all models. Insulation and ventilation of crawlspace were directionally consistent with theory, though p-values were marginal.

A number of curious associations were found. Having an attic fan was consistently an important explanatory variable, though in the opposite direction generally expected from theory. Other variables, such as having hot water heat, gravity feed furnace, and "other" fuel type, had low or marginally low p-values in at least one model. Having a gravity feed furnace, for example, produced an average 75% increase in home radon levels. Explanations for such associations are unclear.

SLAB-ON-GRADE SUBSTRUCTURE

For slab-on-grade homes, age of house and energy efficiency (which may be related to age of house) were consistently important explanatory factors, indicating that the older and less energy-efficient the home, the lower the radon.

A curiosity was the very strong inverse relationship between central air conditioning and radon. Having central air was associated with an average decrease in radon of about 50%. Having a fireplace or woodstove was associated with a <u>decrease</u> in radon, though p-values were relatively large.

Because of the relatively small sample size for slab-on-grade homes caution should be used in assessing the importance of variables based on p-value alone.

DISCUSSION

A number of limitations should be recognized when drawing conclusions from this study. The methods used to select homes for testing produce a greater likelihood of bias than more rigorous, pseudo-random selection methods. Though reasonable steps were taken to assure quality and consistency in data collection, the use of local personnel and home occupants is likely to introduce some error.

Because sampling was conducted by independent local agencies as time permitted, a correlation between local factors (such as housing or geology) and time-variant factors (such as weather) may have been introduced. In addition. lack of local geological data means that correlations between geology and household conditions cannot be identified. Thus, some results may be due to the confounding effects of geology and time-variant factors.

Finally, due to the high degree of correlation between variables, modeling is prone to error. Model results should be considered suggestive, not confirmatory evidence of the actual underlying relationships.

It appears that the vast majority of radon variation is due to factors other than the common household factors considered in this analysis. Such factors may include differences in regional or local geology, housing construction types, weather conditions at the time of monitoring, or household factors not considered (such as the existence of thermal bypasses or vented appliances). This does not indicate, however, that the factors considered in this survey are not important determinants of radon (for example having a brick foundation may increase radon readings an average of 50%) but only that other factors appear to be more important in explaining the variation between houses. Household factors may not be consistent in their effects. This supports policy recommendations that all homes be tested for radon, despite the apparent presence or absence of known risk factors.

Location of the monitor in the basement produced, as expected, a significant increase in radon concentration. Location of the monitor in the bedroom, as opposed to elsewhere on the first floor, was generally unimportant. For research primarily intended to evaluate determinants of home radon concentrations, first floor monitoring in all homes is desirable to allow direct comparisons across all house types.

Season of monitoring was an important explanatory factor. However, the relationship between season and home radon concentration was not consistent with other investigations nor was it consistent across housing substructures. The finding that summer radon concentrations could be as high or higher than other seasons suggests that current guidelines for winter monitoring be re-evaluated. However, since these data reflect the measurement of different homes in different seasons, they should be interpreted with caution. Additional research on seasonal effects in the Midwest and elsewhere in the country are needed.

Basement foundation construction material was a relatively consistent predictor of radon. Brick and stone foundations were consistently higher than poured concrete, even after adjustment for age of house. Block foundations were slightly elevated compared to poured concrete. This suggests opportunities for low cost mitigative strategies if foundation walls are accessible and if a suitable radon barrier can be found.

An entrance to a crawlspace was consistently associated with increased radon. Insulation, exposed earth, and lack of ventilation in the crawlspace were also associated with increased radon, though less consistently. These findings suggest that the common weatherization practices of sealing crawlspace entries, insulating floors, and installing vapor barriers not only save energy, but may reduce radon (through vapor barriers may need to be sealed and vented). Limiting crawlspace ventilation as an energy-saving measure, however, does not appear advisable.

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TABLE 1. VARIABLE NAMES, EXPLANATIONS, CODING, AND THEORETICAL RELATIONSHIP TO INDOOR RADON CONCENTRATION

Variable name	Description	Coding[a]	Relationship to indoor radon[b,c]
Substructure[d]			
BMTCRL	Basement and crawlspace		+
BMTNOC	Basement but no crawlspace		
CRLNOB	Crawlspace but no basement		
SLAB	Slab-on-grade only		-
Season			
WINTER	Monitoring done during the winter		++
SPRING	Monitoring done during the spring		
SUMMER	Monitoring done during the summer		--
FALL	Monitoring done during the fall		
Monitor			
LOCBMT	Monitor located in the basement		++
LOCBDR	Monitor located in the bedroom		--
OTHER	Monitor located somewhere else on first floor		--
N_PEOPLE	How many people will be living in the house for the next month?	count	-
LNAGEHS	What is the age of the house?	natural log of years	+/-
N_SMOKER	Is there at least one smoker in the house?		-
ADJ_SLAB	Does the house have any attached asphalt or concrete slabs(attached garage, carport slab, patio, driveway, etc.)?		+
PC_BRICK	What percent of the outside of the house is covered with brick?	0%=0, >0%=1	+
ENER_EFF	Sum of occupant ratings on five energy efficiency characteristic. Each characteristic rated on scale of 1 to 5.	A scale of 5=least to 25=most energy efficient	+/-
CENT_AC	Do you use central air-conditioning during warm weather?		+/-
ROOM_AC	Do you use a room air_conditioner during warm weather?		?
FAN_ATIC	Do you use a whole house and/or attic fan during warm weather?		-

TABLE 1. VARIABLE NAMES, EXPLANATIONS, CODING, AND THEORETICAL RELATIONSHIP TO INDOOR RADON CONCENTRATION (CONTINUED)

Variable name	Description	Coding[a]	Relationship to indoor radon[b,c]
CENT_FA	Do you use a forced air central heating system during cold weather?		+/-
W_BASE	Do you use a hot water baseboard or radiator system during cold weather?		+/-
CENT_GF	Do you use a gravity flow central heating system during cold weather?		+/-
ELEC_SPA	Do you use an electric space heater during cold weather?		?
WOOD	Do you use a fireplace or wood burning stove during cold weather?		+/-
KEROHEAT	Do you use a kerosene space heater during cold weather?		?
GAS_STOV	Do you use a gas stove during cold weather?		+
HEAT_OTHER	Do you use some other kind of heating system during cold weather that was not mentioned on this questionnaire? If so, specify.		?
B_FINISH	Is all or a portion of the basement frequently used as a bedroom or living area?		?
Foundation	The outside basement walls are primarily composed		
BLOCK	Concrete or cinder block		-
CRET	Poured concrete		-
MORT	Stone and mortar		-
BRK	Brick		-
OTHER	Other and tile		?
ENT_BASE	Can you enter the basement from inside the house?		+/-
CRACKS	Does the basement floor (or sub-surface floor in a split-level home) have large cracks or holes?		-
DRAINS	Does the basement floor (or sub_surface floor in a split-level home) have drains?		-
SUMP	Does the basement floor (or sub-surface floor in a split-level home) have sump pumps?		-

TABLE 1. VARIABLE NAMES, EXPLANATIONS, CODING, AND THEORETICAL RELATIONSHIP TO INDOOR RADON CONCENTRATION (CONTINUED)

Variable name	Description	Coding[a]	Relationship to indoor radon[b,c]
EARTH	Does the basement floor(or sub-surface floor in a split-level home) have exposed earth?		+
CSP_ENTR	Can you enter the crawl space from inside the house(from basement, for example)?		+
CSP_INSL	Is the floor above the crawl space insulated?		-
CSP_VENT	Will the crawl space be vented to the outside during the monitoring period?		-
CSP_EXP	Does the crawl space have exposed earth?		+

a. All Yes/No variables codes as 0=no, 1=yes

b. ++ = strongly and positively related

+ = positively related

\- = negatively related

-- = strongly and negatively related

+/- = both positive and negative relationships may be expected

? = too little information to predict a relationship

c. Based upon references (1) through (11)

d. These variables were used to define datasets and do not appear explicitly in later tables.

TABLE 2: ANALYSIS OF VARIANCE RESULTS FOR RADON CONCENTRATION BY SUBSTRUCTURE TYPE.

Monitor location	Substructure type	Geometric mean concentration (pCi/l)	Geometric Standard Dev.	N
All(a)	All types	2.84	2.30	3,021
	Basement and crawlspace	3.56	2.21	752
	Crawlspace, no basement	1.67	2.11	572
	Basement, no crawlspace	3.16	2.21	1,548
	Slab-on-grade only	2.32	2.33	134
First floor(b)	All types	1.79	2.14	853
	Basement and crawlspace	1.95	1.88	78
	Crawlspace, no basement	1.67	2.11	572
	Basement, no crawlspace	1.81	2.07	69
	Slab-on-grade only	2.32	2.33	134

(a) p-value = <.001 for at least two means differing by substructure type.
(b) p-value = <.001 for at least two means differing by substructure type.

TABLE 3: GEOMETRIC MEAN CONCENTRATION IN pCi/l (AND SAMPLE SIZE) BY SEASON OF MONITORING AND SUBSTRUCTURE TYPE[a]

SEASON	BASEMENT CRAWLSPACE	BASEMENT NO CRAWLSPACE	NO BASEMENT CRAWLSPACE	NO BASEMENT NO CRAWLSPACE
WINTER	3.74 (509)	3.22 (1137)	1.68 (354)	2.27 (97)
SPRING	2.34 (122)	2.51 (218)	1.39 (103)	2.83 (17)
SUMMER	4.76 (65)	3.74 (118)	1.67 (45)	2.34 (14)
FALL	3.94 (56)	3.78 (75)	2.03 (70)	1.70 (6)

a. p-values = <.001 for both main effects and interaction

TABLE 4: MULTIPLE REGRESSION RESULTS FOR MODELS OF HOME RADON CONCENTRATION:
HOMES BUILT OVER BASEMENT AND CRAWLSPACE

VARIABLE	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G
INTERCEPT	-	.62447	.90441	.63720	.13636	-.06271	.42381
	-	(<.01)	(<.01)	(<.01)	(<.01)	(.79)	(.20)
WINTER	-.13391		-.11985	-.13353	-.19473		-.17511
	(.34)		(.38)	(.34)	(.14)		(.19)
SPRING	-.60418		-.54158	-.62871	-.66264	-.48379	-.64939
	(<.01)		(<.01)	(<.01)	(<.01)	(<.01)	(<.01)
SUMMER	.15321		.10257	.05199	-.03172		-.08679
	(.74)		(.82)	(.91)	(.94)		(.84)
LOCBMT	.66483	.66483	.57401	.55822	.58134	.63876	.57936
	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)
LOCBDR	-.02230	-.02230	-.08867	-.22949	-.11436		-.11565
	(.91)	(.91)	(.65)	(.24)	(.55)		(.54)
N_PEOPLE	-.05905			-.05277			-.04495
	(.03)			(.05)			(.07)
ADJ_SLAB	.10375			.08877			
	(.17)			(.26)			
N_SMOKER	.09009			.10630			
	(.21)			(.13)			
LNAGEHS	-.04625			-.05477			-.06157
	(.18)			(.20)			(.13)
ENER_EFF	.02528			.01958	.02655	.02516	.02513
	(.01)			(.04)	(<.01)	(<.01)	(<.01)
PC_BRICK	-.07020			.50320		.34598	
	(.45)			(<.01)		(<.01)	
CENT_AC	.09944			.08401			
	(.17)			(.33)			
ROOM_AC	-.14919			-.06130			
	(.06)			(.49)			
FAN_ATIC	.05429			.10389			
	(.60)			(.30)			
CENT_FA	.05843			-.03392			
	(.52)			(.81)			
W_BASE	-.05531			.01585			
	(.62)			(.92)			
CENT_GF	-.30802			-.27069			
	(.19)			(.26)			
ELEC_SPA	-.22500			-.02960			
	(.06)			(.80)			
WOOD	-.03622			-.10073			
	(.63)			(.16)			
KEROHEAT	-.09649			.00570			
	(.47)			(.96)			
GAS_STOV	-.31293			-.24238			
	(.14)			(.24)			
HEAT_OTHER	.12606			.31080			
	(.35)			(.03)			

TABLE 4: MULTIPLE REGRESSION RESULTS FOR MODELS OF HOME RADON CONCENTRATION:
HOMES BUILT OVER BASEMENT AND CRAWLSPACE (CONTINUE)

VARIABLE	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G
BLOCK	.09408			.10501			.13430
	(.27)			(.23)			(.10)
MORT	.13457			.41139			.39434
	(.32)			(<.01)			(<.01)
BRK	.33532			-.13263	.34835		.50465
	(<.01)			(.15)	(<.01)		(<.01)
OTHERBMT	.18767			.32299			.34548
	(.21)			(.03)			(.02)
B_FINISH	.01927			.02686			
	(.81)			(.75)			
ENT_BASE	.26429			.05568			
	(.02)			(.61)			
CRACKS	-.05275			-.03644			
	(.47)			(.61)			
DRAINS	-.04133			-.11459			
	(.66)			(.20)			
SUMP	-.03177			-.00855			
	(.66)			(.26)			
EARTH	.06191			.08333			
	(.45)			(.32)			
CSP_ENTR	.30078			.21091	.23927	.22295	.25269
	(<.01)			(.03)	(.01)	(.01)	(<.01)
CSP_INSL	-.03825			-.06228			
	(.62)			(.40)			
CSP_VENT	-.13419			-.20053	-.18782	-.18901	-.19699
	(.07)			(<.01)	(.01)	(.01)	(.01)
CSP_EXP	.06678			.09223	.19421	.20200	.14370
	(.47)			(.34)	(.03)	(.02)	(.13)
Multiple R^2		.07481	.12360	.25315	.19353	.18992	.21719
(p-value)		(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)
R^4-Change			.04879	.12955			
(p-value)			(<.01)	(<.01)			

TABLE 5: MULTIPLE REGRESSION RESULTS FOR MODELS OF HOME RADON CONCENTRATION: HOMES BUILT OVER BASEMENT BUT NO CRAWLSPACE

VARIABLE	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G
INTERCEPT	-	.68446	.96252	.73018	.84825	.50784	.78389
	-	(<.01)	(<.01)	(.02)	(<.01)	(.02)	(<.01)
WINTER	-.18722		-.16864	-.20245	-.17015		-.17590
	(.13)		(.17)	(.10)	(.16)		(.14)
SPRING	-.46281		-.41092	-.42518	-.40259	-.23534	-.41147
	(<.01)		(<.01)	(<.01)	(<.01)	(<.01)	(<.01)
SUMMER	-.09921		-.09921	-.11711	-.07166		-.09674
	(.76)		(.76)	(.71)	(.82)		(.76)
LOCBMT	.47646	.47646	.39752	.40905	.39413	.57138	.39319
	(<.01)	(<.01)	(.01)	(<.01)	(.01)	(<.01)	(<.01)
LOCBDR	-.29852	-.29852	-.33525	-.47366	-.43520	-.47317	-.36979
	(.19)	(.19)	(.14)	(.04)	(.05)	(.04)	(.11)
N_PEOPLE	.02780			.03166			
	(.12)			(.08)			
ADJ_SLAB	.07140			.11599			
	(.16)			(.04)			
N_SMOKER	.02038			-.00685			
	(.67)			(.89)			
LNAGEHS	-.02615			-.08970		-.08629	-.09404
	(.29)			(<.01)		(<.01)	(<.01)
ENER_EFF	.01519			.02134	.01692	.01666	.01699
	(.02)			(<.01)	(.01)	(.02)	(.01)
PC_BRICK	-.11062			-.07839			
	(.04)			(.15)			
CENT_AC	-.11208			-.12129	-.12048	-.12346	
	(.02)			(.05)	(.02)	(.02)	
ROOM_AC	.04593			-.08926			
	(.43)			(.21)			
FAN_ATIC	-.11001			-.09317			
	(.13)			(.20)			
CENT_FA	-.11838			-.13650			-.11611
	(.05)			(.24)			(.04)
W_BASE	.10301			-.03680			
	(.15)			(.77)			
CENT_GF	.01615			-.14266			
	(.92)			(.47)			
ELEC_SPA	-.02207			-.02826			
	(.80)			(.75)			
WOOD	.02871			.01815			
	(.57)			(.72)			
KEROHEAT	.11347			.12184			
	(.29)			(.25)			
GAS_STOV	-.01023			.02939			
	(.94)			(.83)			
HEAT_OTHER	.06506			-.03535			
	(.52)			(.77)			
BLOCK	.21535			.28573	.27904	.26975	.27563
	(<.01)			(<.01)	(<.01)	(<.01)	(<.01)

TABLE 5: MULTIPLE REGRESSION RESULTS FOR MODELS OF HOME RADON CONCENTRATION: HOMES BUILT OVER BASEMENT BUT NO CRAWLSPACE (CONTINUED)

VARIABLE	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G
MORT	.35438			.46092	.48845	.48387	
	(<.01)			(<.01)	(<.01)	(<.01)	
BRK	.26990			.38522	.40233	.40290	.49618
	(<.01)			(<.01)	(<.01)	(<.01)	(<.01)
OTHERBMT	-.04626			.07880			.39319
	(.72)			(.55)			(<.01)
B_FINISH	-.06937			-.10759		-.11224	.08526
	(.15)			(.03)		(.02)	(.51)
LOCFIN (a)							.64436
							(.12)
ENT_BASE	.02046			-.01569			-.74116
	(.85)			(.89)			(.08)
CRACKS	.08293			.05840			
	(.09)			(.25)			
DRAINS	.04636			.06675			
	(.52)			(.35)			
SUMP	-.02555			-.04301			
	(.59)			(.39)			
EARTH	.09408			.13934			.15700
	(.31)			(.15)			(.10)
Multiple R^2		.02426	.03894	.10581	.08507	.08036	.09169
(p-value)		(<.01)	(<.01)	(<.01)	(<.01)	(<.01)	(<.01)
R^2-Change			.01468	.06687			
(p-value)			(<.01)	(<.01)			

TABLE 6: MULTIPLE REGRESSION RESULTS FOR MODELS OF HOME RADON CONCENTRATION: HOMES BUILT OVER CRAWLSPACE BUT NO BASEMENT

VARIABLE	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G
INTERCEPT	-	.43901	.63841	.28924	.60853	.50219	.74458
	-	(<.01)	(<.01)	(.42)	(<.01)	(<.01)	(<.01)
WINTER	-.16455		-.19250	-.23470	-.26874		-.29359
(.14)		(.09)	(.07)	(.02)		(.01)	
SPRING	-.38879		-.42165	-.40197	-.44044	-.19195	-.50885
	(<.01)		(<.01)	(.01)	(<.01)	(.03)	(<.01)
SUMMER	-.21478		-.27490	-.32321	-.41428		-.39123
	(.24)		(.14)	(.11)	(.03)		(.04)
LOCBMT							
LOCBDR	.11316	.11316	.14463	.15581	.17344		.15547
	(.13)	(.13)	(.05)	(.04)	(.02)		(.04)
N_PEOPLE	.00389			.01128			
	(.89)			(.70)			
ADJ_SLAB	.04341			.10461			
	(.58)			(.20)			
N_SMOKER	.11543			.06467			
	(.11)			(.38)			
LNAGEHS	.04566			.03790			
	(.24)			(.41)			
ENER_EFF	.00355			.01355			
	(.72)			(.21)			
PC_BRICK	.02862			.03722			
	(.77)			(.71)			
CENT_AC	-.02534			.06893			
	(.72)			(.51)			
ROOM_AC	.01281			.02986			
	(.87)			(.77)			
FAN_ATIC	-.29695			-.25446	-.24573	-.26775	
	(<.01)			(.02)	(.02)	(.01)	
CENT_FA	-.05006			-.17104			
	(.52)			(.22)			
W_BASE	.30619			.22883	.36088	.32856	
	(.03)			(.21)	(.01)	(.02)	
CENT_GF	-.57371			-.56661			
	(.07)			(.09)			
ELEC_SPA	-.16027			-.11494			
	(.18)			(.35)			
WOOD	-.07852			-.06947			
	(.34)			(.40)			
KEROHEAT	-.06352			-.00999			
	(.71)			(.96)			
GAS_STOV	.19141			.07700			
	(.17)			(.64)			
HEAT_OTHER	-.19467			-.24163			
	(.39)			(.20)			
CSP_ENTR	.22661			.28046	.26974	.21505	.28106
	(<.01)			(<.01)	(<.01)	(.01)	(<.01)

TABLE 6: MULTIPLE REGRESSION RESULTS FOR MODELS OF HOME RADON CONCENTRATION: HOMES BUILT OVER CRAWLSPACE BUT NO BASEMENT (CONTINUED)

VARIABLE	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G
CSP_INSL	-.12095			-.11359			-.10899
	(.12)			(.16)			(.14)
CSP_VENT	-.08019			-.13048			-.12354
	(.26)			(.08)			(.09)
CSP_EXP	.03655			.01987			
	(.69)			(.83)			
Multiple R^2		.00492	.02936	.11306	.07685	.05571	.06398
(p-value)		(.13)	(.01)	(<.01)	(<.01)	(.00)	(<.01)
R^2-Change			.02444	.08370			
(p-value)			(.01)	(.01)			

TABLE 7: MULTIPLE REGRESSION RESULTS FOR MODELS OF HOME RADON CONCENTRATION: HOMES BUILT OVER SLAB-ON-GRADE ONLY

VARIABLE	MODEL A	MODEL B	MODEL C	MODEL D	MODEL E	MODEL F	MODEL G
INTERCEPT	-	.72577	.30640	-1.38722	.47208	1.07722	-1.47057
	-	(<.01)	(.44)	(.08)	(.23)	(<.01)	(.05)
WINTER	.44310		.43118	.55750	.49918		.40731
	(.27)		(.28)	(.18)	(21)		(.30)
SPRING	.70936		.63447	.79930	.63153		.63846
	(.11)		(.16)	(.09)	(.15)		(.15)
SUMMER	.45747		.38257	.59130	.56041		.36715
	(.32)		(.41)	(.22)	(.23)		(.42)
LOCBDR	.24511	.24511	.21398	.11732	.19420		.19473
	(.14)	(.14)	(.21)	(.52)	(.25)		(.24)
N_PEOPLE	-.06949			-.04225			
	(.31)			(.59)			
N_SMOKER	.25388			.26591			
	(.13)			(.13)			
LNAGEHS	.13552			.23415			.23172
	(.14)			(.03)			(.02)
ENER_EFF	.03208			.08430			.05745
	(.17)			(<.01)			(.03)
PC_BRICK	-.09390			-.23546			
	(.65)			(.28)			
CENT_AC	-.39525			-.54079	-.39441	-.39525	
	(.02)			(.01)	(.02)	(.02)	
ROOM_AC	.10428			-.41429			
	(.60)			(.13)			
FAN_ATIC	.26593			.57891			
	(.43)			(.10)			
CENT_FA	-.16207			.20092			
	(.39)			(.54)			
W_BASE	.13815			.38537			
	(.63)			(.31)			
CENT_GF	.11750			.32170			
	(.82)			(.58)			
ELEC_SPA	-.03449			.13368			
	(.92)			(.71)			
WOOD	-.21622			-.25058			
	(.24)			(.19)			
KEROHEAT	.73459			.91013			
	(.24)			(.17)			
GAS_STOV	-.20941			.20125			
	(.64)			(.70)			
HEAT_OTHER	.09399			.01911			
	(.72)			(.95)			
Multiple R^2		.02009	.03912	.24870	.08740	.05156	.10304
(p-value)		(.14)	(.37)	(.10)	(.08)	(.02)	(.07)
R^2-Change			.01904	.20959			
(p-value)			(.55)	(.09)			