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Poverty Status and IQ Gains from Revising the Dust Lead Hazard Standards: A Method for Evaluating Environmental Justice Implications?

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DISCLAIMER

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September 27, 2010

Abstract

The purpose of this paper is to outline a method for evaluating the Environmental Justice (EJ) implications of revising the dust lead hazard standards for floors. For simplicity this paper only addresses populations as defined by poverty status, but the methods described can be applied to evaluate distributional implications by race, ethnicity, and populations defined according to alternative income categories. The method for estimating IQ gains from changes in dust lead levels follows the approach described in EPA's 2008 report, *The Approach Used for Estimating Changes in Children's IQ from Lead Dust Generated during Renovation, Repair, and Painting in Residences and Child-occupied Facilities* (EPA 2008). The results presented indicate that children living below the poverty level are more likely to live where dust lead levels exceed the alternative hazard standard level of 10 µg/ft^2 for floors and therefore have the potential to benefit more from a revision to the standard compared to children living above the poverty level.

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Poverty Status and IQ Gains from Revising the Dust Lead Hazard Standards: A Method for Evaluating Environmental Justice Implications

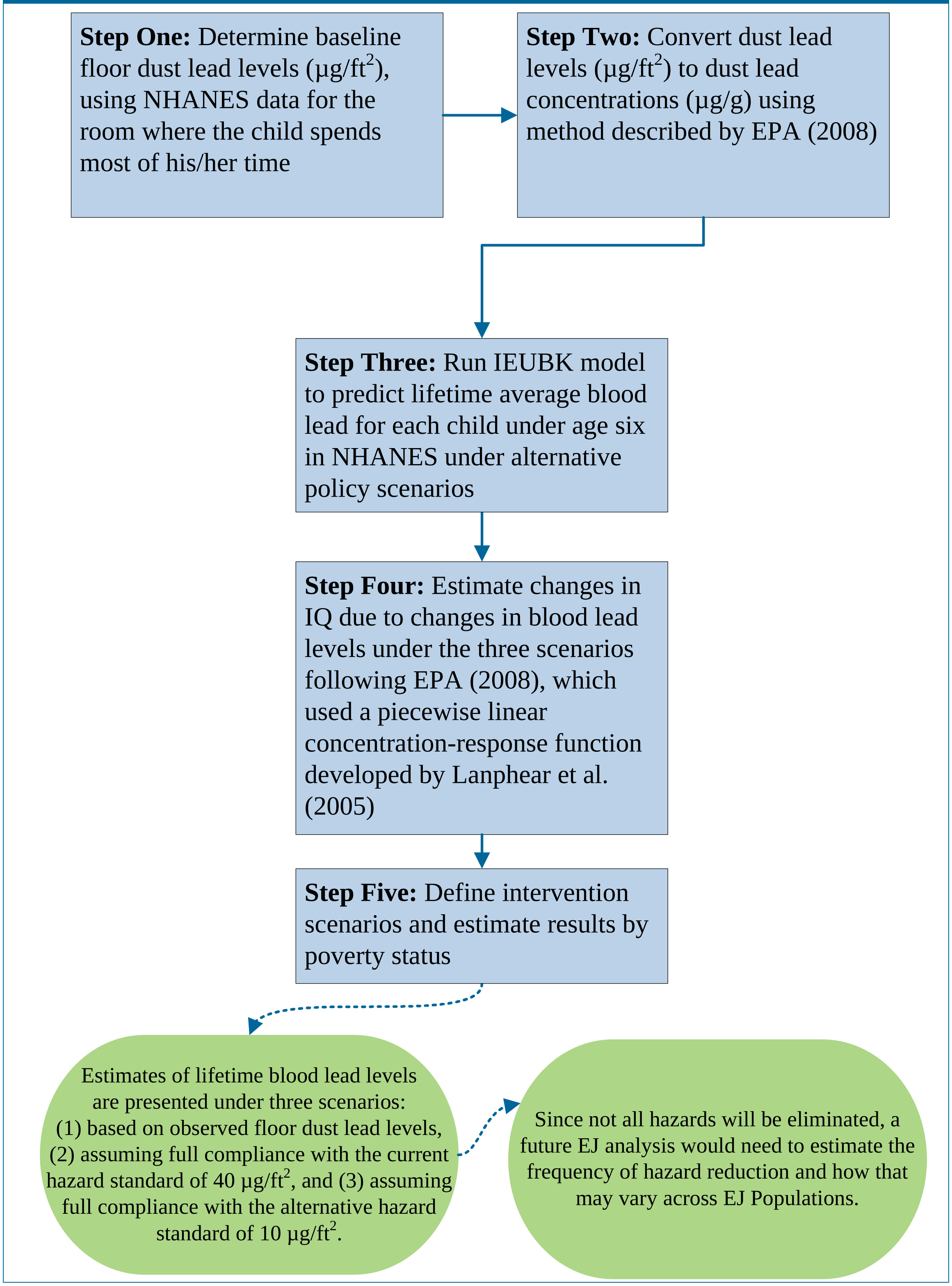
In 2009 the U.S. Environmental Protection Agency (EPA) received a petition filed by the National Center for Healthy Housing, the Alliance for Healthy Homes, the Sierra Club and others requesting that EPA lower dust lead hazard standards and modify the definition of lead-based paint in its regulations promulgated under sections 401 and 403 of the Toxic Substances Control Act (TSCA) (EPA 2009a). The petitioners requested that EPA lower dust lead hazard standards from 40 micrograms of lead per square foot of surface area ($\mu g/ft^2$) to 10 $\mu g/ft^2$ or less for floors and from 250 $\mu g/ft^2$ to 100 $\mu g/ft^2$ or less for window sills. The petitioners also requested that EPA revise the definition of lead-based paint to reduce the lead levels from 0.5 percent by weight (5,000 parts per million (ppm)) to 0.06 percent by weight (600 ppm) with a corresponding reduction in the 1.0 milligram per square centimeter standard.

EPA agreed to revisit the current dust lead hazard standard in response to the petition and to work with the U.S. Department of Housing and Urban Development (HUD) to modify the definition of lead-based paint in its regulations (EPA 2009b). An important consideration in evaluating alternative options for revising these standards is the distributional effects, if any, on any sensitive subpopulations.

The purpose of this paper is to outline a method for evaluating the environmental justice (EJ) implications of revising the dust lead hazard standards for floors. For simplicity this paper only addresses populations as defined by poverty status, but the methods described can be applied to evaluate distributional implications by race, ethnicity, and populations defined according to alternative income categories. Thus, this analysis focuses on how the revised standards would affect the blood lead levels of children under the age of six by poverty status and how those effects on blood lead levels would affect their cognitive abilities. The preliminary results presented in this paper show that populations of children living below the poverty line are more likely to live where dust lead levels exceed the alternative dust lead standard of 10 µg/ft^2 and therefore are likely to see more IQ gains from revising the standard.

The paper is organized according to the five primary analysis steps for estimating IQ changes from changes in dust lead levels, presented in Figure 1. In step 1 the distributions of floor dust lead levels (µg/ft^2) by poverty status are estimated using the National Health and Nutrition Examination Survey (NHANES). Steps 2 and 4 follow almost exactly the same approach as EPA's 2008 report, *The Approach Used for Estimating Changes in Children's IQ from Lead Dust Generated during Renovation, Repair, and Painting in Residences and Child-occupied Facilities* (EPA 2008). For step 3 this paper's approach diverges from that of EPA (2008) by selecting the Integrated Exposure Uptake Biokinetic (IEUBK) Model for estimating blood lead levels from dust lead concentrations (µg/g) (EPA 2005). In step 5 the intervention scenarios are defined as achieving the two alternative floor standards in all households, 40 µg/ft^2 and 10 µg/ft^2, and the results are estimated by poverty status.

Figure 1: Primary Analysis Steps



1 Estimating Floor Dust Lead Levels

In order to investigate the potential distributional implications across children in different income categories of a change in the floor dust lead hazard standards, the baseline level of lead in dust must first be estimated. The baseline levels of lead in dust and soil were estimated using data from the NHANES. The NHANES is administered by the National Center for Health Statistics (NCHS), the organization within the Centers for Disease Control and Prevention (CDC) that is responsible for producing the vital and health statistics for the nation (CDC 1999-2004). Since 1999 the NHANES has been conducted on a continuous basis, examining a nationally representative sample of about 5,000 persons each year. The samples are drawn from persons located in counties across the country, 15 of which are visited each year.

For this analysis dust lead samples collected for the NHANES from 1999 through 2004 are used. The NHANES data includes floor dust lead samples from housing units where 3,440 children ages 12 to 72 months reside. Samples were taken from the floors of the rooms where respondents reported that their children spent most of their time. Of the 3,440 children with floor dust lead samples, 89 and 5 live in housing units where floor dust lead levels exceeded 10 $\mu g/ft^2$ and 40 $\mu g/ft^2$, respectively. Since this analysis focuses on the distributional implications of a change in the floor dust lead hazard standard from 40 $\mu g/ft^2$ to 10 $\mu g/ft^2$, these 94 children under the age of six are the only children in the NHANES sample potentially affected by such a change. Poverty status is reported for 82 of these 94 children.

This paper's general approach is to compare the differences in the IQ gains from reducing exposures under two intervention scenarios: (1) one scenario where floors with dust lead levels exceeding 40 $\mu g/ft^2$ are reduced to 40 $\mu g/ft^2$, and (2) a second scenario where floors with dust lead levels exceeding 10 $\mu g/ft^2$ are reduced to 10 $\mu g/ft^2$. Thus, the pre-intervention (baseline) average floor dust lead level for each housing unit is the floor dust lead level reported in the NHANES data, and the assumption that the post-intervention floor dust lead levels are reduced to the hazard standard level is made.

One important limitation of using the NHANES data is that the sample is designed to be nationally representative for the population, but it is not designed to be nationally representative for the housing stock. The results of this analysis could be biased if the NHANES sample does not adequately represent the age distribution of national housing stock, because older housing is more likely to contain lead-based paint hazards. HUD's (2001) National Survey of Lead and Allergens in Housing (NSLAH) was considered as a data source for this analysis, which has a sample designed to be nationally representative for the housing stock, rather than for the population. The main advantage of the NHANES data over the NSLAH data is its larger sample of floor dust lead levels that exceed 10 $\mu g/ft^2$. Another important advantage of the NHANES data over the NSLAH is that blood lead measurements were taken for the NHANES and these data can be used in a future analysis to compare this paper's predicted blood lead levels to the blood lead levels observed in the NHANES data.

2 Estimating Dust Lead Concentrations From Dust Lead Levels

The concentration of lead in floor dust (µg/g) must be estimated from the floor dust lead levels ($\mu g/ft^2$) in order to estimate the blood lead levels in children using EPA's IEUBK Model for Lead in Children. Floor dust lead levels are converted into dust lead concentrations by utilizing the equations estimated for EPA's 2008 report, *The Approach Used for Estimating Changes in Children's IQ from Lead Dust Generated during Renovation, Repair, and Painting in Residences and Child-occupied Facilities* (EPA 2008)

EPA (2008) developed a two-step method for converting dust lead levels (µg/ft^2) taken from dust wipe samples into dust lead concentrations (µg/g). The first step is to convert wipe sample indoor dust levels ($DLEVEL_W$) to the equivalent Blue Nozzle (BN) floor dust lead levels ($DLEVEL_{BN}$). The BN method measures the weight of the lead found in the dust that is vacuumed from a square foot area of floor, whereas the floor dust wipe method measures the weight of the lead found in the dust from a cloth wiped over a square foot area of the floor. This conversion is carried out using the following equation for uncarpeted floors, from "Conversion Equations for Use in Section 403 Rulemaking" (EPA, 1997):

$$DLEVEL_{BN} = 0.185*(DLEVEL_W)^{0.931} \qquad \text{(equation 1)}$$

The second step is to convert the BN floor dust lead level estimates (µg/ft^2) into dust lead concentrations (µg/g) following the method developed by EPA (2008). EPA (2008) estimated the relationship between BN floor dust lead levels (µg/ft^2) and floor dust lead concentrations (µg/g) using data from the U.S. Department of Housing and Urban Development's (HUD) National Survey of Lead-Based Paint in Housing. This survey collected data from a nationally representative sample of 300 private residences and 100 public housing units in 1989 and 1990. As part of this HUD survey (EPA 1995), both Blue Nozzle (BN) floor dust lead levels and Blue Nozzle (BN) floor dust lead concentrations (DCONC) were measured in each housing unit. Using linear regression, EPA (2008) estimated the relationship between floor dust lead concentrations and floor dust lead levels for four housing vintages: housing built before 1930, between 1930 and 1949, between 1950 and 1959, and between 1960 and 1978.[1] In addition, EPA (2008) estimated this relationship for all housing built before 1978. The estimated relationships from EPA (2008) are presented in Table 1. The NHANES data includes categorical information about the year of housing construction, but since the categories in the NHANES and the HUD data used for the

[1] Lead-based paint was banned in 1978.

EPA (2008) analysis differ slightly the HUD vintage categories were mapped to the closest NHANES vintage category as shown in Table 1. The estimated parameters are increasing with the age of the housing, consistent with higher lead concentrations in older housing.

Table 1: Equations for Converting Dust Lead Levels to Dust Lead Concentrations

HUD Vintage	Closest NHANES Vintage	Equation	
Pre-1930	Pre-1940	$DCONC = \exp(5.28+0.56*\ln(DLEVEL_{BN}))$	(equation 2.1)
1930-1949	1940-1949	$DCONC = \exp(4.98 +0.47*\ln(DLEVEL_{BN}))$	(equation 2.2)
1950-1959	1950-1959	$DCONC = \exp(4.97+0.42*\ln(DLEVEL_{BN}))$	(equation 2.3)
1960-1978	1960-1978	$DCONC = \exp(4.78+0.36*\ln(DLEVEL_{BN}))$	(equation 2.4)
All Pre-1978	All Pre-1978	$DCONC = \exp(4.90+0.48*\ln(DLEVEL_{BN}))$	(equation 2.5)

In addition to equations 2.1 through 2.5 estimated by EPA (2008), the relationship between dust lead concentrations and dust lead levels in post-1978 housing was estimated for this paper using the 1989-1990 HUD data for 1960-1978 housing without lead-based paint (LBP) (EPA 1995). These housing units are most similar to post-1978 housing (which was not in the HUD study because post-1978 housing generally does not contain lead-based paint). This estimated relationship is given in equation 3:

$$DCONC_{(Post\text{-}1978)} = \exp(4.59+0.27*\ln(DLEVEL_{BN})) \qquad \text{(equation 3)}$$

The estimated parameters presented in equation 3 are consistent with the equations (2.1-2.5) estimated by EPA (2008), but the model fit in terms of R^2 for equation 3 was not as good. However, this equation is only used to calculate summary statistics. It is not used to compare the alternative standards because none of the post-1978 housing units in the NHANES sample had a floor lead dust level above the alternative dust lead standard of 10 ug/ft^2. These methods for converting floor dust lead wipe samples to dust lead concentrations introduce additional uncertainty to this analysis,[2] the direction and magnitude of which is unknown.

3 Estimating Blood Lead Levels from Dust Lead Concentrations

The method for estimating blood lead levels is one aspect of this paper that diverges from the methods employed by EPA's (2008) analysis. Where EPA's (2008) analysis used the International Commission for Radiation Protection (ICRP) model (also known as the Legget model), this analysis uses the Integrated Exposure Uptake Biokenetic (IEUBK) model. The primary reason why the Leggett model was chosen for EPA's (2008) analysis was that its design is well suited for examining episodic peak exposures and subsequent reductions in exposure levels, such as would be expected from renovation activities. In contrast, the IEUBK model is designed to model longer term exposures to lead in dust, soil, air and water. The IEUBK model is well suited for this paper because it focuses on examining the effects of longer term reductions in exposure to dust lead.

The IEUBK model is a multi-compartmental pharmacokinetics model linked to an exposure and probabilistic model of blood lead concentration distributions in children (U.S. Environmental Protection Agency, 1994a,b; White et al., 1998, as cited by EPA 2006). The model simulates the exposure and biokinetics of lead from 6 to 84 months of age in order to predict average quasi-steady state blood lead concentrations corresponding to daily average exposures, averaged over periods of one year or more. The IEUBK model consists of four major compartments or submodels (EPA 2006):

[2] The EPA (1995) survey data did not include the primary sampling unit and strata information necessary to correctly calculate the standard errors for the parameters in equation 3. This information was censored to protect the confidentiality of respondent households.

(1) An exposure model that calculates average daily intakes of lead (μg/day, averaged over a 1 year time increment) for each inputted exposure concentration (or rate) of lead in air, diet, dust, soil, and water.

(2) An uptake model that converts environmental media-specific lead intake rates from the exposure model into media-specific time-averaged rates of uptake (μg/day) of lead to the central compartment (blood plasma).

(3) A biokinetic model that (1) simulates the transfer of absorbed lead between blood and other body tissues, as well as the elimination of lead from the body (via urine, feces, skin, hair, and nails), and (2) predicts an average blood lead concentration.

(4) A lognormal blood lead level probability distribution based on the output from item (3) above to predict probabilities for exceeding a specified blood lead concentration in a population of similarly exposed children.

4 Estimating Changes in IQ Associated with Changes in Blood Lead Levels

The negative effects of elevated blood lead levels on neurobehavioral outcomes are well established in the scientific literature. According to EPA's Air Quality Criteria Document (AQCD) for Lead (EPA 2006, p. 6-76):

> Effects of Pb on neurobehavior have been reported with remarkable consistency across numerous studies of various designs, populations studied, and developmental assessment protocols. The negative impact of Pb on IQ and other neurobehavioral outcomes persist in most recent studies following adjustment for numerous confounding factors including social class, quality of caregiving, and parental intelligence. Moreover, these effects

> appear to persist into adolescence and young adulthood in the absence of marked reductions in environmental exposure to Pb… Recent studies examining the Pb associations with intellectual attainment and academic performance in children with low Pb exposures have consistently observed effects at blood Pb concentrations below 10 μg/dL. The large international pooled analysis of 1,333 children estimated decline of 6.2 points (95% CI: 3.8, 8.6) in full scale IQ for an increase in concurrent blood Pb levels from 1 to 10 μg/dL.

Chapter 6 of the AQCD for lead presents the details of several epidemiologic studies that link lead exposure to health effects (EPA 2006). The study that is most relevant to predicting neurocognitive effects in children in response to elevated blood lead levels is Lanphear et al. (2005). Other studies that are relevant include Canfield et al. (2003), Kordas et al. (2006), and Tellez-Rojo et al. (2006), all of which examine the effects of elevated blood lead on cognitive abilities.

The pooled analysis by Lanphear et al. (2005) is the best study available for estimating the IQ loss associated with elevated blood lead levels because it evaluated the relationship between elevated blood lead levels and IQ loss across a much larger population across several countries, various patterns of lead exposure, and a wider range of socioeconomic conditions compared to any other study (EPA 2008). The Lanphear et al. (2005) pooled analysis included seven prospective studies initiated prior to 1995 that included 1,333 children where complete data on confounding factors were available. The primary response variable in the pooled study was full-scale IQ at school age and four measures of lead exposure were evaluated: (1) concurrent blood lead level (the blood lead level closest in time to the IQ test), (2) maximum blood lead level (peak blood lead level taken prior to the IQ test), (3) average lifetime blood lead (mean blood lead from 6 months to the concurrent blood lead level), and (4) early childhood blood lead (mean blood lead from 6 to 24 months).

This paper follows EPA (2008) by selecting lifetime average blood lead level as the blood lead metric. The lifetime average blood lead metric can be used to extend the analysis to evaluate the benefits of achieving alternative dust lead levels on floors at different points in time whereas the alternative metrics cannot. For example:

- if concurrent blood lead levels were used it would not be possible to differentiate between scenarios where lead hazard reductions were achieved at different points in a child's life;
- if peak blood lead levels were selected, benefits could not be estimated for reducing exposures after peak blood lead levels had occurred;
- if early childhood blood lead levels were selected, benefits could not be estimated for reducing exposures after early childhood.

Note that only interventions that occur prior to any childhood exposure were examined for this paper, and therefore any of the four blood lead metrics could be used to evaluate these scenarios. However, the lifetime average blood lead metric is the only suitable metric for extending this analysis for an economic analysis to support a rulemaking, which will need to estimate the benefits of reducing floor dust lead levels at different stages of childhood.

Lanphear et al. (2005) found that the log-linear model demonstrated the strongest relationship between blood lead and IQ when compared to linear, cubic, spline, log-linear, and piecewise linear models. As EPA (2008) pointed out, the log-linear blood lead-IQ slope decreases rapidly at low levels of blood lead and goes to negative infinity at zero blood lead, which limits its use for predicting IQ changes at low blood lead levels. Since the focus of this paper is a comparison of the benefits of achieving alternative low levels of floor dust lead, the same piecewise linear model utilized in EPA's 2008 analysis was selected (as shown below).

For Blood Lead < 1, IQ Change = 0 (equation 4)

For Blood Lead = 1 to 10, IQ Change = Blood Lead * -0.88

For Blood Lead > 10, IQ Change = -8.75 + (Blood Lead – 10) * -0.10

Equation 4 shows that no change in IQ is estimated for blood lead levels below 1 μg/dL and estimated IQ is more sensitive to changes in blood lead for initial blood lead between 1 and 10 μg/dL compared to those for initial blood lead levels above 10 μg/dL.

5 Potential IQ Gains from Achieving Alternative Hazard Standard Levels

The extent to which the benefits of alternative dust lead hazard standards vary across populations can be attributed to two different factors: (1) the percentage of the population that lives in housing where dust lead hazards exist, and (2) the likelihood that a hazard is mitigated for a given population. The results presented in this paper reflect the variations across populations as defined by poverty status associated with only the first factor – the extent to which baseline exposure to dust lead hazards varies across populations of different poverty status. However, since testing for residential lead hazards is typically not performed on a regular basis the second factor may be as or more important.

There are a number of situations where interventions to lower floor dust lead levels might occur. For example, testing for lead hazards is required by HUD's Lead Safe Housing Rule for housing receiving HUD or other federal assistance (e.g., public housing, housing with HUD owned mortgages, rehabilitation assistance). Interventions might also occur in instances where a child was found to have elevated blood lead levels.

5.1 Full Compliance Scenarios: Methods and Some Preliminary Results

The preliminary results presented in this paper represent a comparison of how IQ gains would vary across populations as defined by poverty status if alternative standards for floor dust lead hazards were achieved. This is useful information for policy makers because it provides a measure of the extent to which populations as defined by poverty status are affected by dust lead levels above the alternative standards.

The two post-intervention scenarios considered are: (1) a scenario where floor dust lead levels are reduced to 40 $\mu g/ft^2$ before any exposure to dust lead occurs, and (2) a scenario where floor dust lead levels are reduced to 10 $\mu g/ft^2$ before any exposure to dust lead occurs. The current hazard standard for dust lead on floors is 40 $\mu g/ft^2$, so the first scenario represents the baseline intervention scenario. The alternative policy scenario selected for this analysis was 10 $\mu g/ft^2$, the hazard standard suggested by the Section 21 petitioners.

Since this analysis estimates the IQ changes associated with lifetime average blood lead levels, defined as average blood lead levels between the ages of 6 and 72 months, the IQ changes associated with the average blood lead levels from exposure to floor dust lead levels of 10 $\mu g/ft^2$ are compared with the IQ changes associated with the average blood lead levels from exposure to floor dust lead levels of 40 $\mu g/ft^2$. This comparison examines the difference in IQ gains that would be achieved under the two different hazard standards assuming that dust lead levels are reduced to the standards before the housing unit is occupied by the child. This type of scenario would occur when the lead hazard reduction activities are performed before a child is born, such as before a family moves in to a new home.

5.1.1 Some preliminary results: benefits of achieving full compliance with alternative floor dust lead hazards by poverty status

Table 2 presents summary statistics by poverty status under the baseline scenario, the scenario estimated from the conditions as observed in the NHANES data. A child is defined as being near poverty if household income is less than 125% of the poverty level. The table shows the mean, median, 95th, and 99th percentiles of floor dust lead levels, dust lead concentrations as estimated using the methodology presented in Section 2, lifetime average blood lead as estimated using the methodology presented in Section 3, and IQ gains associated with reducing lead exposure as estimated using the methodology presented in Section 4. The results presented in the table show that floor dust lead levels are higher for children near poverty both on average and at the high end of the distribution. It follows that estimated dust lead concentrations, predicted blood lead levels, and estimated IQ decrements attributable to lead exposure are higher for children with household incomes near the poverty level.

Table 2: Baseline Summary Statistics: Levels, Concentrations, Blood Lead Levels and IQ Decrements Under Observed Dust Lead Levels

Statistic	Poverty Status	Baseline Summary Statistics			
		Dust Lead Level (µg/ft^2)	Dust Lead Concentration (µg/g)	Lifetime Average Blood Lead	IQ Decrement from Lead Exposure
Mean	Near Poverty	1.94	68	1.62	1.43
	Above Poverty	0.85	55	1.46	1.28
Median	Near Poverty	0.62	53	1.44	1.27
	Above Poverty	0.38	48	1.37	1.21
95th Percentile	Near Poverty	6.50	149	2.61	2.30
	Above Poverty	2.85	108	2.12	1.87
99th Percentile	Near Poverty	25.10	353	4.91	4.32
	Above Poverty	7.00	185	3.04	2.67

Note: The sample sizes were 1,598, 1,632, and 210 for the near poverty, above poverty, and unknown poverty status populations, respectively. Poverty status was unknown for some respondents who did not know or refused to respond to questions about their income.

Table 3 presents the number of observations in the NHANES data as well as the weighted estimates of population share by poverty status and floor dust lead level category. The table shows that there are about the same number of observations for children near poverty status and those above poverty, which reflects the survey's over-sampling of disadvantaged populations.

Table 3: Number of Observations and Percentage of Population by Dust Lead Levels and Poverty Status				
Dust Lead Levels (µg/ft^2)	Number of Observations		Estimated Percentage of Population (Standard Error)*	
	Near Poverty	Above Poverty	Near Poverty	Above Poverty
<10	1,534	1,614	96.53% (0.77%)	99.20% (0.27%)
10 to 40	61	17	3.17% (0.68%)	0.73% (0.26%)
>40	3	1	0.30% (0.24%)	0.07% (0.07%)
Total	1,598	1,632	100.0%	100.0%

*Estimates and standard errors calculated using provided survey weights, pseudo strata, and primary sampling unit variables.

Table 3 shows that the percentages of children living in homes where the dust lead levels exceed the alternative hazard levels are higher for children living below the poverty line. A logistic regression analysis was performed to estimate whether these differences are statistically significant (see Table 4). The results presented in Table 4 show that children living below the poverty line are more likely to live in homes where the dust lead levels exceed the alternative hazard level of 10 µg/ft^2. The differences by poverty status are not statistically significant for the hazard level of 40 µg/ft^2, which is not surprising given that there are only four observations where dust lead levels exceed this standard.

Table 4: Logistic Regression Analysis for Exceeding Alternative Dust Lead Hazard Standards: Odds Ratio Estimates for Near Poverty Versus Above Poverty			
Hazard Standard	**Odds Ratio**	**95% Wald Confidence Limits**	
10 µg/ft^2	4.44*	2.02	9.77
40 µg/ft^2	4.19	0.36	49.49

Note: An odds ratio greater than 1 indicates that children of near poverty status are mroe likely to live where the hazard level is exceeded.
*Statistically different from 1 at the 95 percent confidence level.

Table 5 compares the benefits in terms of IQ gains under full compliance scenarios, which are defined as scenarios where no child would be exposed to floor dust lead levels exceeding the hazard standard. Columns three through five consider only the population of children that may benefit under the alternative hazard standard (i.e., children in homes where floor dust lead levels would otherwise exceed 10 µg/ft^2). Columns six through eight consider the entire population of young children, including those children where no hazard reduction would occur because floor dust lead levels are below 10 µg/ft^2. Thus, while columns three through five examine the extent to which affected children might benefit from an alternative standard, columns six through eight also capture the extent to which children of different poverty status live in housing units where flood dust lead levels exceed alternative hazard standards.

The mean IQ gain for children of near poverty status in column five of Table 5 is higher than for those children of above poverty status, implying the average benefit among those living where floor dust lead levels were reduced would be greater for those of near poverty status compared to children of above poverty status. The relative differences in IQ gain for children of near poverty status compared to children of above poverty status are greater in column eight compared to column five. This implies that a greater proportion of near poverty status children that would be affected if all floor dust lead levels were reduced to 10 µg/ft^2. This result reflects the higher percentage of them living in older homes which are more likely to have lead-based paint hazards. It is important to note, however, that an analysis of these data by Gaitens et al. (2009) found higher levels of dust lead associated with households with lower poverty-to-income ratios even after controlling for other indicators of dust lead such as housing age and floor condition. Thus, some of the factors driving the higher dust lead levels in poorer households remain unknown.

Table 5: Comparison of Expected Per-Child IQ Gain by Achieving Floor Dust Lead Levels of 10 µg/ft^2 Versus 40 µg/ft^2, by Poverty Status

Summary Statistic	Poverty Status	Population with baseline floor dust lead levels > 10 µg/ft^2			Full Population		
		40 µg/ft^2 hazard standard	10 µg/ft^2 hazard standard	IQ Gain: < 40 µg/ft^2 to < 10 µg/ft^2	40 µg/ft^2 hazard standard	10 µg/ft^2 hazard standard	IQ Gain: < 40 µg/ft^2 to < 10 µg/ft^2
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Mean	Near Poverty	0.12	0.89	0.77	0.004	0.031	0.027
	Above Poverty	0.11	0.76	0.64	0.001	0.006	0.005
Median	Near Poverty	0.00	0.53	0.53	0.000	0.000	0.000
	Above Poverty	0.00	0.22	0.22	0.000	0.000	0.000
95th Percentile	Near Poverty	0.66	2.07	1.92	0.000	0.000	0.000
	Above Poverty	1.27	3.74	2.47	0.000	0.000	0.000
99th Percentile	Near Poverty	2.98	5.44	2.47	0.000	1.324	1.324
	Above Poverty	1.27	3.74	2.47	0.000	0.000	0.000

Notes: Statistics calculated using NHANES survey weights. All zeros shown in table are true zeros.

6 Conclusions and Limitations

The primary contribution of this paper is the analytical method it describes, which can be extended to an economic analysis supporting a potential rulemaking, including the EJ component of the economic analysis. For simplicity this paper only addresses populations as defined by poverty status, but the methods described can be applied to evaluate distributional implications by race, ethnicity, and populations defined according to alternative income categories.

The results presented indicate that children living below the poverty level are more likely to live where dust lead levels exceed the alternative hazard standard level of 10 µg/ft^2 for floors and therefore have the potential to benefit more from a revision to the standard compared to children living above the poverty level.

One of the main limitations of this analysis is that the methods outlined in this paper do not provide a method for statistically testing whether two different populations' potential IQ gains differ from one another. This is because additional uncertainties, some of which cannot be quantified, are introduced in each of the five analysis steps for estimating IQ changes from changes in dust lead levels.

There are several additional limitations and uncertainties associated with the methodology described in this paper, the most important of which are the following:

- The NHANES includes the dust lead level from a single floor sample for a given home, whereas using six to eight samples are recommended by HUD (1995 as cited in Gaitens et al. 2009) to reduce spatial variability.
- The NHANES data are designed to be nationally representative for the population, not the housing stock. The results of this analysis could be biased if the NHANES sample

does not adequately represent the distribution of lead-based paint hazards in the national housing stock, which are more likely to be present in older housing.

- The numbers of observations for children living in housing exceeding the alternative hazard standards are small, 82 and 4 for the 10 $\mu g/ft^2$ and 40 $\mu g/ft^2$ standards, respectively, where poverty status is known. Since this analysis focuses on the distributional implications of a change in the floor dust lead hazard standard from 40 $\mu g/ft^2$ to 10 $\mu g/ft^2$, the primary results rely on the samples of 64 and 18 children living below and above the poverty level, respectively.
- Two conversions are necessary to translate dust lead levels into dust lead concentrations, adding additional uncertainty.

While the methods described in this paper can be extended to an EJ analysis supporting a potential rulemaking, additional considerations not fully addressed here will also need to be taken into account. In particular, since testing for residential lead hazards is typically not performed on a regular basis the frequency of achieving alternative compliance standards will also need to be estimated for the EJ populations. This will require estimating EJ population-specific frequencies of interventions, which are driven by instances where testing for lead hazards is required by HUD's Lead Safe Housing Rule, EPA's Proposed Lead, Renovation, Repair, and Painting Clearance Rule, or instances where a child was found to have elevated blood lead levels.

If an EJ analysis is performed to support a potential rulemaking for revising the dust lead hazard standards, an alternative approach should also be considered. Dixon et al. (2009) performed a regression analysis of how dust lead levels influence blood lead levels using the same NHANES data utilized in this paper. The Dixon et al. (2009) analysis includes estimates of parameters for poverty-income-ratio and race/ethnicity effects that can be used to estimate EJ-specific changes in blood lead from changes in floor dust lead. Employing the approach of Dixon et al. (2009) would have several advantages over the approach described in this paper, including the following:

- Developing a statistical test for whether two different populations' potential IQ gains differ from one another would be more straightforward since Dixon et al. (2009) reports the standard errors associated with the estimated parameters

- Using the parameters estimated by Dixon et al. (2009) would allow the EJ analysis to capture additional unknown factors or factors that are not quantified that may drive differences in impacts between EJ populations (e.g., exposures from other lead sources, differences in diet)

The advantage of the approach described in this paper over one that estimates blood lead changes from dust lead changes using the parameters from Dixon et al. (2009) is that the methods described in this paper mirror EPA's (2008) approach, which was developed through a Clean Air Scientific Advisory Committee (CASAC) panel peer review process. A rigorous economic and EJ analysis could employ both the method described in this paper and a method that estimates changes in blood lead from changes in dust lead using an empirical approach such as using the parameters estimated by Dixon et al. (2009).

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