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THE EFFECT OF BUILDING CODES AND HOUSE AGE ON RADON CONCENTRATIONS IN MINNESOTA

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ABSTRACT

Many public radon reduction programs focus on making changes in building codes to include radon resistant features. In Minnesota, attempts to get radon-resistant construction into the building code have been resisted by builders' associations. Opponents claim that recent changes to the existing Minnesota code have already reduced radon in newly constructed homes. To investigate this claim, long-term radon concentrations were measured in the living spaces in three different groups of homes. The first two groups were sampled as part of radon mapping project. These homes were randomly selected from selected zip code areas throughout Minnesota. When no statistically significant radon difference was found in these homes built in different eras, a regionally focused study was conducted in central Minnesota. Houses in six towns, where the new code is required, were sampled to compare new and old houses that were similar in geology, climate and housing styles. No statistically significant difference was found between the radon concentrations in the homes built with the new code compared to those neighboring homes built with older codes. These data suggest that there is little difference in the median indoor radon concentration or percentage of homes exceeding the radon action level for houses constructed during the past 50 years, either with the old statewide building code, the new code, or a local code.

INTRODUCTION

Radon-resistant building practices for new construction (RRNC) are a goal of many public radon reduction programs. In Minnesota, attempts to get RRNC into the building code have been resisted by builders' associations. RRNC opponents claim that recent Minnesota code changes to improve energy efficiency and quality standards have already reduced radon in new homes. In 2000, the state building code was changed to include new energy conservation practices. Among the provisions of the new energy code with potential radon altering effects were new ventilation and gas entry standards. The new provisions called for continuous vapor barriers, sub grade waterproofing, and balanced interior ventilation standards. In 2003, the building code was changed again to add some of the specifications of the International Residential Code (IRC). These changes could affect radon entry and exit through altering the integrity of structural components (MNDIL 2006). However, the specific section of the IRC that would include explicitly include RRNC, Appendix F, were not adopted in the 2003 state code.

The Minnesota Department of Health (MDH) proposed in 2005 that Appendix F be added to the state code. The Builder's Association of Minnesota (BAM) opposed that proposal (Linner 2005). The most important reason cited by BAM in opposition was the lack of information about the number of newly constructed homes with radon concentrations that exceed the US EPA action level of 4 pCi/L. BAM cited anecdotal evidence from builder initiated radon measurements as proof that newly constructed homes didn't have a serious radon problem. They identified the current code requirements for new clean fill under the slab covered by a continuous polyethylene barrier along with stack pressure reductions created by envelope sealing, mechanical ventilation, and vented appliances as important radon-reducing features that were already in place.

These features do have the potential to affect radon entry and egress. However, the difference between policy and practice along with the possible interaction between the changes in radon entry and egress caused by the new standards suggest that only an empirical test could substantiate their claim. The purpose of this work is to provide a scientific examination of the question: Do the recent changes to the Minnesota State Building Code significantly reduce or eliminate elevated indoor radon concentrations in new construction?

METHODS

Sampling sites and measurement protocols

Mapping survey houses

Preliminary data on indoor radon, house age, and building codes were collected from a randomized sample of homes that were being measured as part of a statewide mapping project. Towns were selected for this project based on the need for adequate coverage of the rapid radon spatial variation and densely populated areas. Within a selected town, participants were solicited randomly from a list of telephone numbers. Those who agreed to participate were sent a RADTRAK® (Landauer Inc. Glenwood, IL) detector with instructions to expose it for 90 days in the lowest level of their home where someone spent 10 or more hours per week. They were also given additional placement instructions that conform to the EPA detector placement protocol.

This mapping survey started in 2001 but only houses from the 2003-04 and 2004-06 enrollment period are included in this work. In the 2003-04 periods, the towns were selected to try to sample near high indoor radon gradient regions. This sample comes mostly from the southern and western portions of Minnesota where new houses are less common. (See Figure 1) In 2005, questionnaires were sent to these participants as a follow-up to the radon measurements. Because the issue of the possible effects of house age and building codes on indoor radon was being discussed by the Minnesota Department of Health (MDH), a question was included about the house age. Participants were asked to indicate if their house was new (built in 2000-2004), recent (1999-1984), old (1983-1954) or very old. The 2004-2005 survey participants were contacted by telephone after receiving their radon results and asked the year that their house was built. During 2005 -2006, the age of the house was obtained from the participants when they enrolled in the survey. This sample of house was statewide but was geographically biased to the more heavily populated eastern and southern parts of Minnesota. A preliminary analysis of the data from these two groups showed that the radon distributions had large standard deviations. This made comparisons between houses of different ages more difficult.

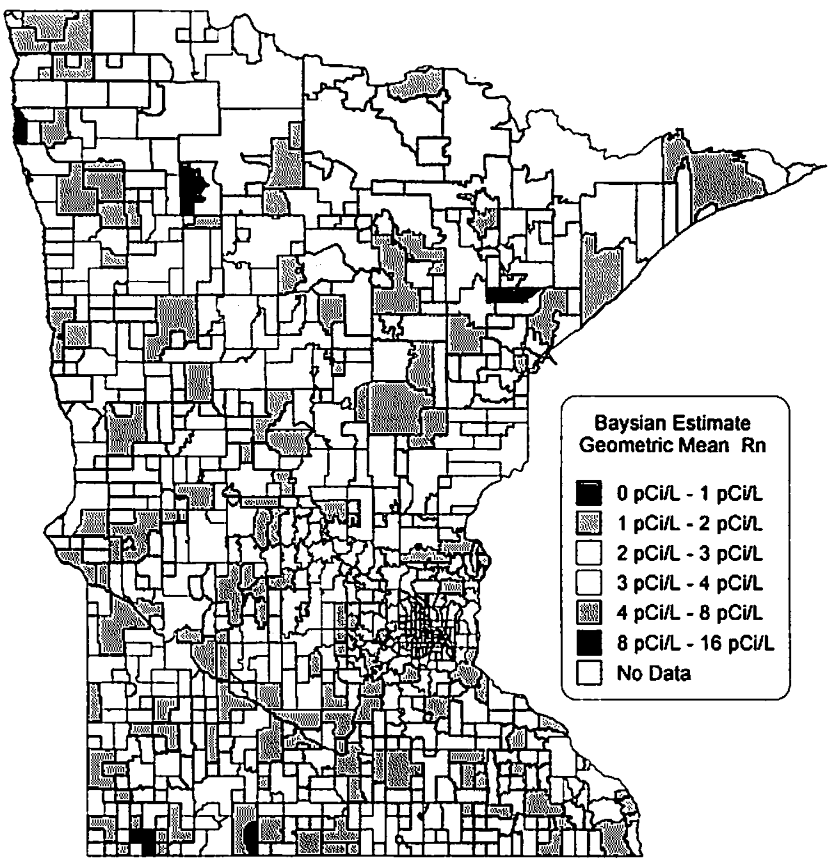

Figure 1 Preliminary Radon Map of Minnesota by postal code areas

Central Minnesota regional houses

To reduce the variation in age comparison groups that might be caused by other factors, a focused study was started in March 2006 in central Minnesota. The regional sample should reduce variations in the results that may be due to sampling location, season, weather, geological source potential and housing styles. The selected region shows low town-to-town radon variation. New houses, those built in 2003 or later, were selected from building permit lists of two neighborhoods of a small city (St. Cloud), three of its suburbs, and two rural towns in a 200 square-mile area centered on Collegeville (roughly in the center of the map above; halfway between the indentation along the eastern border and the protuberance along the western border). The surface material in the populated areas of these towns is glacial till from the same general geologic source and has similar radium content. In each house, two ATDs were exposed for 90 days. While the instructions asked for exposure on the two lowest lived-in levels, a sizeable fraction of these homes only had one occupied level. Following the enrollment of the new houses, additional participants were solicited from nearby houses to get a sample of older houses located in similar conditions.

Statistical analysis

Two measures were used to compare the relative radon concentrations of different aggregates of houses. Since most of the aggregates that contain large numbers of houses are distributed log normally, the geometric means and geometric standard deviation were used for statistical tests (t and F tests). In addition, the percentage of homes that exceed the USEPA action level (4 pCi/L [150 Bqm^{-3}]) provides a measure relative to a policy standard for the changes that may be caused by age or building practices.

RESULTS

Table 1 shows the radon distribution parameters for the two data sets from the mapping project homes. For newer homes in the 2000-06 group, three aggregates are used to try to compare the effects of recent code changes. One aggregate, houses built from 2000 to 2002, would reflect any changes that may have been caused by the adoption of the 2000 energy provisions alone. The second aggregate, houses built between 2003 and 2006, would reflect additional changes brought about by the 2003 IRC adoption. Since the number of samples is limited for these new houses, we also aggregated all house built after 2000 into a third group for comparison (show as the shaded row in Table 1).

Table 1: The distribution of indoor radon (^{222}Rn) measured in selected mapping project Minnesota homes grouped by age.

Data Set Era	N	^{222}Rn Mean[1]	^{222}Rn GM[2] (GSD)	% ≥ 4 pCi/L
Map 03-04	95	6.3	5.5 (1.6)	70
Young	8	6.6	5.6 (1.7)	75
Recent	25	6.8	5.9 (1.7)	80
Old	39	6.1	5.6 (1.5)	70
Very old	23	5.9	4.9 (1.7)	60
Map 04-06	483	4.2	3.0 (2.3)	35
2000-2006	45	4.7	3.4 (2.3)	50
2003-2006	20	4.6	3.6 (2.1)	60
2000-2002	25	4.8	3.2 (2.5)	45
1990-1999	73	3.9	2.7 (2.4)	40
1980-1989	56	4.8	3.1 (2.7)	40
1970-1979	68	4.5	3.2 (2.3)	30
1960-1969	41	4.7	3.2 (2.5)	40
1950-1959	41	3.9	3.1 (2.0)	35
1940-1949	27	3.6	2.7 (2.2)	30
1930-1939	27	4.9	3.2 (2.5)	45
1920-1929	29	3.3	2.4 (2.3)	25
1910-1919	15	3.0	2.3(2.0)	20
1900-1909	47	4.3	3.0 (2.3)	30
1840-1899	14	3.3	2.5 (2.1)	15

[1]Units are pCi/L
[2] Lognormal distribution; Geometric mean and (geometric standard deviation).

Figures 2 and 3 compares the geometric means of houses built in different eras without regard to the building code status. Figure 4 and 5 show geometric means and the percentage of homes exceeding the action level separately by code status. The extreme values for the NO code houses in 2000 result from the random fluctuations that can affect a small sample like this (3). For every other grouping, the distribution parameters are so similar between code status cases that no separate description is needed.

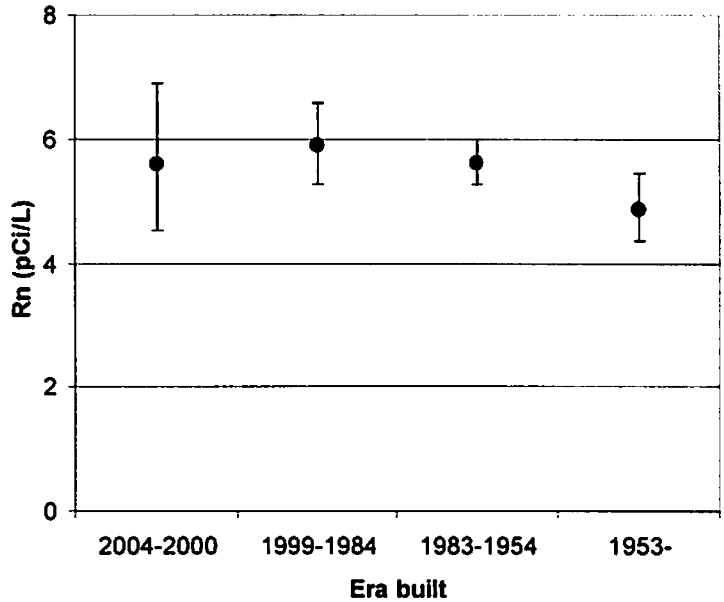

Figure 2 Geometric means, with uncertainties, of radon in houses measured by age block for mapping project houses measure from 10/2003 to 10/2004.

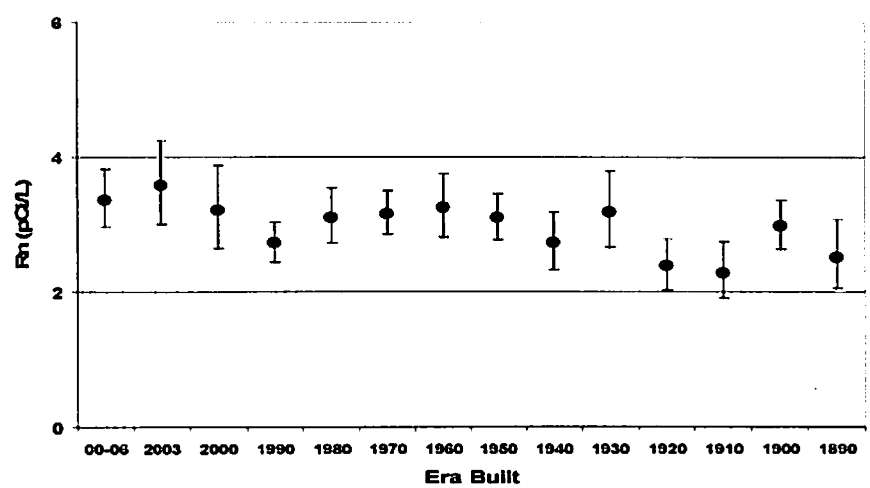

Figure 3 Geometric means, with uncertainties, of houses measured by age block for mapping project houses measured from 10/2004 to 11/2006.

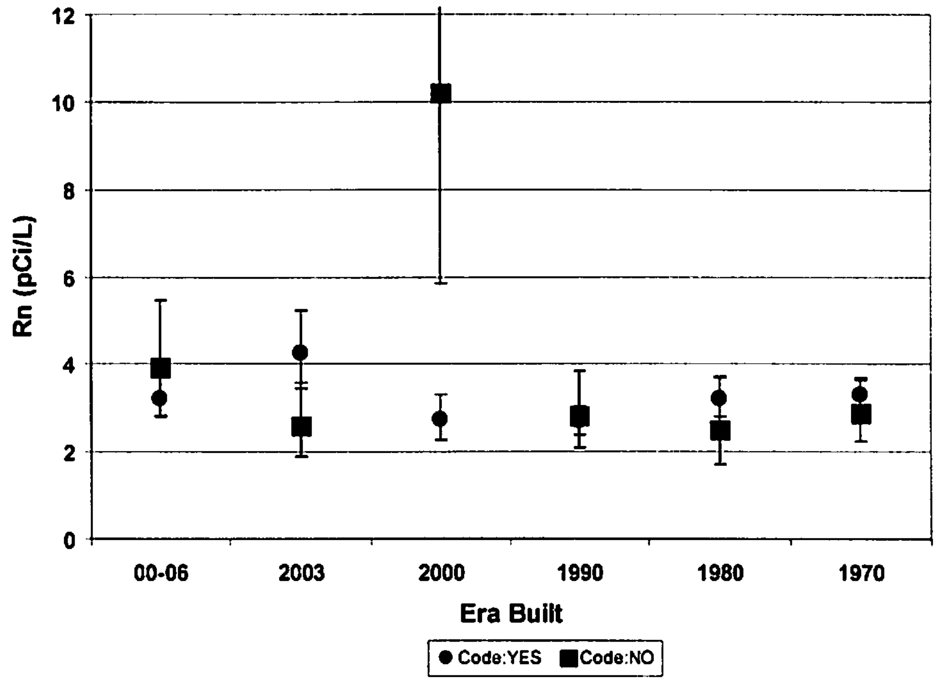

Figure 4 Geometric means, with uncertainties, of houses measured by age block and building code coverage status for mapping project houses measured from 10/2004 to 11/2006.

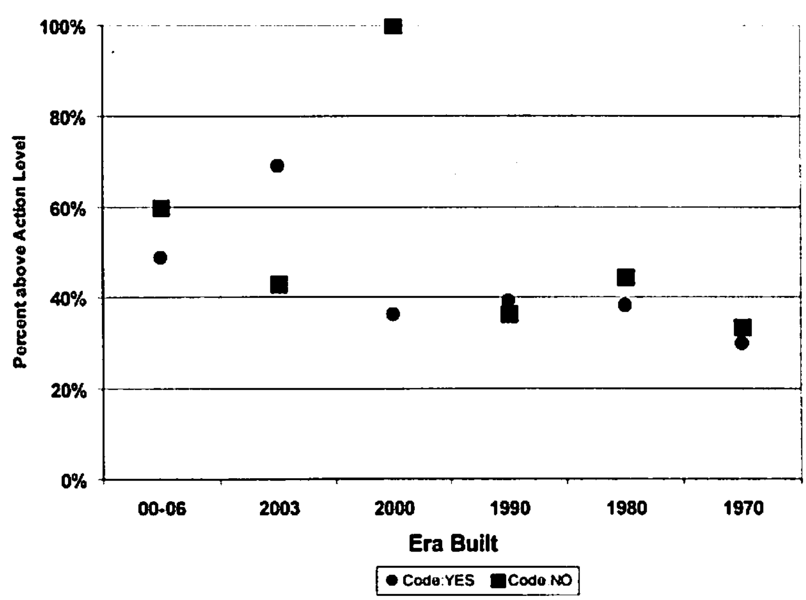

Figure 5 Percent of houses exceeding the EPA action level by age block and building code status.

Table 2 Indoor radon measured in the living spaces of selected central Minnesota homes.

Data Set	N	^{222}Rn Mean[1]	^{222}Rn GM[2] (GSD)	% ≥4 pCi/L
Built 2003-2006	37			22
Basement	25	3.0	2.4 (2.0)	30
First Floor	37	1.7	1.4 (1.9)	3
Before	50			22
Basement	40	3.1	2.7 (1.8)	28
First Floor	49	2.0	1.6 (1.9)	8
ALL	87			22
Basement	65	3.1	2.5(1.9)	
First Floor	86	1.9	1.5(1.9)	

[1]Units are pCi/L
[2] Lognormal distribution; Geometric mean and (geometric standard deviation).

The measurements from the 87 houses studied in Central Minnesota are shown in Table 2. The final data set contains 37 houses built with the 2003 code and 50 built under earlier codes.

DISCUSSION

There have been few reports in the scientific literature of the dependence of indoor radon concentrations on house age or surveys of the effects of building codes on radon.

Cohen observed no age dependence of radon in a Pittsburgh area study but in a later national survey he found a slight dependence in two decade age groups, slightly elevated radon or the1940-50's era and slightly lower in the1920-30's (Cohen 1985, 1986).

No statistically significant age effect is apparent in our two mapping survey data sets. It is clear that roughly 50% of these new Minnesota homes that were built under the 2003 state building code have radon concentrations that exceed the EPA action level.

The focused study in Central Minnesota has the potential to detect smaller differences that the new code may cause. All these houses were built subject to the state code in force at the time of construction. This region has slightly below average radon compared to the rest of Minnesota. In our sample, the older houses tended to have a larger fraction of basements used as living spaces (80% vs. 70%). This may reflect the recent local trend toward building patio homes. In comparing new houses to older ones, there is little meaningful difference between radon distributions, including the percent of homes that exceed the EPA action level.

CONCLUSIONS

There is little difference in the indoor radon concentration distributions for Minnesota houses constructed during the past 50 years. The percentage of homes exceeding the radon action level is the same for homes built, either with the old statewide building code, the new code, or a local code. It appears that the 2003 state building code features do not significantly affect indoor radon in Minnesota.

ACKNOWLEDGMENTS

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