

# Identifying Jurisdictions at Risk of Containing Housing Units With Deteriorated Paint: Results and Targeting Implications for the US Department of Housing and Urban Development

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## ABSTRACT

**Context:** The US Department of Housing and Urban Development provides millions in annual funding to make low-income housing lead safe, but funds are limited relative to need. To adequately target efforts, local program administrators must identify neighborhoods that are the most “at risk” of residential lead exposure; however, no federal agency currently provides a public data set for this use.

**Objectives:** To examine pre-1980 households with large areas of deteriorated paint, a significant and common predictor of lead dust, and identify high-risk jurisdictions. To highlight the potential use of a newly available data set for strategic lead poisoning prevention and targeting.

**Design:** Microdata from the 2011 American Housing Survey and the 2009-2013 American Community Survey were used to develop a household-level predicted risk metric that identifies housing units at risk of containing large areas of deteriorated paint. Predicted risk, defined as the mean predicted percentage of occupied housing units at risk of containing deteriorated paint within a given jurisdiction, was summarized by state, county, and tract.

**Setting:** National, all occupied housing units.

**Participants:** Occupied housing units summarized by household (n = 9363 000), census tract (n = 72 235), county (n = 3143), and state (n = 51).

**Main Outcome Measure:** Housing units built prior to 1980 with a large area of deteriorated paint.

**Results:** New York, Rhode Island, New Jersey, Massachusetts, and Pennsylvania had the highest predicted percentage of at-risk households (range: 2.52%-2.90%). County-level and tract-level estimates are the most useful when examining a predefined jurisdiction; New York state was presented as a case study. County-level quartile risk scores revealed Albany as an at-risk jurisdiction. Tract-level quartile risk scores further identified at-risk neighborhoods in northeastern Albany.

**Conclusions:** Findings can help housing and health policy makers identify and target geographic areas with a high probability of households at risk of potential exposure to deteriorated lead-based paint.

**KEY WORDS:** housing, lead poisoning, prevention, public health, targeting

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The authors conducted secondary data analysis using microdata collected by the US Census Bureau. Ms Garrison has Census Special Sworn Status (SSS) and is trained as a data steward. Secondary analyses were conducted in compliance with the Census Bureau's Title 13 data security standards.

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Lead is a well-known neurotoxin with established routes of exposure. Although lead exposure can occur through ingestion of contaminated water, soil, and consumer products

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containing lead, the most common pathway of higher-level lead exposure is through ingestion of household lead dust resulting primarily from deteriorated lead-based paint (LBP).<sup>1</sup> If LBP begins to deteriorate, chipping and flaking paint and paint on friction and other surfaces contribute to lead-contaminated dust.<sup>2</sup> Settled dust can be ingested, particularly by young children due to mouthing behavior.<sup>3</sup> Residential lead dust surface loading is highly correlated with elevated blood-lead levels (EBLLs).<sup>4</sup> For this reason, human exposure to lead dust is a public health issue that highlights the important link between housing and health.<sup>1,5,6</sup>

Presence of lead loading in indoor dust is highly associated with housing age and deteriorated paint, a characteristic of substandard housing.<sup>7,8</sup> Prior national surveys highlight that the year housing was built is a strong predictor of residential dust lead exposure; pre-1940 and pre-1978 housing are 2 thresholds commonly associated with elevated lead dust risk.<sup>9,10</sup> Analyses of the American Healthy Homes Survey (AHHHS) estimated that 34.9% of US homes had some LBP, 14.5% had “significantly deteriorated LBP,” and 21.9% had 1 or more LBP hazards.<sup>11</sup> Deteriorated paint in old housing is a significant risk factor for potential household lead dust exposure.

Several other sociodemographic factors have also emerged as key indicators associated with residential lead hazards. For example, poor housing quality and rental housing are associated with EBLLs.<sup>12</sup> Race is also an important predictor of lead poisoning; black children are at a significantly higher risk of lead exposure.<sup>13</sup> In addition, several community characteristics are associated with EBLLs including poverty, population density, housing value, and educational attainment.<sup>14-16</sup>

Researchers argue that to adequately prevent household lead exposure, housing indicators should be used to screen for potential hazards.<sup>12</sup> Although the US Department of Housing and Urban Development (HUD) provides millions in annual funding to make low-income, privately owned housing lead safe, funds are limited with respect to the scope of the need.<sup>17</sup> To adequately target efforts, local program administrators must identify neighborhoods that are the most “at risk” of residential lead exposure where deteriorated paint is the primary source. However, the HUD does not currently provide a publicly available data set for use when targeting potential households. In June 2018, the Government Accountability Office recommended that the HUD operationalize a model that identifies lead risk that can assist grant administrators.<sup>18</sup> In addition, the Federal Action Plan to Reduce Childhood Lead Exposure and Associated Health Impacts published by the President’s

Task Force on Environmental Health Risks and Safety Risks to Children highlights the need to “Generate data ... to identify high exposure communities ... for prioritization efforts.”<sup>19</sup> Although HUD funding is provided to remediate specific housing units, privacy and confidentiality concerns prohibit the identification of specific housing units. However, the ability to classify high-risk neighborhoods facilitates identification of intervention origination pathways.

Several news media companies have recently released online maps that highlight communities at risk of lead poisoning, but these maps are limited in scope.<sup>20,21</sup> In addition, no national data sets have been publicly released by any federal agency that highlights the potential risk of household lead exposure attributable to deteriorated paint. Although there is emerging federal consensus regarding the use of online mapping efforts that cluster spatial data to discern patterns of lead poisoning risk, cross-agency federal efforts are still underway to collaboratively develop, validate, and release national lead risk maps that can be used for differing purposes (eg, identifying environmental lead-based hazards vs identifying areas that need increased provider screening). The US Department of Housing and Urban Development, the Environmental Protection Agency (EPA), and the Centers for Disease Control and Prevention (CDC) prioritization efforts all have distinct yet defined audiences and purposes that reflect agency mission related to lead poisoning prevention.<sup>22</sup>

The hazards and risk factors associated with lead exposure attributable to deteriorated LBP are well understood, but the ability to identify jurisdictions with the highest predicted risk of residential LBP hazards is limited. The goal of this study was to identify households with large areas of deteriorated paint, defined as areas bigger than 8 in by 11 in, in the US housing stock and to identify corresponding jurisdictions with the highest percentage of at-risk occupied units. Using data from 2 national surveys, this study produces the first nationwide estimates that can be used to predict deteriorated paint, a significant predictor for potential household lead dust, at multiple geographic levels: state, county, and tract. This study can inform policy makers and promote the targeted use of limited resources for lead abatement and remediation programs.

## Methods

The study used microdata from the 2011 American Housing Survey (AHS) and the 2009-2013 American Community Survey (ACS) to develop a predicted risk measure. This metric estimates the predicted percentage of occupied housing units with

large areas of interior deteriorated paint for 3 geographic levels: state, county, and tract. The primary methodological goal of the study was to post-fit ACS households with  $\beta$  coefficients from an AHS model that predicted the presence of a large area of deteriorated paint.  $\beta$  coefficients are model parameter estimates that quantify the additive effect for a 1-unit change in an explanatory variable. Prior research shows that both surveys produce similar housing information and this methodology can be used for small area estimation<sup>23</sup> (also S. Bucholtz, PhD, oral communication, August 1, 2017).

### **Data sources**

#### ***AHS, 2011***

The AHS is the most comprehensive nationally representative housing survey. Conducted biennially, the AHS is sponsored by the HUD and administered by the Census Bureau. The AHS provides data on housing and neighborhood quality. Survey respondents include household respondents in occupied housing units; vacant housing units are assessed by knowledgeable respondents. Approximately 155 000 housing units are surveyed every cycle.<sup>24</sup>

#### ***ACS, 2009-2013***

The ACS provides detailed demographic information on individuals and households, including educational attainment, income, disability status, employment, and housing circumstances. The ACS is sent to approximately 3.5 million people annually. Using restricted-use, geocoded household-level data, this study used household as the unit of analysis; 5-year estimates were used to ensure sufficient sample size when aggregating by tract. The 2009-2013 file was used because it temporally aligns with the AHS predictor data set.<sup>25</sup>

### **Data processing**

Several data-processing steps were used to develop risk estimates (see Supplemental Digital Content Appendix A, available at <http://links.lww.com/JPHMP/A681>).

#### ***Data standardization***

Variables in the AHS and the ACS were standardized to facilitate data integration. Since  $\beta$  coefficients from the AHS were postfitted to the ACS, it was important to ensure that both data sets measured the same selected variables. To ensure validity, selected characteristics of occupied households were examined side by side in both data sets (see Supplemental Digital

Content Appendix B, available at <http://links.lww.com/JPHMP/A682>).

#### ***Develop AHS risk model***

The AHS was used to develop the outcome risk measure, deteriorated paint, which was defined as housing units built prior to 1980 that reported a large area of deteriorated paint. Among respondents, approximately 2% (2.06%) of household respondents reported deteriorated paint in their housing units.

Several attributes were selected for the AHS model that were used to postfit to ACS data. The AHS logistic regression model captures potential household lead dust exposure attributable to deteriorated paint for a household (H). H is a function of the particular combination of household head characteristics (X), household characteristics (C), and unobservable factors (e):  $H = f(X, C, e)$ . The model revealed which characteristics are associated with elevated risk.

#### ***Postfit AHS to ACS***

Using the same unit of analysis and covariates in the AHS and the ACS, logistic regression  $\beta$  coefficients from the AHS model were fitted to the ACS, resulting in the development of a predicted risk exposure score for each ACS housing unit (P). The predicted score, P, is a function that accounts for a occupied housing unit's unique combination of household head characteristics (X), household characteristics (C), and unobservable factors (e):  $P = f(X, C, e)$ . The higher the predicted score, the higher the likelihood of the predicted outcome.

After applying  $\beta$  coefficients from the AHS model to 9.4 million ACS-occupied units, unadjusted predicted risk of potential lead dust exposure risk attributable to deteriorated paint was examined for each of the identified study characteristics. When examining the percent difference between true percentage (AHS) and predicted percentage (ACS), estimates were, on average, less than 0.05% points different (average = 0.041%). In addition, summary statistics were calculated for each geographic level to ensure consistency across data sets (see Supplemental Digital Content Appendix C, available at <http://links.lww.com/JPHMP/A683>).

#### ***Summarize predicted risk***

Household-level risk scores potentially violate confidentiality requirements; therefore, all risk scores were summarized. For each state and the District of Columbia (n = 51), county (n = 3143), and tract (n = 72 236), a risk score was calculated by summarizing the mean household-level risk score across each respective jurisdiction.

## Statistical analysis

Analyses were conducted using SAS Version 9.1.4 (SAS Institute Inc, Cary, North Carolina). Household-level ACS and AHS microdata were used. Analyses were conducted in a Census-approved partner institution Federal Statistical Research Data Center.

The Taylor Series linearization method was used to account for complex survey design and utilization of proper weighting. PROC SURVEYFREQ was used to assess ACS and AHS household characteristics. PROC SURVEYLOGISTIC was used to model risk indicators using a binary logistic regression model. To push out model parameters, a STORE statement was used to save parameter estimate results from the logistic procedure into a binary file. PROC PLM was used to postfit parameters. After new parameter estimates were applied, each ACS household was assigned a predicted probability of containing deteriorated paint. PROC SURVEYMEANS and PROC SUMMARY were used to calculate mean predicted probability.

## Measures

### Outcome

The outcome risk variable, deteriorated paint, was created at the household level using 2011 AHS microdata. Risk was derived using 2 data elements that capture the year a housing unit was built and the presence of deteriorated paint. Household respondents were asked: “Do the walls on the inside of this housing unit have any areas of peeling paint or broken plaster? Are any of these areas bigger than 8 inches by 11 inches? (the size of a standard business letter).”<sup>26</sup> The deteriorated paint response was paired with year built (pre-1980) since the sale of residential LBP was banned in 1978.<sup>9</sup> At-risk households resided in occupied housing units built prior to 1980 and reported deteriorated paint. The year 1980 was the threshold used because the ACS categorizes year built by decade.

### Covariates

Using domain expertise, bivariate testing, and the caveat that all modeling variables must be consistent and available in both data sets, 7 sociodemographic variables were selected as covariates to predict risk. Head of household characteristics included race (self-reported; recoded as white, black, and other); ethnicity (Hispanic or not); and education level (less than high school, high school diploma, some college and no degree, and bachelor’s degree or higher). The high school graduate category included the tests of general educational development. Household-level covariates

included presence of children (yes or no); housing tenure status (owned, rented, or other); household income (<\$20 000, \$20 000-\$44 999, \$45 000-\$79 999, and \$80 000+); and region (northeast, Midwest, south, and west). The “other” tenure category included respondents occupying a housing unit without rent payment.

## Data display

The AHS and the ACS are both designed to provide nationally representative estimates of US household characteristics. Since the ACS sample had a smaller standard error, household characteristics were summarized using ACS; however, estimates between the 2 surveys are similar, which is consistent with prior research (see Supplemental Digital Content Appendix B, available at <http://links.lww.com/JPHMP/A682>).<sup>24,25</sup>

## Results

### US household characteristics

Occupied households are primarily headed by individuals who are white (78.5%), non-Hispanic (89.6%), or have a bachelor’s degree or higher (31.2%). Approximately one-third of households contain children (32.7%) and most households (66.5%) live in owned units. Approximately 30.6% of households have an annual household income at or above \$80 000. Most occupied households are in the south (37.0%) or the Midwest (22.9%; see Supplemental Digital Content Appendix B, available at <http://links.lww.com/JPHMP/A682>).

### Risk of deteriorated paint

An estimated 1.73% of occupied households contain large interior areas of deteriorated paint, a significant risk factor associated with household lead dust exposure (Table 1). Consistent with prior literature, several household characteristics are associated with increased risk. Adjusted odds ratios revealed the following household characteristics as the most significant predictors of deteriorated paint: head of household race, housing tenure, household income, and regional residence. When compared with households headed by white individuals, households headed by black individuals were 1.94 times (95% confidence interval [CI], 1.94-1.95) more likely to live in units with deteriorated paint. When compared with owner households, renter households were 1.82 times (95% CI, 1.82-1.83) more likely to be at risk of deteriorated paint.

**TABLE 1**  
**US-Occupied Households at Risk<sup>a</sup> of Deteriorated Paint by Characteristic, Adjusted and Unadjusted Estimates, United States, 2009-2013**

Characteristic	AHS, 2011			ACS, 2009-2013	
	Unadjusted		Adjusted	Unadjusted	% Difference
	Weighted %	SE	AOR (95% CI)	Mean Predicted %	
Overall risk	1.74			1.73	– 0.01
Head of household					
Race					
White	1.51	0.04	1.00 (Reference)	1.54	0.03
Black	3.41	0.18	1.94 (1.94-1.95)	2.38	– 1.03
Other	1.35	0.15	0.84 (0.83-0.84)	2.57	1.22
Ethnicity					
Hispanic	2.16	0.13	1.17 (1.17-1.18)	2.34	0.18
Not Hispanic	1.68	0.05	1.00 (Reference)	1.67	– 0.01
Education level					
Less than high school	2.47	0.14	1.30 (1.30-1.30)	2.46	– 0.01
High school diploma <sup>b</sup>	1.75	0.09	1.04 (1.04-1.04)	1.96	0.21
Some college, no degree	1.81	0.08	1.13 (1.13-1.13)	1.69	– 0.12
Bachelor's degree or higher	1.34	0.07	1.00 (Reference)	1.37	0.03
Presence of children					
Yes	1.88	0.09	1.09 (1.09-1.10)	1.89	0.01
No	1.68	0.05	1.00 (Reference)	1.66	– 0.02
Housing tenure					
Owned	1.21	0.05	1.00 (Reference)	1.22	0.01
Rented	2.78	0.10	1.82 (1.82-1.83)	2.61	– 0.17
Other <sup>c</sup>	3.93	0.45	2.31 (2.30-2.32)	4.40	0.47
Household income					
<\$20 000	2.44	0.11	1.38 (1.38-1.39)	2.61	0.17
\$20 000-\$44 999	1.99	0.09	1.36 (1.35-1.36)	1.98	– 0.01
\$45 000-\$79 999	1.47	0.08	1.13 (1.12-1.13)	1.53	0.06
\$80 000+	1.14	0.07	1.00 (Reference)	1.18	0.04
Census region					
Northeast	2.81	0.13	2.06 (2.05-2.07)	2.66	– 0.15
Midwest	1.81	0.09	1.37 (1.37-1.38)	1.90	0.09
South	1.38	0.07	0.93 (0.92-0.93)	1.51	0.13
West	1.35	0.08	1.00 (Reference)	1.17	– 0.18

Abbreviations: ACS, American Community Survey; AHS, American Housing Survey; AOR, adjusted odds ratio; CI, confidence interval.

<sup>a</sup>Risk defined as household respondents who reported a large area of peeling paint (larger than 9 in by 11 in) and that their housing unit was built prior to 1980.

<sup>b</sup>Category includes the General Educational Development (GED) tests.

<sup>c</sup>The "other" tenure category included respondents occupying a housing unit without rent payment.

Low-income households were also at an elevated risk when compared with higher-income households. Households with an income less than \$20 000 were 1.38 times (95% CI, 1.38-1.39) more likely to experience the risk outcome than households with a household income of \$80 000 or more. Finally, geographic regional residence emerged as a key characteristic associated with deteriorated paint. When compared with households in the west, households in the

northeast were 2.06 times (95% CI, 2.05-2.07) more likely to be at risk; households in the Midwest were 1.37 times (95% CI, 1.37-1.38) more likely to be at risk.

### High-risk jurisdictions

Predicted risk, defined as the predicted percentage of occupied housing units at risk of containing large

areas of deteriorated paint within a given jurisdiction, was summarized for 3 geographic levels: state, county, and tract. Scores were calculated using the predicted household-level mean across each respective unit of analysis.

### **States**

Predicted risk rates of household exposure to deteriorated paint were summarized for all 50 states and the District of Columbia (Figure 1). Predicted percentage estimates across state entities ranged from 2.90% (New York) to 1.02% (Wyoming). The 5 states with the highest predicted percentage of housing units with deteriorated paint were states located in the northeastern region: New York (2.90%), Rhode Island (2.66%), New Jersey (2.61%), Massachusetts (2.56%), and Pennsylvania (2.52%). The states with the lowest predicted percentage were primarily in the West: Wyoming (1.02%), Utah (1.02%), Idaho (1.05%), Colorado (1.06%), and Montana (1.06%).

### **Counties**

Predicted risk was also summarized for 3143 US counties (Table 2). County-level predicted risk rates estimate the percentage of occupied units within a given county that contain deteriorated paint, increasing the likelihood of exposure to lead dust. A county-level interactive map that displays information for 3143 US counties is available online via the HUD-eGIS Open Data Storefront.<sup>27,28</sup>

### **Tracts**

One advantage of this analysis is that granular geographic estimates were produced. Currently, most lead risk data are publicly released at the county level. This study developed household-level predicted exposure rates for 72 235 census tracts. Tract-level predicted risk rates estimate the percentage of occupied units within a given tract that contain large areas of deteriorated paint. Producing granular estimates is important because tract characteristics are unique to a community; therefore, when conducting targeting analyses, predicted risk should be viewed within a predefined jurisdiction. A tract-level interactive map that displays information for 72 235 US census tracts is available online via the HUD-eGIS Open Data Storefront.<sup>27,28</sup>

### **New York State case study**

County-level and tract-level estimates are the most useful when examining a predefined jurisdiction. To reinforce this perspective, predicted rates were subset and examined in New York, the state with the highest overall predicted risk.

After applying quartile classification, several counties and tracts emerged as potential neighborhoods where policy makers and practitioners can focus lead remediation efforts. For example, county-level quartile risk scores revealed Albany as an at-risk jurisdiction (Figure 2a). An estimated 2.6% to 4.6% of occupied units within Albany county are at risk of containing pre-1980 housing units with large areas of deteriorated paint. Tract-level quartile risk scores (range: 1.7%-4.4%) further identified specific at-risk neighborhoods in eastern Albany with tracts in the highest quartile having risk scores ranging from 3.4% to 4.4% (Figure 2b). Identification of these at-risk tracts can inform lead remediation targeting efforts for state and local administrators.

### **Public use data and interactive map**

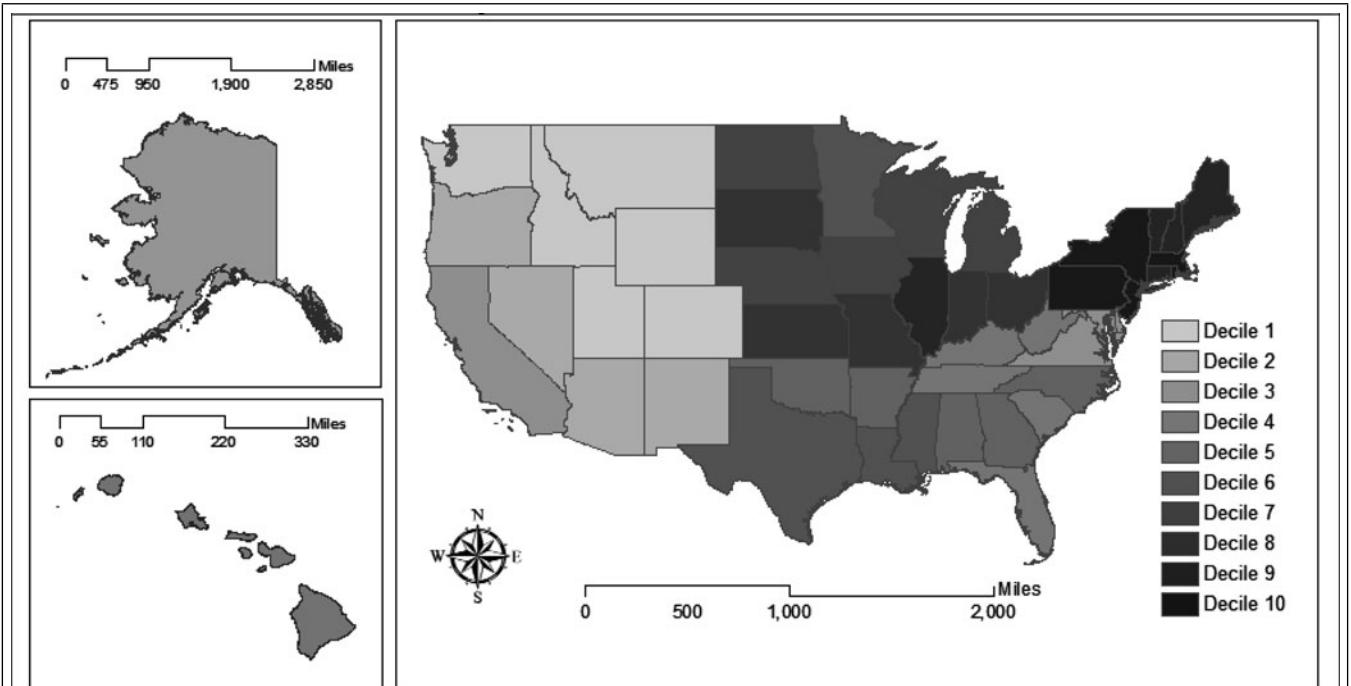
The data set discussed in this article, HUD's Deteriorated Paint Index (DPI), is publicly available on the HUD-eGIS Open Data Storefront at the state, county, and tract levels.<sup>29-31</sup> In addition, an interactive map and a corresponding user's guide are now available for use by state and local practitioners.<sup>27,28</sup>

### **Discussion and Conclusion**

Lead dust is a well-known neurotoxin and the most common pathway of lead exposure in US households.<sup>1</sup> Although there are estimates of the prevalence of deteriorated paint in US housing at national and regional scales, estimates for smaller geographic areas are not readily available. This study filled this gap by developing a predicted risk interactive map that can identify jurisdictions at risk of containing housing units with deteriorated paint. Counties, states, and tracts with a high percentage of at-risk units were identified. Results from the study represent the first nationwide, tract-level estimates for potential lead dust exposure attributable to large areas of deteriorated paint. Results underscore 3 key findings.

### **Key findings**

First, when examining states and counties with the most at-risk households, there are clear regional differences. This finding is both consistent and divergent from prior research. For example, prior lead exposure research shows that persons in the northeast and the Midwest regions experience higher rates of lead exposure, a finding consistent with this study.<sup>32</sup> When compared with the west, housing units in the northeast had a risk that was more than 2-fold. Conversely, a CDC surveillance study found that New York, Pennsylvania, California, and Illinois have the largest



Decile Rank <sup>a</sup>	State <sup>b</sup> Names			Mean Predicted % Range
10	New York New Jersey	Rhode Island Massachusetts	Pennsylvania	2.52-2.90
9	Connecticut New Hampshire	Maine Illinois	Vermont	1.95-2.51
8	Indiana Ohio	Kansas South Dakota	Missouri	1.90-1.93
7	Iowa North Dakota	Michigan Wisconsin	Nebraska	1.80-1.89
6	Louisiana Texas	Minnesota Mississippi	District of Columbia	1.57-1.77
5	Alabama North Carolina	Arkansas Oklahoma	Georgia	1.51-1.55
4	Florida South Carolina	Kentucky West Virginia	Tennessee	1.43-1.51
3	California Maryland	Delaware Virginia	Hawaii	1.23-1.42
2	Alaska New Mexico	Arizona Oregon	Nevada	1.09-1.21
1	Washington Idaho	Montana Utah	Colorado Wyoming	1.02-1.08

**FIGURE 1** State-Level Predicted Risk of the Presence of Occupied Housing Units With Large Areas of Deteriorated Paint by Decile, United States, 2009-2013

<sup>a</sup>The higher the decile ranking, the higher the predicted risk of containing occupied units with large areas of deteriorated paint.

<sup>b</sup>States list includes the District of Columbia.

**TABLE 2****US Counties With the Highest and Lowest Mean Predicted Risk of Occupied Units<sup>a</sup> Exposed to Lead Dust (n = 3143)<sup>b</sup>**

Rank	Name, State Abbreviation	Corresponding CBSA	Predicted % Units
Highest			
1	Bronx County, NY	New York-Newark-Jersey City, NY-NJ-PA	4.61
2	Buffalo County, SD		3.59
3	Kings County, NY	New York-Newark-Jersey City, NY-NJ-PA	3.58
4	Hudson County, NJ	New York-Newark-Jersey City, NY-NJ-PA	3.47
5	Todd County, SD		3.42
6	Queens County, NY	New York-Newark-Jersey City, NY-NJ-PA	3.34
7	Shannon County, SD		3.33
8	Sioux County, ND	Bismarck, ND	3.32
9	New York County, NY	New York-Newark-Jersey City, NY-NJ-PA	3.29
10	Suffolk County, MA	Boston-Cambridge-Newton, MA-NH	3.27
11	Essex County, NJ	New York-Newark-Jersey City, NY-NJ-PA	3.26
12	Ziebach County, SD		3.25
13	Philadelphia County, PA	Philadelphia-Camden-Wilmington, PA-NJ-DE-	3.23
14	Passaic County, NJ	New York-Newark-Jersey City, NY-NJ-PA	3.06
15	Corson County, SD		3.03
Lowest			
3134	Lincoln County, WY		0.89
3135	Summit County, UT	Summit Park, UT	0.88
3136	Jefferson County, MT	Helena, MT	0.87
3137	Los Alamos County, NM	Los Alamos, NM	0.86
3138	Clear Creek County, CO	Denver-Aurora-Lakewood, CO	0.86
3139	Douglas County, CO	Denver-Aurora-Lakewood, CO	0.82
3140	Park County, CO	Denver-Aurora-Lakewood, CO	0.82
3141	Storey County, NV	Reno, NV	0.80
3142	Morgan County, UT	Ogden-Clearfield, UT	0.80
3143	Elbert County, CO	Denver-Aurora-Lakewood, CO	0.79

Abbreviation: CBSA, core-based statistical area.

<sup>a</sup>The predicted units metric represents the predicted percentage of occupied housing units at risk of containing deteriorated paint within each respective county. The denominator for this metric is all occupied housing units in the county. The predicted measure should be used by communities to identify counties with a large share at "at-risk" units.

<sup>b</sup>A county-level interactive map that displays information for most US counties (n = 3143) is available online via the HUD-eGIS Open Data Storefront.<sup>27,28</sup>

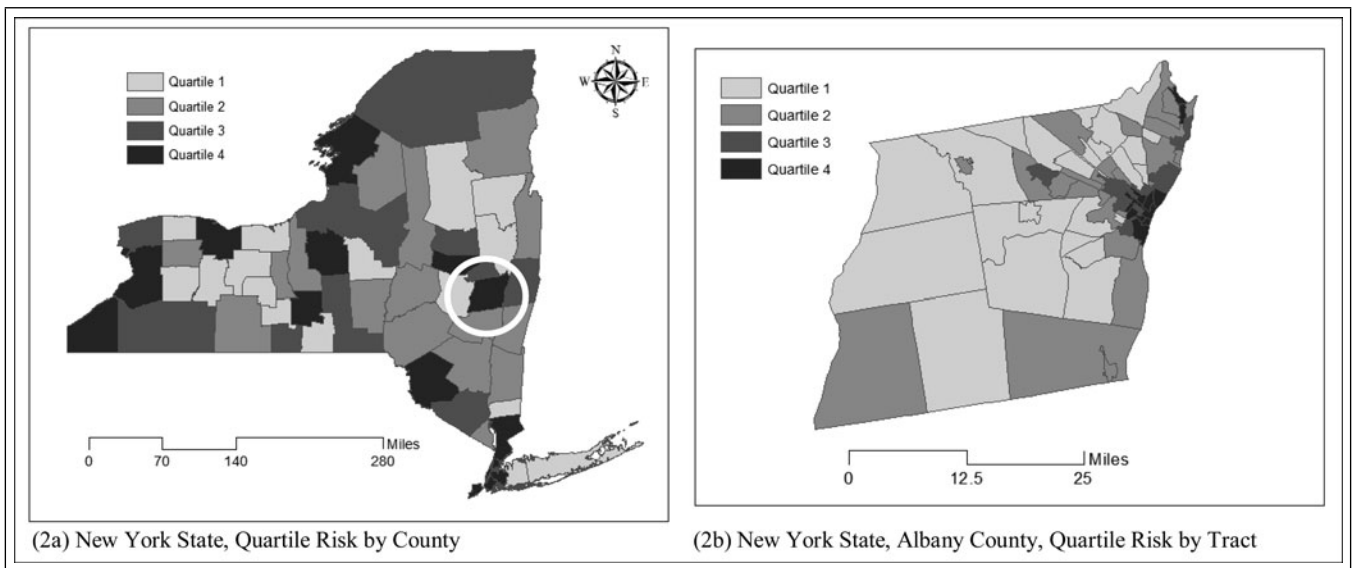
number of pre-1950 units containing children with confirmed EBLs.<sup>33</sup> This study did not find California to be one of the top high-risk states. However, it is also important to note that California had some abnormally high outliers in the CDC study.

The second key finding underscores that the risk of deteriorated paint, a condition associated with substandard housing, represents a health equity issue. Namely, several racial, ethnic, and economic disparities emerged. For example, the predicted percentage of units exposed to deteriorated paint was 2.38% for households headed by a black individual while it was only 1.54% for households headed by white persons. When compared with white families, black families were 1.94 (95% CI, 1.94-1.95) times more likely to report deteriorated paint. In addition, 2.34%

of Hispanic-headed households and 1.67% of non-Hispanic-headed households were at risk, a statistically significant finding. Finally, when compared with higher-income families, low-income families (household income <\$20 000) were 1.38 (95% CI, 1.38-1.39) times more likely to have large areas of deteriorated paint. Findings are consistent with prior research that has referred to childhood lead poisoning as an environmental justice issue.<sup>34</sup>

Finally, it is important to highlight the study's findings pertinent to children because children are the most susceptible to the adverse health impacts of lead exposure.<sup>3</sup> There is no known safe level of lead exposure in children and lead dust exposure can lead to irreversible damage.<sup>35</sup> This study estimates that approximately one-third (32.7%) of US households





**FIGURE 2** County-Level and Tract-Level Predicted Risk of the Presence of Occupied Housing Units With Large Areas of Deteriorated Paint by Quartile<sup>a</sup>, New York State, 2009–2013

<sup>a</sup>The higher the quartile ranking, the higher the predicted risk.

contain children aged 0 to 17 years. An estimated 1.89% of households with children contain large areas of deteriorated paint.

### Limitations

Although the presented study offers new information regarding potential lead dust exposure attributable to deteriorated paint, several key limitations must be highlighted. First, the study outcome occurred in a small subset of the overall population; approximately 3200 households reported the outcome used in the predictive model. Low sample size reduces the chance of detecting a true effect, especially when subsetting by small geographic units. Second, the study was limited to covariates that were available in both ACS and AHS. For categorical variables, the breaks had to be consistent. Several predictors that would have been ideally included in the model could not be included. The presence of children aged 0 to 5 years is more useful; however, this indicator was not available in both surveys. Third, the AHS responses are self-reported, which can lead to bias. One prior housing quality study found key differences between self-report and expert assessment.<sup>36</sup> Fourth, although a household reported the risk outcome, there is no way to determine whether the housing unit has already undergone significant remediation. Fifth, not all deteriorated paint is LBP; however, prior research using the National Health and Nutrition Examination Survey (NHANES) found that among homes that reported

chipping, peeling, or flaking (ie, deteriorated) paint, dust wipe samples revealed higher windowsill dust lead loadings compared with homes that did not report deteriorated paint.<sup>9</sup> This methodology also does not account for other forms of potential lead exposure, such as contaminated soil or water. There are also reporting discrepancies regarding year housing built across surveys. In the AHS, an estimated 67.2% of housing units were built before 1980; in the ACS, an estimated 56.4% of housing units were built prior to 1980. Although this represents a 10-percentage point difference, this discrepancy mirrors previous research comparing the 2 surveys.<sup>23</sup>

Finally, the self-reported (1.73%) and predicted percentage (1.74%) of deteriorated paint in this study is considerably lower than the estimated prevalence of significantly deteriorated LBP in the AHHS (14.5%). This large difference is due to several reasons. First, this study accounted for large areas of interior deteriorated paint (defined as areas bigger than 8 in by 11 in) while the AHHS accounted for significantly deteriorated LBP identified using in situ measurements of lead in paint, a more liberal definition. Notably, deterioration in the AHHS was defined as “more than 20 square feet (exterior) or 2 square feet (interior) of LBP on large surface area components (walls, doors), or damage to more than 10% of the total surface area of interior small surface components (windowsills, baseboards, trim).”<sup>37</sup> Inclusion of exterior and trim deterioration in the AHHS contributes to the large discrepancy between AHHS and AHS findings. Second, the

AHHS data were collected through physical inspection of the interior and exterior of the home. These differences underscore that the value of the discussed study is the ability to identify jurisdictions at higher risk of having housing units with interior deteriorated paint; however, the AHHS should be used for accurate prevalence estimates of US housing units containing significantly deteriorated LBP. Finally, it is important to note that due to confidentiality and privacy mandates, household-level, restricted-use ACS cannot be linked with the AHHS data.

## Conclusion

Past research highlights the importance of making housing lead safe by addressing lead hazards in and around the home.<sup>38,39</sup> Prior efforts to predict lead exposure are limited. Often, online mapping tools focus solely on year of construction and poverty indicators, an approach that does not account for housing condition. In addition, many past studies can be used only to develop tract-level analyses for a limited geographic area.<sup>19,40,41</sup> This study provides national, tract-level estimates that predict risk for deteriorated paint, a well-established risk factor for elevated dust lead levels.

Exposure to residential lead dust will continue to be a public health problem until housing with deteriorated lead paint and lead contaminated soil is remediated. The only effective intervention for mitigating the adverse health impacts of lead is the prevention of the initial exposure.<sup>42</sup> However, funding for remediation and abatement is limited.<sup>43</sup> This study can help inform local administrators and policy makers by providing a neighborhood targeting data set for the use of limited lead abatement and remediation resources. To further refine targeting efforts, state and local community stakeholders should consider overlaying unique community-level variables (eg, blood-lead-screening data, number of children aged 0-5 years, housing units that received prior remediation, or high-Medicaid usage zones) with HUD's DPI. For example, collaboration with a local health department that collects EBLs can further filter high-risk communities. National EBL data were not included in this study because no reliable data set containing census tract-level information currently exists at the national level, and prior research shows that only half of state EBL data are reported to the CDC.<sup>44</sup> Study results provide much-needed evidence that can be used to identify geographies with the highest probability of containing housing units at significant risk of containing LBP hazards.

This research presents important findings, but next steps must focus on collaboration, dissemination,

## Implications for Policy & Practice

- Lead dust is the most common pathway of lead exposure in US occupied households.
- This study discusses national, state-level, county-level, and tract-level estimates that can be used to predict a jurisdiction's risk for deteriorated paint, a well-established risk factor for elevated dust lead levels.
- Funding for remediation and abatement is limited. To adequately target households eligible for home remediation and associated intervention efforts, local healthy homes and environmental health program administrators must identify neighborhoods that present the greatest risk of residential lead exposure where deteriorated paint is the primary source.
- The state-level, county-level, and tract-level data set presented in this study, titled HUD's Deteriorated Paint Index (DPI), is now publicly available online. In addition, an interactive map and a corresponding user's guide are now available for use by state and local practitioners.
- Exposure to residential lead dust will continue to be a public health problem until housing with deteriorated lead paint is remediated. Public health practitioners interested in strategically allocating healthy homes funding should consult this data set and overlay predicted rates of deteriorated paint with important and unique local data to develop comprehensive targeting strategies.

and practice. Notably, HUD is currently collaborating with EPA and CDC partners to further validate and utilize this model with extant environmental and outcome data sets, including blood-lead surveillance data. For example, EPA has incorporated HUD's DPI for several states into lead mapping and analyses alongside 2 EPA lead exposure indices for the purposes of collaborative federal-state joint planning discussions. As expected, statistical convergence among the 3 indices is strong, given their use of similar variables and data, although they were developed for different purposes.<sup>22</sup> In addition, collaboration with the CDC analysts using the NHANES data shows a reasonable level of concordance between HUD's DPI and NHANES EBL data.<sup>22</sup>

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