Closing the Radon Gap: A Socioecological Approach to Addressing Social Determinants and Disparities in Testing Rates Across Illinois Cities and Towns

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Abstract **Radon causes an estimated 21,000 lung cancer deaths annually in the U.S. Despite available resources, radon screening rates remain low. Our analysis used a socioecological approach to examine sociodemographic factors influencing radon testing behavior in 756 Illinois cities and towns from 2008 to 2012. Analyzing data from the Illinois Emergency Management Agency and the American Community Survey, our study employed multivariate linear regression to identify significant relationships between radon testing and various sociodemographic indicators. Our results indicated that median household income had the strongest positive impact on testing rates, whereas the percentage of Hispanic individuals had the strongest negative impact. Individuals who identified as Black and individuals with only a high school diploma were also significant factors. Furthermore, our findings revealed disparities in radon testing based on race and ethnicity, income level, and education attained. To promote environmental health equity, we recommend that policies provide incentives, educational campaigns, and resources for underserved and English-as-a-second-language communities with a focus on multilevel interventions that address various socioecological factors.**

Keywords: radon, residential radon testing, social determinants of health, risk factors, environmental public health

Introduction

Radon, a naturally occurring radioactive gas, poses a major yet often overlooked public health risk. As the second leading cause of lung cancer in the U.S. and the primary cause of lung cancer among nonsmokers, the negative impact of radon on human health is substantial (Pawel & Puskin, 2004). Modern scientific understanding has established a clear link between radon exposure and lung cancer, with an estimated 21,000 cancer deaths each year in the U.S. attributed to radon exposure (U.S. Environmental Protection Agency [U.S. EPA], 2016). Despite its serious health implications and the availability of mitigation strategies, public awareness and testing rates remain alarmingly low (U.S. EPA, 2025a).

Radon is formed by the decay of uranium in soil and rock, and radon can accumulate in buildings to dangerous levels, particularly in basements and lower floors (Illinois Emergency Management Agency [IEMA], 2025). The health effects of radon exposure have been documented since the 16th century, with early observations of lung disease among miners in the Erz Mountains along the German-Czech border (Goldstein & Goldstein, 2002).

In the U.S., radon risks vary by region, with some areas facing higher risks than others. Regardless of geographic location, all homes should be tested for radon, because variations in the soil can differ even within neighboring properties (U.S. EPA, 2025b). Illinois presents a particularly concerning example, as the Illinois Emergency Management Agency (IEMA, 2025) estimates that up to 41% of homes in the state could have radon concentrations at or above the action level of 4 pCi/L of air, a level that far exceeds the national average of 1.3 pCi/L estimated by the U.S. Environmental Protection Agency (U.S. EPA, 2012; Zahnd et al., 2018). Additionally, more than one half of Illinois is classified as Zone 1, which is the highest priority rating for indoor radon measurement and mitigation. Nearly 20% of the state's 102 counties have recorded radon levels >4 pCi/L in more than 50% of the homes tested (Duckworth et al., 2002).

Despite known risks and the availability of testing methods, radon testing rates remain low nationwide. U.S. EPA estimates that only 20% of homeowners have tested for indoor radon concentrations (U.S. EPA, 2025a). This discrepancy between risk awareness and action underscores the need for a deeper understanding of the factors influencing radon testing behaviors (Weinstein et al., 1990). While numerous studies have examined individual-level factors influencing radon testing and mitigation behaviors (Darby et al., 2005; Weinstein et al., 1990), large gaps remain in the scientific literature.

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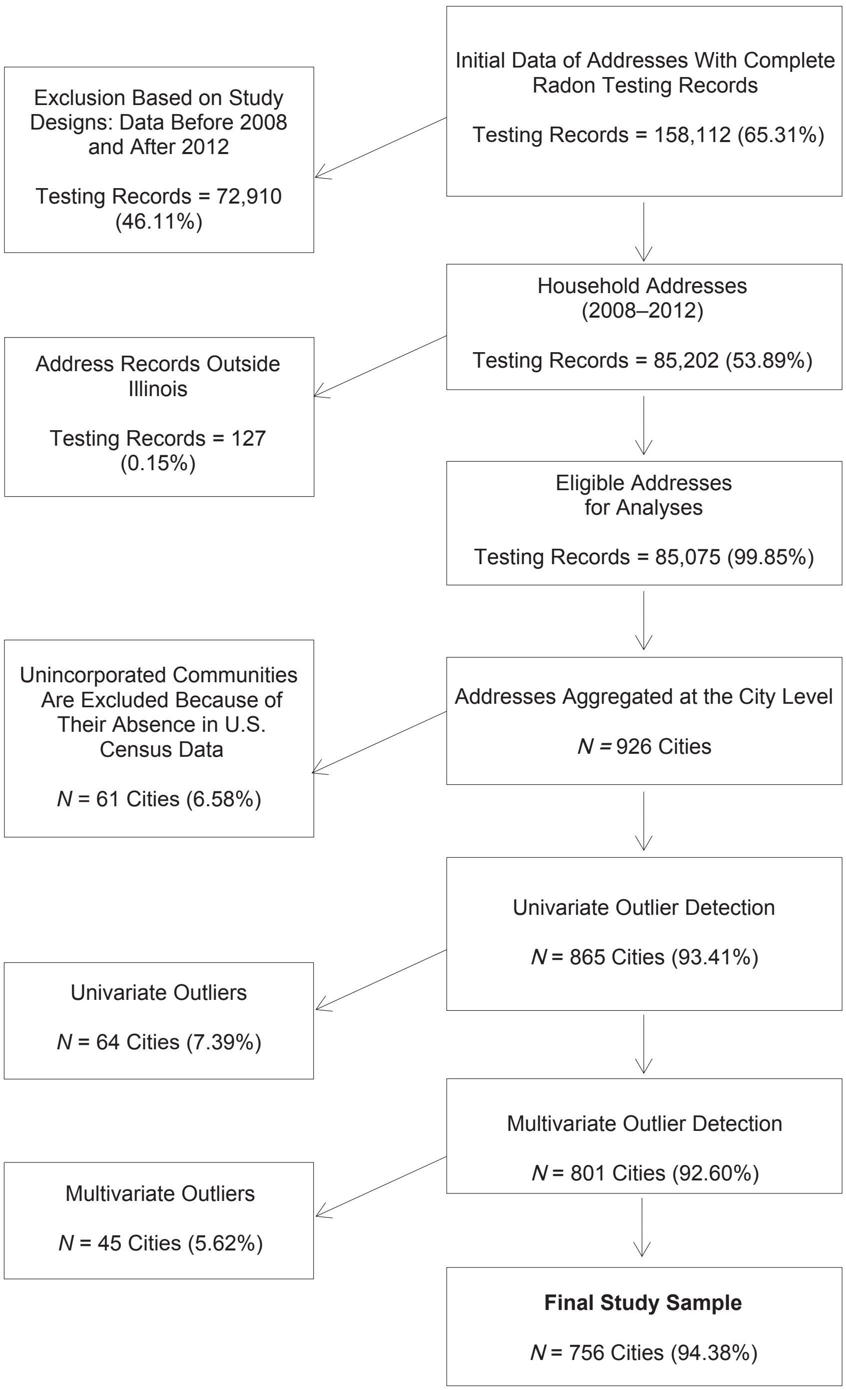
FIGURE 1

Flow Chart for Sample Selection in the Study



First, population-level analyses that have examined radon testing rates and their association with sociodemographic variables are scarce (Stanifer et al., 2022; Zahnd et al., 2018). Second, the application of multilevel ecological models to frame radon testing behaviors is limited (Weichenthal et al., 2014). These gaps constrain our understanding of broader societal and environmental factors that could influence radon testing rates.

Our study aims to address these knowledge gaps by examining the association between sociodemographic variables and radon testing rates at the city level in Illinois. Using a comprehensive database of radon testing results and a socioecological model (SEM), we sought to better understand the factors that can influence radon testing behaviors. Our research objectives were to:

1. Determine the relationship between sociodemographic variables and radon testing rates across Illinois cities.
2. Examine the influence of sociodemographic variables at different levels of SEM on radon testing rates.

Methods

Study Design and Theoretical Framework

Our retrospective analysis employed a socioecological approach to examine city-level residential radon testing in Illinois from 2008 through 2012. Using SEM (McLeroy et al., 1988) as our conceptual framework, we identified key study variables influencing an individual's willingness to conduct residential radon testing. This ecological approach provided a framework for environmental health research and revealed potential study variables at the intrapersonal, interpersonal, institutional, community, and public policy levels.

Data Sources and Sample Selection

Our primary source of data was the database of household radon testing results provided by IEMA. We also used the 2008–2012 American Community Survey (ACS) data from the U.S. Census Bureau to describe city-level demographic, socioeconomic, and housing characteristics associated with radon risk knowledge and testing.

The raw data from the IEMA test results comprised 236,970 radon measurements taken throughout Illinois from January 1, 2003, to December 31, 2012. Because of fundamental policy changes in testing and reporting laws after 2012, data collected after this year were excluded from our study. The data were filtered to include only complete household radon testing records assigned to an address, reducing the test result numbers to 158,112 radon measurement records. Exclusion based on our study design and the availability of data sets released by IEMA resulted in only tests from January 1, 2008, to December 31, 2012, which totaled 85,202 test results (i.e., radon measurement records).

We excluded 127 tests (0.15%) because the addresses were outside of Illinois, which resulted in 85,075 eligible test results in the database. Next, we aggregated the data by city/town name, which identified 926 cities/towns in the sample. We retained addresses only in incorporated cities, which eliminated 61 cities/towns (6.48%) and left a total of 865 cities/towns. Univariate outliers eliminated 64 additional cities/towns, and multivariate outliers eliminated 45 additional cities/towns, which left a total of 756 cities/towns in our final study sample (Figure 1).

TABLE **1**

Descriptive Statistics for the Dependent Variable and Independent Variables for Regression Model 4 (*N* = 765)

Variable	Description	*M*	*SD*
Dependent	Frequency of testing in occupied housing (per 1,000 residences)	19.70	17.26
Independent			
SEM level: Intrapersonal factors	Individuals who are ≥65 years (%)	15.105	5.730
	Individuals who are ≥25 years with only a high school diploma or equivalent (%)	35.420	10.264
	Male individuals (%)	48.794	3.125
SEM level: Interpersonal factors	Households with ≥1 individual who is <18 years (%)	32.766	7.848
	Median household income (in thousands)	54.082	20.358
SEM level: Community factors	Owner-occupied residences (%)	77.978	10.674
	Individuals who identified as Black (%)	3.155	7.702
	Individuals who identified as Hispanic or Latino (%)	5.754	8.961

Note. SEM = socioecological model.

Variables and Measurement

The dependent variable in our study was the testing ratio, which was calculated as the number of radon measurement tests conducted in each city/town per 1,000 occupied residences, as reported in the 2010 American Community Survey 5-year average. Data for the dependent variable were also obtained from the IEMA database of household radon measurements and U.S. Census Bureau reports on occupied residences in sample Illinois cities.

The independent variables, reflecting social determinants of health, were city/town-level variables derived from the 5-year average data of the U.S. Census Bureau's 2010 American Community Survey. The selection of independent variables in our study was guided by SEM, which provides a comprehensive framework that considers multiple levels of influence on health behaviors, including radon testing (McLeroy et al., 1988).

At the intrapersonal level, we included variables such as age and education level as percentages at the city/town level (e.g., percentage of individuals with only a high school diploma or equivalent). These factors represent individual characteristics that can influence knowledge, attitudes, and behaviors related to radon testing. For example, age and education level could affect awareness of radon risks and the ability to understand radon testing information (Duckworth et al., 2002; Ferng & Lawson, 1996; Halpern & Warner, 1994; Zahnd et al., 2018).

At the interpersonal level, we incorporated variables related to household composition and income level. The percentage of households with children under 18 years was included because previous research suggests that parents might be more likely to engage in protective health actions when children are present in the home (Petrescu & Petrescu-Mag, 2017; Slovic, 1987). Median household income was selected as a proxy for financial capacity, which might influence a family's ability to afford radon testing and mitigation actions (Bandura, 1977; Hahn et al., 2018; Halpern & Warner, 1994; Zahnd et al., 2018).

At the community level, we chose variables that reflected the broader social context, including homeownership rates and racial and ethnic composition of the population. Homeownership was included because, compared with renters, property owners might be more inclined to invest in home testing and mitigation actions (Duckworth et al., 2002; Hahn et al., 2018; Larsson, 2014; Zahnd et al., 2018). The percentage of individuals who identified as Black and the percentage of individuals who identified as Hispanic or Latino in the city/town were included to examine potential disparities in radon testing rates across different racial and ethnic communities (Halpern & Warner, 1994).

Statistical Analyses

Descriptive statistics—including means, standard deviations, and ranges—were used to summarize the study variables. Variance inflation factors were applied to determine multicollinearity. Prior to conducting the regression analysis, assumptions of normality, linearity, multicollinearity, and homoscedasticity were examined. A review of the partial regression scatter plots and a histogram of the standardized residuals supported the presumption of linearity. Casewise diagnostics identified nine cases with standard deviation values >3.0, but these cases did not introduce significant bias. A normal P–P plot of the expected and observed cumulative probability was within acceptable limits.

The values for mean Mahalanobis distance (7.989), Cook's distance (0.001), and the centered leverage value (0.011) support the normality of distribution. We used the Durbin–Watson statistic to determine the independence of errors (1.912), which supported the assumption that the independent errors are valid. The mean sum of residuals ($p < .001$) indicated normality of error distribution.

We evaluated the relationship between city/town-level social determinants of health and Illinois residential radon testing rates using a series of multivariate linear regression analyses. Model fit was assessed using R^2 and adjusted R^2 values. A Pearson's correlation coefficient was computed to determine onlmif

TABLE **2**

Correlations for Study Variables in Model 4 (*N* = 756)

Variable	1	2	3	4	5	6	7	8	9
1. Frequency of testing in occupied residences	–								
2. Percentage of individuals ≥65 years	-0.152 ***	–							
3. Percentage of individuals with only a high school diploma or equivalent	-0.310 ***	0.237 ***	–						
4. Percentage of male individuals	0.055	-0.257 ***	0.023	–					
5. Percentage of households with ≥1 individual who is <18 years	0.183 ***	-0.509 ***	-0.222 ***	0.088 **	–				
6. Median household income	0.433 ***	-0.357 ***	-0.666 ***	0.083 *	0.370 ***	–			
7. Percentage of owner-occupied residences	0.225 ***	-0.017	-0.058	0.080 *	0.194 ***	0.476 ***	–		
8. Percentage of individuals who identified as Black	-0.102 **	-0.161 ***	-0.218 ***	-0.062 *	0.035	-0.010	-0.257 ***	–	
9. Percentage of individuals who identified as Hispanic or Latino	-0.130 ***	-0.335 ***	-0.242 ***	0.096 **	0.308 ***	0.130 ***	-0.177 ***	0.270 ***	–

* $p < .05$. ** $p < .01$. *** $p < .001$.

TABLE **3**

Regression Coefficients for Regression Model 4

Variable	*B*	β	*SE*
Percentage of individuals ≥65 years	-0.012	-0.039	0.012
Percentage of individuals who are ≥25 years with only a high school diploma or equivalent	-0.022 **	-0.131	0.008
Percentage of male individuals	0.017	0.031	0.018
Percentage of households with ≥1 individual who is <18 years	0.019	0.084	0.009
Median household income (in thousands)	0.288 ***	0.340	0.000
Percentage of owner-occupied residences	-0.004	-0.026	0.007
Percentage of individuals who identified as Black	-0.018 **	-0.079	0.008
Percentage of individuals who identified as Hispanic or Latino	-0.045 ***	-0.232	0.007
R^2	0.243		
ΔR^2	0.235		

* $p < .05$. ** $p < .01$. *** $p < .001$.

there was a relationship between potential independent variables and dependent variables. All statistical analyses were performed using IBM SPSS Statistics (version 29), with a significance level set at .05.

Results

Descriptive statistics for the dependent variable and independent variables included in our final regression model are shown in Table 1. The mean radon testing rate was 19.70 tests per 1,000 occupied residences (*SD* = 17.26). Among the independent variables, the mean percentage of owner-occupied residences was highest at 77.98% (*SD* = 10.67%), while the mean percentage of individuals who identified as Black was lowest at 3.16% (*SD* = 7.70%).

We tabulated mean scores and standard deviations of all SEM variables (Table 2). Frequency of testing in occupied residences demonstrated the highest correlation with median household income ($r = .433$, $p < .001$), followed by the percentage of individuals with only a high school diploma or equivalent ($r = -.310$, $p < .001$). The percentage of owner-occupied residences was also associated with the frequency of radon testing in occupied residences ($r = .225$, $p < .001$). The association was weak between the frequency of testing in occupied residences and the percentage of individuals who identified as Black ($r = -.102$, $p < .01$).

We developed four multiple regression models to investigate the relationships between radon testing rates and potential predictors within the SEM framework: Model 1 (SEM Intrapersonal Level), Model 2 (SEM Interpersonal Level), Model 3 (SEM Community Level), and Model 4 (final model incorporating variables from all SEM levels).

Our final model, Model 4, included 8 independent variables spanning demographic, socioeconomic, and housing characteristics: 1) percentage of individuals ≥65 years, 2) percentage of individuals with only a high school diploma or equivalent, 3) percentage of individuals who are male, 4) percentage of households with individuals ≤18 years, 5) median household income (in thousands), 6) percentage of owner-occupied residences, 7) percentage of individuals who identified as Black, and 8) percentage of individuals who identified as Hispanic or Latino.

This multiple linear regression model building was conducted to predict the frequency of radon testing in occupied residences in various Illinois cities (Table 3). Our final regression model was statistically significant, $F(8, 747) = 30.035$, $p < .001$, which explains 24.3% of the variance. The effect size was 0.321, indicating a medium effect. Overall, five sociodemographic factors were significantly associated with radon testing rates.

The three factors with the largest influence on the outcome variable were 1) median household income, 2) percentage of the individuals who identified as Hispanic or Latino, and 3) percentage of individuals with only a high school diploma or equivalent. Median household income had the strongest positive impact on household radon testing ($\beta = .340$, $p < .001$), whereas the percentage of individuals who identified as Hispanic or Latino had the strongest negative impact ($\beta = -.232$, $p < .001$). The percentage of individuals with only a high school diploma or equivalent was also negatively associated with testing rates ($\beta = -.131$, $p < .01$). The percentage of individuals ≥65 years, the percentage of male individuals, and the percentage of owner-occupied residences were not significantly related to radon testing behavior.

Discussion

Our study examined the relationship between U.S. Census city/town-level data related to social determinants of health and residential radon testing rates in Illinois. Our findings identified significant predictors of testing rates, which included median household income, education level, and race and ethnicity. Our results offer valuable insights into public health policy and practice aimed at mitigating radon exposure and reducing the associated risk of lung cancer.

Intrapersonal-Level Factors of Residential Radon Testing

Education level significantly predicted radon testing rates in Illinois cities. Specifically, a higher percentage of individuals with only a high school diploma or equivalent was negatively associated with testing rates. This finding aligns with previous research that indicated that higher education levels correlate with greater awareness of radon risks and increased access to radon testing information (Stanifer et al., 2022; Zahnd et al., 2018). To address this disparity, interventions should prioritize enhancing educational outreach to promote radon testing in communities with lower educational attainment. For example, incorporating radon and cancer education into high school curricula could increase awareness among students and their families in communities with lower education levels, potentially leading to higher radon testing rates. Furthermore, health promotion officials and environmental health divisions at the city/town level should advocate for and implement comprehensive radon education and testing programs, especially in communities with a higher percentage of individuals with lower education levels.

Interpersonal-Level Factors of Residential Radon Testing

Median household income emerged as the strongest predictor of radon testing rates, which aligns with previous study findings that higher income is associated with increased testing rates (Halpern & Warner, 1994; Stanifer et al., 2022; Zahnd et al., 2018). This finding highlights the importance of financial resources in enabling protective health behaviors. The concept of self-efficacy from Bandura (1977) suggests that access to resources influences outcome expectancy. Therefore, successful radon reduction campaigns require substantial public investment to support screening, follow-up measurements, and remediation efforts across the entire policy cycle (Sandman & Weinstein, 1993; Weinstein et al., 1990).

Interestingly, the presence of individuals <18 years in a household did not significantly predict radon testing rates, contrary to our initial hypothesis based on the psychometric paradigm (Slovic, 1987) and studies suggesting increased risk perception related to children's health (Petrescu & Petrescu-Mag, 2017). This unexpected finding supports the need for further investigation to understand the specific factors that influence radon testing behavior in families in Illinois. One possible explanation is that families with young children could be more likely to live in newer homes built with radon-resistant construction techniques.

Community-Level Factors of Residential Radon Testing

Race and ethnicity were significant predictors of testing rates, with lower rates observed in communities of color. Specifically, a higher percentage of Hispanic or Latino individuals had a stronger negative association with radon testing rates than did the percentage who identified as Black individuals. These results underscore major health equity concerns and highlight the need for specific interventions in underserved communities (Casey et al., 2017).

Contrary to our hypothesis and some previous studies (Larsson, 2014; Stanifer et al., 2022), home ownership was not significantly associated with radon testing rates in our final model, which aligns with a study by Zahnd et al. (2018). Our findings could be explained by several factors. First, renters in Illinois could be more proactive about requesting radon tests from their landlords, particularly if there have been local awareness campaigns or regulations encouraging such practices. This explanation aligns with research by Weinstein et al. (1990), who found that risk communication strategies can influence radon testing behavior.

Alternatively, there might be confounding variables not accounted for in our model that influence both home ownership rates and testing behavior. For instance, areas with higher proportions of newer housing stock might have lower ownership rates because of more recent housing development but also higher testing rates because of more stringent building codes or greater awareness among new homebuyers, as suggested by Keller et al. (2006) in their study of radon risk perceptions.

Significance and Limitations

The use of SEM in our study provides a comprehensive framework for understanding the multifaceted influences on radon testing behavior. Our final model, which integrated variables from all levels of SEM, demonstrates the highest predictive value. This finding underscores the importance of multilevel interventions in promoting radon testing.

Several limitations deserve further consideration. First, the use of the 2008–2012 American Community Survey data for independent variables might not fully capture more recent demographic shifts. Second, our sample did not include all Illinois cities; however, the low exclusion of only 6.58% of cities is unlikely to affect the representativeness of our findings. Third, the cross-sectional design of our study limits our ability to infer causality. Despite these limitations, our study contributes valuable insights to the existing literature and can inform environmental health practice.

Conclusion and Recommendations

We investigated the association between city/town-level social determinants of health and residential radon testing rates in Illinois. Our findings revealed significant predictors of testing rates: median household income level, education level, and race and ethnicity. Using SEM, we identified factors at the intrapersonal, interpersonal, and community levels that influence testing behavior.

We found that higher median household income was the strongest positive predictor, whereas lower educational attainment (high school diploma only) and higher percentages of Hispanic or Latino individuals were associated with lower testing rates. This multilevel approach provides valuable insights into the complex factors that influence radon testing and highlights the need for targeted, culturally sensitive interventions to reduce disparities and improve testing rates.

In summary, our findings have critical implications for public health practice. Disparities in radon testing rates based on income, education, and race and ethnicity underscore the need for targeted public health interventions. We recommend implementing comprehensive radon education programs in communities with lower educational attainment, focusing on culturally relevant messaging and addressing barriers to testing. Furthermore, we recommend subsidizing or providing free radon testing kits to low-income households to improve radon testing rates and reduce radon exposure.

Public health agencies should also collaborate with community leaders and trusted organizations to promote radon awareness and testing in communities of color, ensuring that interventions are culturally sensitive and address specific community needs. Lastly, policymakers should consider policies that require or incentivize radon testing in rental properties to further protect vulnerable populations. These multifaceted approaches are essential to reducing radon exposure and mitigating the risk of lung cancer across all communities.

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