ENERGY USE/WEATHERIZATION AND INDOOR AIR QUALITY: FIELD STUDY RESULTS*

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Abstract

In a recent indoor air quality field study involving over 300 residences, approximately half received an in-depth energy audit. These audits, conducted by trained utility energy advisors, provided an extensive characterization of the building's space conditioning equipment and systems and other factors related to the structure's energy use or weatherization. Comparisons are made between indoor radon levels and the basic house type, crawlspace design, design of the space conditioning system, and the degree of door and window weatherization.

Introduction

An ongoing research question concerns the interrelationship between indoor air quality and building design and energy use. Various researchers have examined these interrelationships in either small samples of homes in a given area (2), or a large sample distributed over a large area (3). To reduce experimental variability from small sample sizes and regional diversity, this analysis is based on a large sample population (140 homes) located in a single East Tennessee county.

From October 1985 through August 1986, an intensive investigation of the indoor air quality in over 300 residences was conducted. This study was a component of a larger study of indoor air quality in six U.S. cities (5). The site of this study was Roane County, Tennessee, which has two small cities, Kingston and Harriman. Radon, NO_2, respirable particulates, bioaerosols, water vapor, formaldehyde, polynuclear aromatic hydrocarbons, and air exchange measurements were made in the winter and the summer season. The radon data obtained from upstairs sampling locations are examined in this paper. Radon measurements were made over a 3-5 month period using a passive alpha-track detector (1).

Approximately half the homeowners participating in the study consented to have a detailed energy audit conducted on their homes. These audits were done by trained utility energy advisors. The audit included inspection of over 150 different building equipment and structural factors and the development of floor plans and side views to illustrate the specific location of relevant features (e.g., duct supplies and returns). These audits assessed the following: housing type; space conditioning system types, fuels, capacities, and design; attic and floor insulation and ventilation; wall insulation; duct insulation and condition; window and door weatherization (e.g., storm windows, weatherstripping, and caulking); building ventilation and air distribution systems (e.g., attic fans, exhaust fans, and ceiling fans); foundation and floor design features; and combustion appliance locations and design. Other building data were also collected.

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Results and Discussion

For the indoor radon data set, a series of comparisons was made between indoor concentrations and four major building and energy use factors. Table 1 presents the distributions of radon levels for different housing types. Basement, crawlspace, and slab building-type assignments were made if their area was 75 percent of the floor area of the structure. Partial basements had areas between 25-75 percent of floor area, and the mixed classification accounted for the remainder. A pair-wise comparison of the data suggests a seasonal effect for the indoor radon data, particularly for the basement, partial basement, and crawlspace building types ($p < 0.05$). The partial basement indoor radon levels were the highest in both winter and summer. Seasonal differences were also observed in the Pacific Northwest (3).

Table 1. Distribution of radon levels (Bq/m^3) among building categories and seasons

Building Type	Season	N	Min.	Max.	Mean	SEM*	Sum./Win. Ratio
Basement	Winter	24	11	250	64	13	0.63
	Summer	27	7	135	40	6	
Crawlspace	Winter	37	13	321	81	13	0.47
	Summer	40	4	237	38	6	
Slab	Winter	4	23	235	82	51	0.34
	Summer	6	11	74	28	10	
Partial basement	Winter	48	18	801	109	20	0.62
	Summer	55	15	381	68	10	
Other	Winter	16	14	152	54	10	0.96
	Summer	20	11	318	52	15	

*Standard error of the mean.

Table 2 further examines some specific effects of building design on indoor pollutant levels. Here the crawlspace design is specifically studied, and the presence of duct work in the crawlspace is the major variable. A pair-wise comparison of the indoor radon data suggests that radon entry may be lower in the summer for crawlspaces without duct work ($p < 0.05$). Transport for unconditioned areas through leaky duct work is a possible rationale for this observation (4).

Table 2. Distribution of radon levels (Bq/m^3) according to duct location for crawlspace houses

Return Duct Location	Season	N	Min.	Max.	Mean	SEM*
Crawlspace	Winter	15	13	309	103	25
	Summer	17	7	237	54	14
Other/None	Winter	19	18	321	68	17
	Summer	20	4	78	26	5

*Standard error of the mean.

Table 3 compares indoor radon levels with the basic design of the building's space conditioning system (i.e., convecting or nonconvecting). The primary difference between these designs is the degree of air mixing and transport. Convective systems exhibited higher summer indoor radon levels than the nonconvective systems ($p < 0.05$). The nonconvective data showed a significant seasonal dependence ($p < 0.05$). As with the crawlspace analysis, transport from unconditioned areas or basements may explain differences observed between convecting and nonconvecting systems (i.e., forced air vs radiant heat).

Table 3. Distribution of radon levels (Bq/m^3) according to type of heating, ventilation, and air conditioning (HVAC) system

HVAC Type	Season	N	Min.	Max.	Mean	SEM*
Convecting	Winter	74	11	555	88	10
	Summer	85	7	381	68	8
Woodburning (nonconvecting)	Winter	22	12	801	90	35
	Summer	25	4	137	34	7
Mixed (nonconvecting)	Winter	33	18	321	73	13
	Summer	38	7	81	25	3

*Standard error of the mean.

A question of primary interest concerning indoor air quality and building characteristics is weatherization. Usually weatherization means caulking, weatherstripping, and the use of storm windows and storm doors. Table 4 compares the degree of window and door weatherization to indoor radon levels. Interestingly, pair-wise analysis did not identify a significant interaction ($p < 0.05$) between house sets where both doors and windows were completely weatherized and when they were not. Once again, a seasonal effect in these two data sets was observed ($p < 0.05$).

Table 4. Distribution of radon levels (Bq/m^3) according to weatherization of doors and windows

Weatherized Doors	Weatherized Windows	Season	N	Min.	Max.	Mean	SEM*
Yes	Yes	Winter	30	22	272	81	12
		Summer	37	11	281	54	8
Yes	No	Winter	11	14	100	45	7
		Summer	12	4	111	37	9
No	Yes	Winter	32	12	555	91	18
		Summer	36	7	381	62	14
No	No	Winter	56	11	801	91	17
		Summer	63	7	252	46	6

*Standard error of the mean.

The results presented in this paper are very preliminary. A more detailed analysis of the available data to examine the effects of other building variables (e.g., age, location, etc.) is being performed. Therefore, these results should be interpreted cautiously. The conclusions from this study are that basic building design and energy use factors can have a significant influence on the levels of indoor radon levels. However, building technology options exist and can be implemented which lowers the amount of radon that enters a house.

References

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