Survey of Radon Testing and Mitigation by Wisconsin Residents, Landlords, and School Districts

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ABSTRACT

Introduction: Radon is the second-leading cause of lung cancer in the United States, the leading cause of lung cancer in nonsmokers, and is estimated to cause 21,000 deaths every year. Radon is especially prevalent in the upper Midwest. This study aimed to assess radon testing and mitigation practices among residential homeowners, landlords, and school districts in Wisconsin.

Methods: Two survey sample datasets were used to assess radon testing and mitigation in residential homes: the Survey of the Health of Wisconsin (SHOW) and Wisconsin Behavioral Risk Factor Surveillance System (BRFSS) survey. Wisconsin landlords and school administrators were surveyed to assess radon testing and mitigation in rental properties and schools, respectively.

Results: Approximately 30% of Wisconsin homeowners (22.1% from SHOW and 39.9% from BRFSS) have tested their properties for radon. Similarly, 31.0% of Wisconsin landlords (40/129) and 35.1% of Wisconsin school districts (78/222) have tested their schools for radon. Of homeowners with elevated radon, about 60% mitigated. School districts whose radon levels tested high most commonly did not mitigate, with costs and/or lack of funding cited as the most common barrier.

Discussion/Conclusion: Radon testing and mitigation practices are inadequate in Wisconsin, and future work will seek to determine the best methods to increase testing and mitigation and reduce radon-induced lung cancer deaths in Wisconsin.

INTRODUCTION

Radon is a naturally occurring, colorless, odorless, radioactive, carcinogenic gas that comes from the soil. It is the largest source of background radiation, making up 37% of Americans' total annual radiation exposure.[1] Radon exposure is the second-leading cause of lung cancer nationwide, causing about 21,000 deaths per year in the United States and about 500 deaths per year in Wisconsin.[2] The initial evidence for radon causing lung cancer comes from studies of thousands of uranium miners carried out over 50 years worldwide,[3,4] and further evidence has been provided from residential studies.[5-7] Radon also poses a risk to smokers and may actually synergize with smoking to cause lung cancer;[8,9] indeed, some estimates suggest that a majority of radon-induced lung cancers occur in smokers.[7]

Radon in the home is often assessed at the point of real estate transactions by a certified professional. Alternatively, radon can be assessed using self-test kits, which can be purchased for about $10 from a local health department or hardware store. In Wisconsin, there are 17 local health departments that serve as radon information centers for the general public and test kits are made available at reduced rates. Results from test kits are used to populate an online interactive map that illustrates radon risk potential in the state (https://www.dhs.wisconsin.gov/radon/index.htm). Although high levels of radon have been detected in every state, the upper Midwest has some of the highest levels in the country.[10] The Environmental Protection Agency (EPA) recommends taking action to mitigate radon levels once indoor concentrations meet or exceed 4 pCi/L. However, there is no "safe" level of radon exposure. In Wisconsin, 29 out of 72 (40.3%) counties have a predicted average indoor radon screening level greater than 4 pCi/L, and the remaining 43 (59.7%) counties have a predicted average indoor radon screening level between 2 and

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4 pCi/L.[11] However, these data do not necessarily indicate geographic areas of highest risk, and it is recommended that all homes be tested for radon.

Fortunately, elevated indoor radon levels can be prevented or mitigated with a variety of strategies. Radon-resistant construction techniques can be implemented at the time of building construction, and the cost to the builder of including radon-resistant features in a new home during construction is typically less than the cost to mitigate the home after construction. After construction, elevated radon levels can be easily reduced with an active mitigation system, which usually is installed by a professional and costs about $1000.

Herein, we sought to assess awareness and knowledge of radon in Wisconsin and to determine what percentage of residents, landlords, and school districts in the state have ever tested for radon and mitigated their building(s) if radon levels were high.

METHODS

Survey of the Health of Wisconsin (SHOW)

The Survey of the Health of Wisconsin (SHOW), collected from 2008 to 2013, has been previously detailed.[12] The question "Have you tested for radon in this home? (yes, no, refused, don't know)" was used to assess prevalence of radon testing. If respondents indicated "yes," they were subsequently asked, "What was the result of this test?" Response options included "positive but below recommended action level," "positive but above recommended action level," positive but don't remember action level," or "negative." Data were analyzed using SAS (version 9.4). Rao-Scott Pearson chi-square tests were used to test for significant differences. Multiple logistic regression modeling was performed to assess the relative importance of select demographic factors. Analyses accounted for the clustering and stratification in the sampling design and were weighted to the adult population of Wisconsin age 21 to 74.

Wisconsin Behavioral Risk Factor Surveillance System

The Wisconsin Behavioral Risk Factor Surveillance System (BRFSS) is part of the national surveillance system coordinated by the Centers for Disease Control and Prevention (CDC) to measure adult health risk behaviors and health outcomes by a random-digit-dialed landline and cellular telephone survey of residents aged 18 and older. Prevalence estimates from the core survey questions and a state-added optional radon module were analyzed. Respondents were asked: "Are you aware of the health risks associated with exposure to radon?"; "Has your household air been tested for the presence of radon gas?"; and "Were the radon levels in your household above the Environmental Protection Agency's recommendation action level of 4 picocuries per liter?" If respondents reported a value greater than the EPA's action level (4 pCi/L), they then were asked: "In response to a high radon test, did you take any of the following actions? and were allowed to choose as many of the following choices that applied: retest, have a mitigation system installed, no longer go in basement, do nothing, or do something else. BRFSS core survey demographics were analyzed with the radon module, including age (categorized as 18-34 years, 35-64 years, or 65 years and over), homeowner status (categorized as homeowners, renters, or other), and geographic location in Wisconsin (northern, northeastern, western, southern, or southeastern). Annual Wisconsin BRFSS data from 2014 to 2016 were combined to increase precision of estimates. Data were analyzed using SAS (version 9.4). Rao-Scott Pearson chi-square tests were used to test for significant differences.

Survey of Landlords

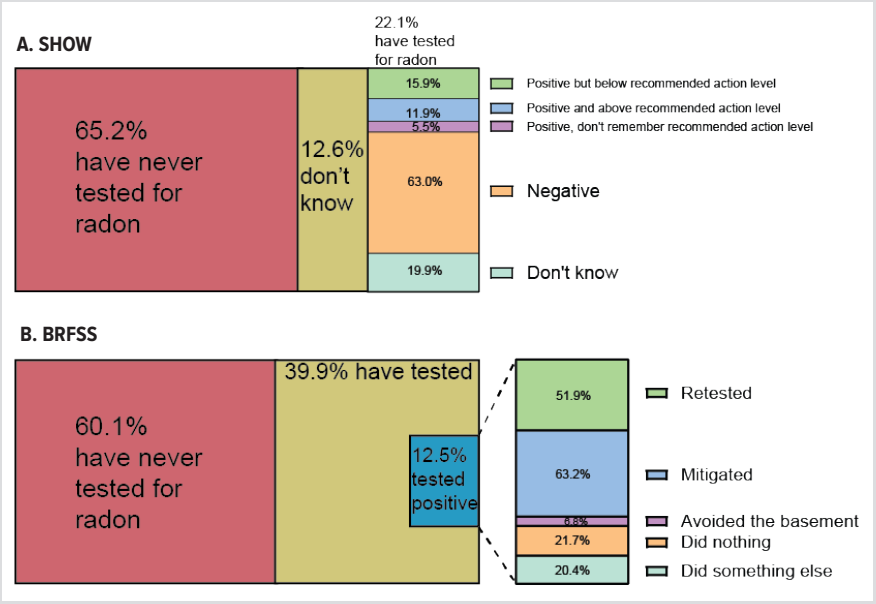
A list of Wisconsin landlords was obtained using the Wisconsin Housing Search (WIHousingSearch.org) database, which compiles a listing of rental housing throughout the state. Lists of landlords were collected from the following metropolitan areas: Milwaukee, Madison, Green Bay, Kenosha, Racine, Appleton, Oshkosh, Eau Claire, Janesville, La Crosse, and Fond du Lac. These areas were chosen because they represent the largest population centers in Wisconsin (combine for approximately 25% of Wisconsin's total population) and are geographically dispersed throughout the state. The Dane County Tenant Resource Center (www.tenantresourcecenter.org) provides a list of Madison's management and rental companies, and this resource was used to supplement the list of landlords contacted in Madison. We randomly selected a subset of landlords within each metropolitan area and called the following number of landlords from each area: 30 from Milwaukee (12 completed responses, 40.0% response rate), 89 from Madison (26 completed responses, 29.2% response rate), 13 from Green Bay (11 completed responses, 84.6% response rate), 17 from Kenosha (13 completed responses, 76.5% response rate), 8 from Racine (7 completed responses, 87.5% response rate), 9 from Appleton (1 completed responses, 11.1% response rate), 11 from Oshkosh (10 completed responses, 90.9% response rate), 63 from Eau Claire (19 completed responses, 30.2% response rate), 14 from Janesville (9 completed responses, 64.3% response rate), 14 from La Crosse (11 completed responses, 78.6% response rate), and 14 from Fond du Lac (12 completed responses, 85.7% response rate). This yielded a total of 282 landlords that were contacted. One hundred fifty-one (53.5%) refused to participate, did not answer the phone after 3 attempts, did not respond to voice mails, or did not respond to an email if an email address was given during the initial phone call. This yielded a total of 131 completed responses. *(See Appendix 1 for survey questions.)*

Survey of School Districts

Public schools were surveyed to assess potential risks of exposure to radon among school children. A publicly available list of school administrators was obtained from the Wisconsin

Department of Public Instruction (DPI). A survey was emailed 3 times to these public school administrators for all districts in Wisconsin (n = 443 administrators). This yielded 174 responses (39.1% response rate). Subsequently, administrators who did not respond were called. This survey yielded a total of 231 completed responses (final response rate of 52.1% of school districts in Wisconsin). A response was considered completed if all survey questions except for the free response questions were completed. Fifty-three responses (22.9%) were obtained from superintendents, 81 (35.1%) from directors/managers of buildings and grounds or facilities, 52 (22.5%) from other district administrators, and 45 (19.5%) from other staff. *See Appendix 2 for survey questions.*

Figure 1. Survey of the Health of Wisconsin (SHOW) assessment of Radon Testing by Wisconsin Residents



1A. Treemap demonstrating the percentage of Wisconsin residents in the Survey of the Health of Wisconsin (SHOW) who have tested for radon and whether their tests were positive or negative.
1B. Treemap demonstrating the percentage of Wisconsin residents in the Wisconsin Behavioral Risk Factor Surveillance System (BRFSS) survey who tested for radon, and mitigated if radon levels were high based on whether they are homeowners or renters.

Statistics

Prior to the study, R (V 3.3.1) was used to calculate expected half-widths of Wald 95% confidence intervals based on various combinations of possible sample sizes and response proportions for both school districts and landlords. Expecting that the response proportion of respondents (for both landlords and school districts) that tested for radon would be 0.25, it was found that a survey sample of at least 73 schools and 73 landlords would result in confidence interval half-widths of approximately 0.1 (Appendix 3A-B).

RESULTS

Radon Awareness, Testing, and Mitigation Practices Among Wisconsin Residents

The SHOW study surveyed 3381 participants from 2008 to 2013, of whom 2753 reported having a basement in their home. Of those with basements, 22.1% (95% CI, 20.0-24.3) reported that they tested their home for radon, 65.2% (95% CI, 62.3-68.1) reported that they had not tested their home for radon and 12.6% (95% CI, 10.6-14.6) responded that they did not know if they had tested their home for radon (Figure 1, Table 1). This percentage did not differ significantly based on sex or urbanicity (Table 1). There was a trend toward greater testing rates for older respondents (Table 1). Also, respondents with higher educational attainment and higher per capita household income were significantly more likely to test for radon (Table 1). Multivariate analysis revealed higher education and home built before 1900 to be associated with testing for radon.

Based on estimates from the 2014-2016 BRFSS sample, 73.4% of Wisconsin residents report being aware of the health risks associated with exposure to radon (Figure 1B). Just over 80% (80.4%) of Wisconsin residents who own their home are aware of radon risks, compared to 54.7% of renters and 47.5% of those who reported living in other arrangements (Table 2). Nearly 40% (39.9%) of Wisconsin residents have tested their households for the presence of radon, which translates to approximately 1.34 million residents. Again, the testing rate was higher for homeowners (41.9%) compared to renters (33.9%) and residents who reported other living arrangements (28.7%) (Table 2). Of the Wisconsin residents who tested for radon, 12.5% found elevated levels of radon (above 4 pCi/L). Of those residents who reported elevated radon levels, 51.9% retested, 63.2% mitigated, 6.8% avoided the basement, 21.7% did nothing, and 20.4% did something else (respondents could select more than 1 choice). Twice as many homeowners as renters mitigated if they found an elevated test result (67.7% of homeowners vs 30.2% of renters and 51.7% of those in other living arrangements) (Table 2).

This study next assessed if there were differences in radon awareness based on age and geographic location. Adults 65 years and older reported the greatest radon awareness (81.8%) compared to younger age groups, but there were no significant differences in testing and mitigation practices based on age (Table 2). When assessing potential differences based on geographic area, radon awareness was greatest in northern Wisconsin (81.1%) and lowest in southeastern Wisconsin (68.9%) (Table 2). Additionally, those from northeast Wisconsin were the most likely to report testing for radon (Table 2). Interestingly, those

Table 1. Survey of the Health of Wisconsin (SHOW) Assessment of Radon Testing

	Tested		Not tested		Don't know				
	N	Percentage[a]	N	Percentage[aa]	N	Percentage[a a]	Chi-Square *P*-value	OR[b]	Regression *P*-value
All participants with basements[c]	637	22.1 (20.0-24.3)	1770	65.2 (6.23-68.1)	346	12.6 (10.6-14.6)			
Age									
21 - 39	166	18.6 (15.5-21.8)	507	61.9 (57.2-66.5)	178	19.5 (15.7-23.3)	<0.001	1.03 (0.67-1.56)	0.91
40 - 54	241	25.2 (21.6-28.8)	625	65.6 (61.1-70.1)	82	9.2 (6.3-12.1)		1.22 (0.92-1.64)	0.17
55 - 74	230	22.6 (19.3-25.9)	638	69.0 (64.9-73.0)	86	8.4 (6.4-10.3)		Ref	
Sex									
Male	273	22.3 (19.4-25.2)	802	66.6 (62.7-70.5)	131	11.1 (8.3-13.8)	0.11	0.95 (0.76-1.19)	0.63
Female	364	21.9 (19.3-24.6)	968	63.9 (60.6-67.2)	215	14.2 (11.9-16.5)		Ref	
Race/ethnicity									
Non-Hispanic white	532	22.6 (20.2-25.0)	1537	66.2 (63.4-68.9)	277	11.2 (9.4-13.1)	0.04	Ref	
Non-Hispanic black	56	19.5 (12.7-26.4)	120	57.7 (47.1-68.3)	36	22.7 (12.0-33.5)		1.60 (0.83-3.07)	0.16
Hispanic	17	20.5 (11.4-29.6)	47	57.7 (37.1-78.3)	13	21.8 (3.3-40.3)		1.40 (0.68-2.92)	0.36
Other	32	18.7 (9.2-28.2)	62	63.7 (53.4-74.0)	20	17.6 (8.0-27.2)		1.38 (0.65-2.94)	0.40
Education									
High school degree or less	148	17.0 (13.4-20.5)	524	66.0 (60.7-71.4)	116	17.0 (12.4-21.6)	<0.001	0.45 (0.32-0.64)	<0.01
Some college or associate's degree	217	20.3 (17.2-23.4)	680	66.8 (62.7-70.9)	132	12.9 (10.0-15.9)		0.67 (0.51-0.89)	0.01
Bachelor's degree or higher	272	28.2 (24.2-32.2)	565	62.9 (58.8-67.1)	97	8.9 (6.7-11.1)		Ref	
Poverty									
< 200% FPL	125	15.2 (11.8-18.6)	456	61.9 (57.3-66.5)	159	22.9 (18.0-27.8)	<0.001	0.87 (0.56-1.36)	0.54
≥ 200% FPL	487	24.6 (21.8-27.5)	1248	67.1 (63.7-70.5)	159	8.3 (6.6-9.9)		Ref	
Urbanicity (2010 Census)[d]									
Urban	407	22.0 (19.5-24.6)	1107	63.9 (60.4-67.4)	241	14.1 (11.4-16.8)	0.05	1.00 (0.72-1.38)	0.99
Rural	230	22.4 (18.2-26.6)	663	68.1 (63.3-72.8)	105	9.5 (7.3-11.7)		Ref	
Wisconsin health region									
Southeastern	230	23.9 (20.0-27.8)	538	62.5 (56.7-68.2)	117	13.6 (9.4-17.8)	0.56	1.10 (0.72-1.67)	0.66
Southern	124	21.2 (17.6-24.7)	352	64.4 (59.7-69.1)	75	14.4 (10.9-18.0)		0.91 (0.60-1.36)	0.64
Western	63	19.5 (13.3-25.8)	240	67.3 (59.6-75.0)	54	13.1 (6.3-19.9)		0.86 (0.51-1.46)	0.57
Northern	86	21.8 (15.8-27.8	250	69.9 (64.2-75.6)	34	8.3 (5.6-11.0)		0.92 (0.56-1.53	0.75
Northeastern	134	22.0 (16.5-27.4)	390	67.6 (61.2-74.0)	66	10.4 (7.4-13.5)		Ref	
Year of home construction									
Before 1900	51	15.8 (11.4-20.1)	197	67.3 (60.8-73.7)	41	17.0 (11.5-22.5)	0.0003	0.61 90.39-0.94)	0.03
1900 - 1950	133	20.5 (16.6-24.4)	406	69.1 (64.7-73.5)	67	10.4 (7.4-13.3)		0.70 (0.47-1.05)	0.09
1951 - 1978	186	26.8 (22.2-31.5)	416	62.5 (56.6-68.3)	65	10.7 (7.0-14.4)		1.08 (0.75-1.56)	0.68
1979 - 1990	82	28.8 (21.5-36.0)	177	63.5 (56.1-71.0)	28	7.7 (4.4-11.0)		1.13 (0.69-1.85)	0.62
1991 - present	138	26.6 (21.7-31.5)	355	65.6 (60.4-70.9)	49	7.8 (5.1-10.5)		Ref	
Duration at current residence (years)									
< 1	38	13.7 (8.5-19.0)	159	66.1 (58.8-73.4)	56	20.2 (14.2-26.2)	<0.001	0.78 (0.42-1.47)	0.44
1 - 4	132	21.3 (16.7-25.9)	365	60.6 (54.8-66.4)	105	18.1 (13.8-22.4)		1.06 (0.68-1.67)	0.79
5 - 9	133	23.3 (18.3-28.2)	377	67.5 (62.5-72.6)	58	9.2 (6.7-11.7)		0.84 (0.56-1.26)	0.40
≥ 10	332	24.3 (21.3-27.3)	856	66.5 (62.4-70.6)	121	9.2 (6.8-11.6)		Ref	

[a]Row percentages weighted to represent the civilian, noninstitutionalized population of Wisconsin age 21 to 74. The estimates also account for the stratification and clustering in the complex survey design.

[b]Multiple logistic regression model of the response "Tested for radon," adjusted for all of the variables in the table, as well as stratification and clustering in the complex survey design.

Abbreviation: FPL, federal poverty level.

from southeast Wisconsin were most likely to report elevated radon levels, yet they were not the most likely to report mitigation if radon levels were high (Table 2). Those from south and northeast Wisconsin were the most likely to mitigate if radon levels were elevated (Table 2).

Radon Testing and Mitigation Practices Among Wisconsin Landlords

This study also assessed radon testing and mitigation practices by lessors/landlords/management companies in Wisconsin (Figure 2A). We found that 31.0% of surveyed landlords reported that they had ever tested at least one of their buildings, while 49.6% reported that they had never tested, and 19.4% were unsure (Figure 2B). There is no significant trend in likelihood to test for radon based on the size of the landlord or management com-

Table 2. Wisconsin Behavioral Risk Factor Surveillance System (BRFSS) Survey of Radon Awareness, Testing, and Mitigation

	Radon Awareness			Radon Testing			Tested and Radon Was Elevated			Elevated Radon and Mitigated		
	N (weighted)	Percentage	*P*-value	N (weighted)	Percentage	*P*-value	N (weighted)	Percentage	*P*-value	N (weighted)	Percentage	*P*-value
Age (years)												
18-34	526,950	55.3 (52.6 - 58.0)	< 0.001	344,326	39.8 (37.1 - 42.5)	0.102	34,379	11.10 (8.4 - 13.9)	0.347	19,241	60.2 (47.4 - 73.0)	0.118
35-64	1,438,601	79.2 (77.9 - 80.5)		719,213	40.8 (39.3 - 42.3)		89,963	13.20 (11.7 - 14.8)		60,520	67.2 (61.4 - 73.1)	
65+	616,136	81.8 (80.3 - 83.3)		273,668	37.6 (35.7 - 39.5)		29,883	12.20 (10.1 - 14.3)		15,683	54.6 (45.7 - 63.5)	
Region												
South	686,735	72.7 (70.3 - 75.0)	< 0.001	342,006	37.9 (35.5 - 40.4)	0.001	31,982	10.10 (7.8 - 12.3)	0.001	22,043	69.5 (59.2 - 79.9)	0.047
North	254,969	81.1 (79.0 - 83.2)		121,914	40.4 (37.9 - 43.0)		12,236	10.80 (8.0 - 13.6)		6,585	53.9 (39.2 - 68.5)	
West	373,408	74.2 (71.7 - 76.7)		175,830	36.5 (33.9 - 39.1)		17,599	10.80 (7.9 - 13.7)		8,624	48.4 (34.4 - 62.4)	
Northeast	595,243	76.3 (74.2 - 78.3)		321,721	43.3 (40.9 - 45.6)		35,381	11.70 (9.6 - 13.9)		23,673	70.4 (61.6 - 79.1)	
Southeast	689,163	68.9 (66.6 - 71.1)		382,789	40.5 (38.3 - 42.8)		57,406	16.70 (14.0 - 19.4)		34,519	62.0 (53.4 - 70.5)	
Living Situation												
Own	2,094,690	80.4 (79.3 - 81.5)	<0.0001	1,069,648	42.0 (40.7 - 43.3)	<0.0001	131,405	12.9 (11.6 - 14.2)	0.1908	88,531	67.7 (62.7 - 72.8)	<0.0001
Rent	444,974	54.7 (52.1 - 57.2)		243,233	33.9 (31.4 - 36.5)		19,693	10.0 (7.1 - 12.9)		5099	30.2 (16.1 - 44.2)	
Other	59,854	47.5 (40.8 - 54.2)		31,380	28.8 (22.9 - 34.7)		3507	12.7 (5.5 - 19.8)		1814	51.7 (22.0 - 81.5)	

P-values are from Rao-Scott chi-square tests.

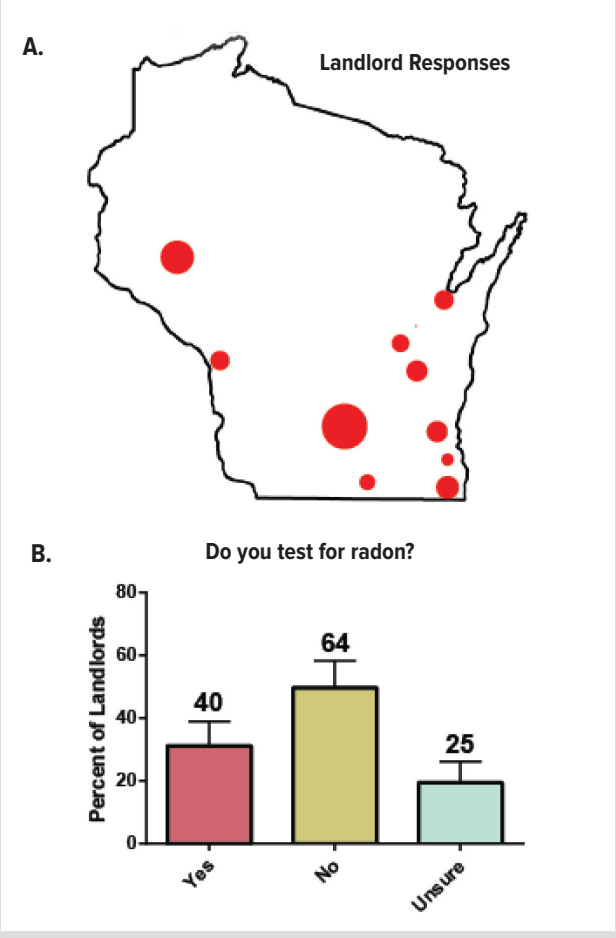
pany (Appendix 4A). A majority of tests were performed using self-test kits (53.2% self-test kits vs 31.9% professional testing and 14.9% unsure; Appendix 4B). Just over 12% of landlords (12.4%) reported that their buildings have mitigation systems, while 43.8% reported that their buildings do not have mitigation systems (Appendix 4C). Additionally, 6.7% of landlords reported that their properties were built with radon-resistant construction compared to 36.5% who reported they did not use radon-resistant construction and 56.7% who were unsure (Appendix 4D).

Radon Testing and Mitigation Practices in Wisconsin Schools

In addition to landlords and residents, our study also assessed radon testing and mitigation practices by public school districts (Figure 3A). Of 231 completed responses, 35.1% of districts reported that all of their schools had been tested previously for radon, 8.1% of school districts reported that a subset of their schools had been tested previously for radon, 19.8% of school districts had not tested for radon, and 36.9% of school districts were unsure (Figure 3B). By examining school district size based on number of buildings and by enrollment, there is no significant difference in propensity to test for radon based on district size. Of 32 districts that reported elevated radon tests, 25.0% took some sort of action (eg, mitigation, fresh air ventilation, or retesting), while 46.9% of schools did nothing in response to a high radon test (Figure 3C). We also asked whether or not school districts installed radon mitigation systems in their schools, either during building construction or ex post facto. Only 2.1% reported having a mitigation system in place, while 79.2% reported no mitigation system.

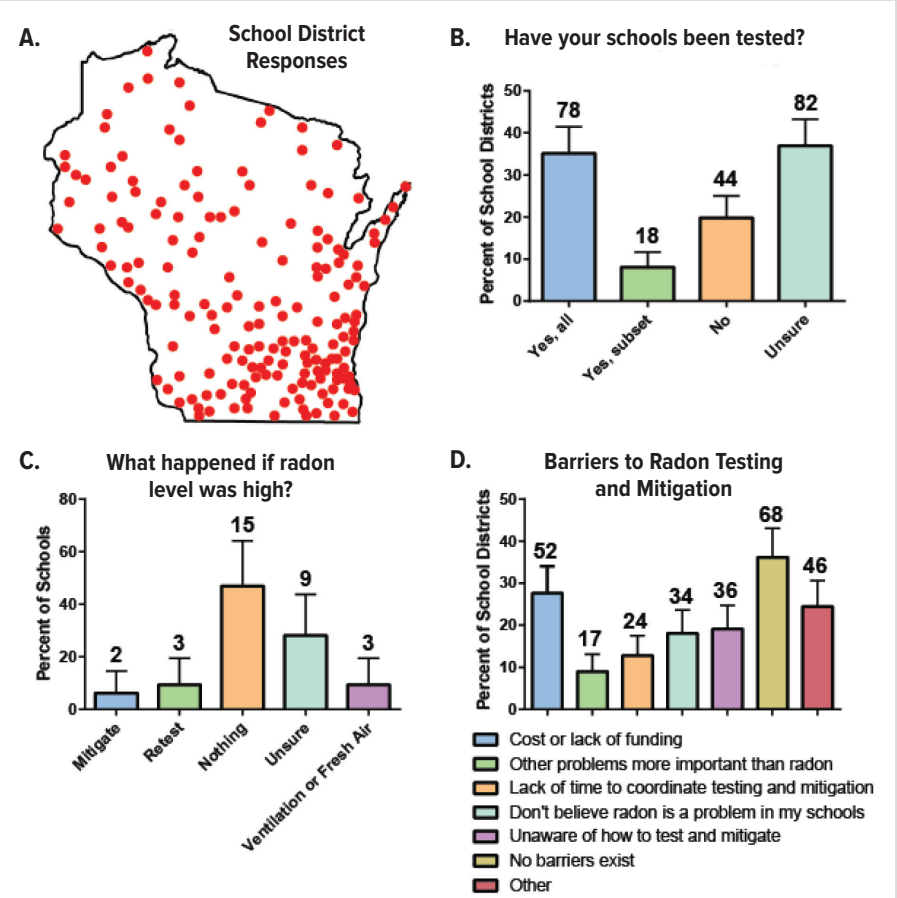
Finally, potential barriers to radon testing and mitigation in schools were assessed (Figure 3D). The most common response was that no barriers exist (36.2% of respondents). The next most common reported barrier was cost or lack of funding (27.7% of respondents).

Figure 2. Survey of Radon Testing and Mitigation by Landlords in Wisconsin



2A. A map of Wisconsin demonstrating the distribution of landlords from which responses were obtained. The sizes of the red circles correlate with the number of completed responses that were obtained from each of the indicated metropolitan areas.
2B. Percentage of landlords that have tested at least 1 of their buildings for radon. The number above each bar is the absolute number of responses in each category.

Figure 3. Survey of Radon Testing and Mitigation in Schools in Wisconsin



3A. A map of Wisconsin demonstrating the distribution of schools from which responses were obtained. Each red circle represents 1 district.
3B. Percentage of school districts that have tested their building(s) for radon.
3C. Actions that were taken by school districts who reported an elevated radon test.
3D. Percent of school districts that reported the following barriers to radon testing and mitigation. Respondents were allowed to choose multiple barriers, if applicable. N = 188. Throughout the figure, bars represent percentages ± 95% CIs, and the absolute number of response is shown above each bar.

DISCUSSION

The results of this study demonstrate that approximately 30% of residential homeowners (22.1% from SHOW and 39.9% from BRFSS), 31.0% of landlords, and 35.1% of public school districts have tested for radon. Furthermore, of the buildings that have been tested, our data demonstrate that approximately 12.5% of buildings have elevated radon. Lastly, of those that reported elevated radon, 63% of residential home owners and 25% of public school districts took actions to mitigate. (We were unable to draw a conclusion from landlords based on the low number of tests with known results.) As 73.4% of residents reported being aware of radon in the BRFSS data, it appears that awareness may not be the biggest barrier to testing in the residential setting. Previous studies have cited lack of perceived threat and cost as the biggest barriers to testing and mitigation.[13] With regard to landlords, the biggest barrier to radon testing and mitigation appears to be awareness, as many landlords surveyed were not aware of radon or were unsure of whether their buildings had ever been tested and/or mitigated. Additionally, some landlords reported that radon testing and mitigation was not their responsibility and thought the state or local government was responsible. Interestingly, of school districts that reported elevated radon levels, only about 25% took some sort of action. The most commonly cited barrier to testing and mitigation was lack of funding, suggesting that providing funding to public schools could improve radon testing and mitigation rates. It may be particularly effective to intervene in schools and protect children, as longer, less-intense exposures to radon are generally more carcinogenic than shorter, more-intense exposures.[14] These results are similar to a recent study of radon testing practices in Minnesota schools, which found that 53 of 331 (16%) school districts report having tested classrooms for radon since 2012.[15] Furthermore, the aforementioned EPA study of 927 schools nationwide estimated that over 70,000 US classrooms were likely to have radon concentrations above the EPA's action level of 4 pCi/L.[16] These results add to existing literature by providing a relatively comprehensive assessment of radon testing and mitigation practices in residential dwellings and schools in an upper Midwest state with high radon levels and demonstrate potential areas of intervention to increase radon testing and mitigation.

A major barrier to radon testing and mitigation is a general lack of awareness and concern surrounding radon, and research and remediation programs have stalled.[17] In fact, a recent review of CDC-funded National Comprehensive Cancer Control Programs found that approximately one-third of these grantees still do not include radon in their cancer control plans.[18] In addition, survey data suggest that even among people who are aware of radon as a health hazard, only a small fraction live in a home that has been tested.[19] A major challenge to communicating radon risk and promoting radon remediation is that the radon threat is inherently perceived as either being low or simply nonexistent. Furthermore, the lack of sensory cues to alert people that radon is an immediate threat prevents people from taking action.[13] Several studies around

the United States have demonstrated a lack of radon awareness and action. Data from New York state suggest that about 1 out of 5 New York residents are aware of radon, and of those, only 15% had their homes tested.[20] Similarly, a survey of Madison County, Alabama, demonstrated that 70.2% of households had heard of radon, but only 7.3% of houses had been tested for radon.[21] Lastly, a study of Vermont residents who tested for radon and had elevated radon levels demonstrated that 43% mitigated.[19] It is unclear how well these survey data can be extrapolated to the upper Midwest where radon levels are highest, and such a survey in Wisconsin has never been reported.

Current radon testing practices and cost of mitigation may increase health disparities. The risks of radon traditionally have been mentioned only with home sale or transfer, making renters less likely to be aware of such risks.[22] Nearly twice as many renter-occupied households are below the poverty line (eg, minorities, low-income individuals) compared to owner-occupied households. The homeownership rate among white Americans is about 71% compared to about 41% for black Americans and about 47% for Hispanic Americans.[23] Furthermore, those who rent may not have the financial resources to install a mitigation system and also do not own the property and may not have the authority to install a mitigation system. This radon disparity may also be true among homeowners, as a study in Illinois found that lower income and more rural households were less likely to have tested their homes for radon.[24] One potential strategy to reduce disparities is to require landlords to test their properties for radon and mitigate if levels are elevated.

Wisconsin law currently requires disclosure of known prior radon testing during real estate transactions but does not require testing and/or mitigation at real estate transactions, by landlords, or by schools. Given the magnitude of the problem, current testing and mitigation policies and efforts are insufficient, but there are several solutions for this problem. First, communities could implement a multipronged, collaborative approach to increase radon testing, similar to an approach employed by Iowa.[25] This approach involved establishing a coalition of stakeholders including the University of Iowa, the American Lung Association, local public health, lung cancer survivors, radon testers, and mitigation specialists, among others. As a result, from 2009 to 2014, the number of radon tests completed in Iowa increased by 20%, and the number of mitigations completed by certified mitigators increased by 108%.

Policy changes also could help address the radon problem. Fourteen states have no laws regarding radon, radon testing, and disclosure to and from homeowners. Twenty-three states (including Wisconsin) require disclosure of previous radon testing during real estate transaction, 4 states require radon testing in schools, and 2 states require radon mitigation in schools if radon is elevated.[26] However, no states require homes to be tested for radon during a real estate transaction. Furthermore, there is a dearth of policies protecting renters from radon. Two states have laws that address the subject of radon in rental housing directly. Maine requires landlords to test for and disclose radon levels in their properties when requested by the tenant, and Illinois requires landlords to disclose known elevated radon levels.[26] Given that one-third of the nation's housing units are occupied by renters and that the risks of radon traditionally have been disclosed only with home sale or transfer, renters are less likely to be aware of the risks of radon. Wisconsin could make significant progress in increasing the prevalence of testing for and mitigation of radon gas through a combination of the policy changes implemented in other states and community-based initiatives to raise awareness of the health risks and the effectiveness of mitigation.

Lastly, physicians could address this problem by asking their patients about radon, ensuring that radon is emphasized in undergraduate and graduate medical education, and by distributing radon test kits in primary care clinics, which represents an intriguing area of future research.

This study has several limitations. The data are based on survey responses, which are subject to multiple biases. The wording of the radon question in SHOW (ie, have you tested for radon in this home?) may pose limitations in estimating the prevalence of radon testing in all residential dwellings. For example, if the respondent focuses on the "you" in the question, they may have reported "no" if someone else did or coordinated the testing. This may explain why this SHOW estimate is lower than the BRFSS estimate. Also, only SHOW participants who reported having a basement in their home were asked about radon testing, which may affect the prevalence estimate. Response bias may have influenced the results of the school district and landlord surveys, as those school districts and landlords that have tested for and/or mitigated radon are more likely to respond and complete the survey. This would artificially increase our measured percentage. While we can speculate that many of the "unsure" responses about testing and mitigation probably indicate a lack of awareness of radon and therefore a lack of testing and/or mitigation, we could not categorize these as such.

CONCLUSION

These results demonstrate that current levels of radon testing and mitigation in residential homes, landlords, and school districts in the state of Wisconsin are inadequate. Implementation of innovative strategies will be required to improve awareness, mitigation, and testing of radon, which could help prevent about 500 unnecessary Wisconsin deaths every year.

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