The social costs of childhood lead exposure in New Jersey

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December 2009

Prepared for the New Jersey Department of the Public Advocate

Executive Summary

The power of lead to damage children's brains has been frequently underestimated. The developing brain is especially susceptible to lead exposure. Lead exposure primarily affects children between the ages of 0 and 6 years. Lead exposure in childhood reduces a child's intelligence, as measured by the intelligence quotient (IQ) test. This reduction in cognitive ability greatly reduces a child's chances of succeeding in school. Lead exposure also causes damage to critical parts of the brain that regulate behavior, which may explain the higher rates of developmental delay and attention deficit/hyperactivity disorder among lead exposed children. It may also explain the higher rates of conduct disorder and criminality among children and young adults who were exposed to lead early in life.

Just five decades ago, it was thought that a child with a blood lead level measured at less than 60 micrograms of lead per deciliter of whole blood (μg/dL) was safe from lasting neurological damage. As science advanced, it was discovered that smaller exposures produce significant damage. As a result, the so-called "safe" blood lead level was first lowered to 25 μg/dL in 1985, and then has been lowered various times since.

Regulations in the late 1970s and early 1980s eliminated lead in the two major sources of childhood lead exposure: household paint and gasoline. As a result of these regulations, blood lead levels in susceptible children fell from an average of 15 μg/dL to an average of 2 μg/dL today. However, other sources of lead have not been removed from the environment, such as lead found in contaminated soil as well as some jewelries, cosmetics, toys and candies. Blood lead levels have more or less stabilized.

As blood lead levels fell, childhood lead exposure slowly became seen as a historical tragedy that continued to affect poor children living in older, dilapidated housing. However, a number of new studies suggest that there is still a danger to the majority of children, both in New Jersey and the nation as a whole. It is now widely recognized that there is no "safe" level of lead in children, but it appears that levels smaller than 1 μg/dL likely produce minimal harm. New Jersey has older housing and more industry than many other states. The average lead level in New Jersey children is closer to 3 μg/dL. For these reasons, the greater the reduction in lead exposure, the more likely New Jersey's children will achieve success and realize their full potential.

Further reductions in the mean blood lead levels of New Jersey's children are possible. This study seeks to estimate the benefits that might be realized if *all* children in New Jersey were to have a blood lead level of less than 1 μg/dL. This study relies on published and electronic data sources to estimate the lifetime effects of present levels of exposure (the status quo) relative to this lower exposure (no child with a blood lead level greater than or equal to 1 μg/dL). Throughout the analysis, conservative methods are employed to ensure that the projected benefits are carefully estimated.

This study finds that childhood lead exposure remains a significant problem in New Jersey, with the majority of children in New Jersey having a blood lead level greater than or equal to 1 μg/dL. Reducing blood lead levels among all New Jersey children aged 0 to 6 years today to less than 1 μg/dL would both reduce future crime and increase on-time high school graduation rates. These changes would lead to large reductions in future cost to the New Jersey government and to New Jersey society at large.

These costs occur in the future, so they are worth less in today's dollars. Therefore, the future savings have been "discounted" to present-day dollars. When the standard 3% discount rate is applied, the net societal benefits arising from these improvements in high school graduation rates and reductions in crime would amount to $31,000 per child. This would result in overall savings of approximately $27 billion across all children aged 0 to 6 years, and would produce an additional 67,000 years of perfect health gained, valued at an additional $6 billion. This total societal benefit of $27 billion reflects benefits among all citizens of New Jersey. The benefits to the state budget are included in the total societal benefits. The New Jersey state budget would realize benefits of $14,000 per student and $9 billion across the entire cohort of children aged 0 to 6 years. These savings apply only to the present cohort of children aged 0 to 6 years. We would expect savings to increase as additional cohorts of children are born in New Jersey.

A cautionary note about this report

Childhood lead exposure produces a wide array of social costs. Some of these costs are well studied, but others less so. While we used the most up-to-date and robust estimates available in the medical literature, some data are older or were obtained from just one or two studies. We also faced some challenges in translating national estimates to New Jersey-specific estimates. To address these challenges, we sometimes exclude costs from our analysis or artificially lower the estimated benefits. This approach helps to ensure that we do not overestimate costs, but it also reduces the likelihood that we have fully estimated the social costs of childhood lead exposure. Readers are cautioned against interpreting the results as definitive. Rather, they should be considered a starting point for understanding the overall monetary and health impact of environmental lead on the health of children.

About the researchers

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The history of childhood lead exposure

While lead has been linked to neurological impairment since the time of the ancient Romans, its power to damage the brain has time and again been underestimated. The Romans observed that large doses of lead resulted in insanity and death among lead miners, but assumed it to be safe in smaller quantities.[1] This false assumption is thought by historians to be a major contributor to the fall of the Roman Empire, which became plagued with bad decision-making and violent behavior.[1] Closer to home, childhood lead exposure is thought to be a major contributor to the crime epidemic in the United States between the 1970s and mid-1990s.[2, 3]

While lead exposure can harm adults, lead primarily affects children, aged 0 to 6 years, whose developing brains are not equipped to defend against environmental toxins. When young children are exposed to environmental lead, permanent damage can occur to parts of the brain involved in higher intellectual function and behavior.[4-12] The net result of this damage is sub-optimal academic performance and a higher propensity toward delinquent behavior.

In the United States the dangerous threshold for lead exposure among children has gradually been lowered. Fifty years ago, a child with a blood lead level of under 60 micrograms of lead per deciliter of whole blood (µg/dL) was considered safe from lasting neurological damage. It has been subsequently discovered that smaller exposures produce significant damage.[1, 13] The safe threshold level was lowered to 25 µg/dL, and then lowered various times since then. It is now clear that blood lead levels significantly less than 10 µg/dL can cause lasting neurological damage in children.[5, 14]

Historically, children were primarily exposed to lead via inhalation of the combustion products of leaded gasoline and via the ingestion of lead-containing paint.[13, 15] By the 1970s and early 1980s, lead was recognized to be too dangerous to use as an additive in these products and was banned by the federal government.

The average blood concentrations of lead reached 15 µg/dL among children aged 0 to 6 years in the late 1970s.[15, 16] Regulations removing lead from gasoline and household paint had a dramatic effect on childhood blood lead levels. Today, blood lead levels in children are at historic lows[3, 15] however, dangerous lead exposure persists.

Many children continue to be exposed to deteriorating lead paint in pre-1978 housing, soil contamination, traditional folk remedies, toys, cosmetics, candies, jewelry, or lead-based industry near places where children live, play, and attend school.[15]However, more can be done to address these ongoing sources of lead exposure. The mean blood levels of lead appear to have leveled off at around 2 µg/dL nationwide[16] and at levels within New Jersey that are closer to 3 µg/dL.[17]This means that a large number of New Jersey's children are still suffering cognitive damage from lead exposure. Childhood lead exposure not only comes at a large human price, but the losses in human capital also sap the resources of the state.

Estimating the cost of childhood lead exposure

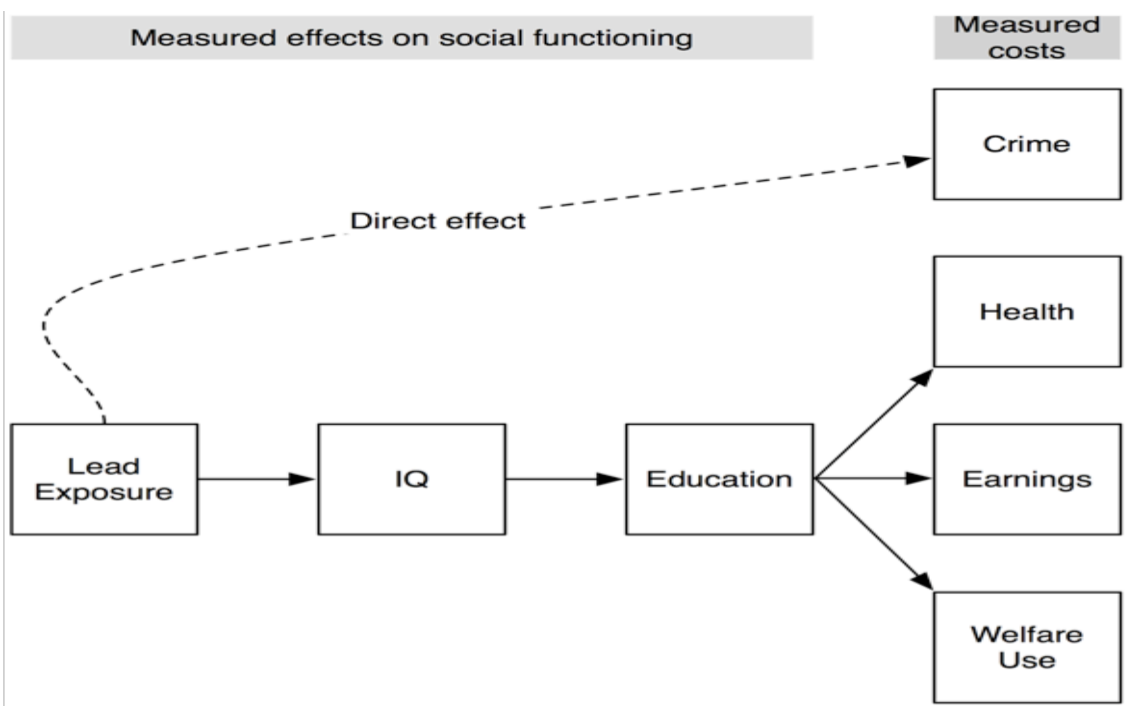
Two different visions of the future

Recent studies have found that childhood lead exposure resulting in blood lead levels as low as a few micrograms per deciliter of whole blood can cause lasting neurological damage.[5, 6, 11] These studies, though, generally find that blood lead levels of less than 1 μg/dL are associated with little or no reduction in IQ. Therefore, if all children in New Jersey had a blood lead level below 1 μg/dL, all other things being equal, we would expect that children would be achieving their full intellectual potential.

The purpose of this report is to estimate the current social benefits associated with reducing lead exposures among children to the point at which no child has a blood lead level at or exceeding 1 μg/dL. This threshold was chosen because complete elimination of childhood lead exposures is unrealistic and because exposures at this level have produced minimal declines in measures of cognitive performance.[5, 6, 11, 14]

This report seeks to obtain a conservative estimate of the overall benefits of minimizing lead exposure among New Jersey's children. A conservative estimate is one that ensures that we do not over count the costs associated with childhood lead exposure in New Jersey. By adhering to the conservative methods and assumptions (see appendix), we can be certain that the presented costs produce reasonable estimates of the "real world" costs of childhood lead exposure in

Figure 1. How childhood lead exposure affects social costs.
Solid lines represent social costs arising from the effect of childhood lead exposure on educational attainment. The dashed line represents the direct effects of childhood lead exposure on crime. (For simplicity, the direct effect of childhood lead exposure on special education and medical treatment costs are not shown.)



New Jersey. By defining the minimal benefits associated with reducing childhood lead exposure in New Jersey, policymakers can better understand the scope of efforts required to reduce future lead exposures among New Jersey's children.

The first step is to estimate the lifetime benefits that the average New Jersey child confers to New Jersey society over his or her lifetime. The lifetime benefit is calculated by adding up the estimated future yearly earnings of the average New Jersey child, and subtracting out any participation in criminal activity or use of welfare services. Premature mortality must also be considered. Those who die prematurely contribute less on average to New Jersey than those who live to retirement. These earnings among survivors are not only taxed, but they also are used for consumer expenditures that keep businesses running. The net benefit produced by the average New Jersey child aged 0 to 6 years alive today over his or her lifetime can be called the ***"status quo"*** since it reflects the projected future contributions of children living in New Jersey.

The next step is to estimate the lifetime benefits that the average child would confer to New Jersey if he or she had blood lead levels below 1 µg/dL between the ages of 0 and 6 years. This will be called the "***< 1 µg/dL***" scenario.

To estimate the lifetime benefit of such children living within New Jersey, we first turn to academic studies and datasets to obtain yearly estimates of the cost of childhood lead exposure. Such costs are examined with respect to New Jersey education system costs (such as grade retention or special education needs), the cost of medical treatment for lead exposure in New Jersey, reduced earnings in New Jersey, increased juvenile and adult criminal activity in New Jersey, and increased welfare use within New Jersey (**Figure 1**). The annual education system, medical, crime and welfare costs associated with lead exposure are subtracted from the annual costs of the average New Jersey child. Likewise, the annual benefits associated with increased earnings are added to the annual benefits of the average New Jersey child.

All other things being equal, children in the < 1 µg/dL scenario (those who would not be subject to the adverse effects of lead exposure) will also be more likely to live longer and thus continue to contribute up to the age of retirement.[18, 19] Therefore, the lifetime benefits of the average New Jersey child in the < 1 µg/dL scenario will be higher than the lifetime benefits of the average New Jersey child in the status quo scenario.

The "overall net lifetime benefit" per child is equal to the net lifetime benefit in the status quo scenario minus the net lifetime benefit in the < 1µg/dL scenario. If this net lifetime benefit per child is multiplied by the total number of children aged 0 to 6 years currently residing in New Jersey, the total benefit for the current cohort of New Jersey children in this age group is obtained.

Costs to society versus budgetary costs

Considering costs from the perspective of the average person in New Jersey, improvements in income that might arise from reducing childhood lead exposures are the most relevant. This is typically referred to as a "societal cost." On the other hand, considering costs from the perspective of the state government of New Jersey, budgetary issues, such as how these changes in earnings affect tax revenues to the state, are more significant. Thus, the societal costs are the most policy relevant costs, since they affect everyone in New Jersey. However, it is also useful to know the cost to New Jersey government, since these costs will affect the state budget.

Table 1. Information on the annual effect of childhood lead exposure per New Jersey resident by childhood blood lead level (BLL). The total number of children in New Jersey ages 0 to 6 years is 683,598.[a]

	BLL < 1 μg/dL	BLL ≥ 1 to < 10 μg/dL	BLL ≥ 10 μg/dL
Number of Children Aged 0-6 Years[a]	86,416	584,520	12,633
Percent Graduating High School[b]	97%	83%	80%
Medical Costs of Lead Exposure[c]	$0	$0	$286
Special Education [d]	$0	$0	$1,083
Crime[e]			
Excess Crimes Committed	0	0.001	0.003
Cost of Crimes Committed	$0	$62	$206

[a]Obtained from the U.S. Bureau of the Census.[20] The BLL figures are from New Jersey Department of Health and Senior Services data on children whose BLL was tested in 2006.
[b]The standardized on time graduation rate for New Jersey was obtained from the Manhattan Institute.[21] The only causal data linking childhood lead exposure to high school graduation was derived from an analysis of dentine lead levels in adolescents.[22] See footnote ii for a discussion of how this rate was modified for the present study.
[c]The medical costs associated with childhood lead exposure were derived from a published estimate[22] based on the cost of case management and medical supplies. This estimate did not include hospitalization costs, so these costs were added using electronic hospitalization data for New Jersey children aged 0 to 6 years and averaged in.[23] Only children with blood lead levels greater than 70 μg/dL were assumed to be hospitalized.
[d]The only estimate from the literature was obtained in 1994 prior to the majority of studies establishing diminished IQ at lower blood lead levels. This study finds that 20% of children with a blood lead level >25 μg/dL will need special education for an average of 3 years. These values therefore reflect costs only among the sub-population of children with an average of >25 μg/dL blood lead level.[22]
[e]Based upon excess crime rate data by blood lead level category.[24] See the technical appendix for more details.

How the severity of exposure affects costs

Although the average child in New Jersey has a mean blood level that is between 2-3 μg/dL, some children will have very low blood lead levels and others will have very high blood lead levels. The goal of this analysis is to estimate how costs would change if all children had a blood lead level lower than 1 μg/dL throughout childhood.

To estimate the annual costs associated with the status quo scenario and the <1 μg/dL scenario separately, it is first necessary to calculate the number of children in New Jersey aged 0 to 6 years who are relatively unaffected by lead exposure and the number of children who are being harmed by lead exposure. When numbers of children are categorized by their blood lead levels, a better sense of the overall cost of childhood lead exposure to New Jersey can be gained. This information was obtained from the New Jersey Department of Health and Senior Services, which collects public health data.

These lead level categories were then used to estimate overall annual costs. For example, the majority of children fall into the blood lead level range of equal to or above 1 μg/dL but below 10 μg/dL. This group will incur costs that are substantially lower than the group of children with a blood lead level greater than 70 μg/dL. An abbreviated breakdown of these costs by blood lead level can be found in **Table 1**. In the actual analysis, eight levels were used to improve the accuracy of the estimates. The costs of childhood lead exposure were examined at different blood lead levels because lead produces different cognitive effects depending upon the child's exposure. In other words, an increase from a blood lead level from 5 μg/dL to 6 μg/dL produces a greater loss of IQ than an increase from 15 μg/dL to 16 μg/dL. More information about this breakdown is available in the technical appendix.

Annual costs by blood lead level

Childhood blood lead levels were used to determine annual: 1) special education costs, 2) direct medical costs associated with case management and hospitalization, 3) juvenile and adult crime costs, and 4) high school graduation rates. For each category, the costs captured were as comprehensive as possible, encompassing administrative, case management, and other social costs (e.g., wage, victim costs for crime) where feasible.

Special education costs

Annual special education use for New Jersey children was obtained by applying a widely used set of methods and assumptions[22] to New Jersey values. One earlier study found that children with certain blood lead levels have increased utilization of special education services. While this study is older and employs quite conservative assumptions, it remains the standard for calculating special education costs. The overall cost of special education use in New Jersey was obtained from the New Jersey School Boards Association after inflating to constant 2008 dollars.[25]

Medical management costs

The federal guidelines for treating lead poisoned children are the same whether applied to children in New Jersey or for children in other states. However, research has shown that although practice guidelines may be the same nationwide, discretionary decision-making by physicians within those guidelines results in variation in the health care costs around the country.[26]In regards to the variation in medical costs, New Jersey has a both a higher utilization of medical services and a higher cost associated with those services, as compared to the national average.[27] Therefore, in keeping with the conservative approach of the report, we obtained medical case management costs from the scientific literature exploring average costs in the United States.[22, 28]Because these costs did not include hospitalization costs, hospitalization costs were added using a database containing virtually all pediatric hospitalizations within New Jersey.[23] Adult medical costs (e.g., heart disease, osteoporosis, and dental caries) were not included in the analysis because a concrete linkage between lead exposure and these costs needs further research.

Crime costs

Annual juvenile and adult crime rates were obtained using crime rate data for New Jersey obtained from the U.S. Department of Justice.[29]Using these rate data and the additional risk of crime associated with childhood lead exposure,[2, 3, 24] we estimated the risk of crime associated with childhood lead exposure. All other things being equal, the risk of committing a crime is lower in a person not exposed to lead during childhood. Since researchers have looked at the average social cost associated with a given crime (including costs to the criminal justice system and to society as a whole),[30] we can simply multiply number of *excess* crimes committed by juveniles and adults who were poisoned as children by the cost of the crime to obtain overall costs.

As with other analyses, this estimate is conservative. While a strong case can be made that *all* crimes should be included, the evidence linking childhood lead exposure to crime is strongest for *violent* crimes, so only those were included.[2, 3, 24]Children aged 0 to 6 years today would not be likely to commit a crime until they reach the age of 14. Thus, it is necessary to estimate what crime rates might look like 8 to 14 years into the future. This projection was obtained from the scientific literature, and accounts for changes in the distribution of childhood lead exposure in the U.S. population.[2] Finally, the cost of violent crimes themselves was obtained from a comprehensive review and analysis of the scientific literature.[31, 32]

Costs of high school dropouts

There is a very extensive literature on the effect of high school graduation on a number of important social outcomes. The effect of childhood lead exposure on high school graduation was used to estimate the remaining annual costs associated with childhood lead exposure in **Figure 1**.

Lead exposure during childhood leads to a lower likelihood of high school graduation. Decreased high school graduation rates, in turn, will reduce a number of benefits associated with a diploma. For instance, it will likely decrease future annual earnings. A decrease in earnings, in turn, will likely increase the use of means-tested welfare programs, such as New Jersey's Medicaid program (approximately half of which is covered by the state and half by the Federal government). Likewise, lower earnings can impede the prospects for living in a safer neighborhood and affording better, healthful food.[33] A lower quality job with lower income can also mean lower rates of health insurance coverage.[34, 35] All of these factors add up to impede the prospects for a longer and healthier life.[36] Differences between high school graduates and dropouts are presented in **Table 2**.[i]

Annual earnings and tax estimates were based on a comprehensive review of the literature and re-analysis using data from the Current Population Survey of the U.S. Census, and tax simulation software.[37] These data were converted to New Jersey-specific values using U.S. Census data.[38] This conversion was obtained by multiplying national values by the ratio of New Jersey values to national values. New Jersey Medicaid values and health values were obtained from previous analyses.[36, 39] These are presented in more detail elsewhere[36, 39] and in the technical appendix. Because New Jersey-specific data were not available, it was necessary to assume that health gains associated with an additional year of education would be the same in New Jersey as anywhere else in the U.S.

Central to this analysis of annual benefits associated with increased high school graduation is the estimate of the high school graduation rates as full diploma recipients in the status quo and the < 1 µg/dL scenarios. This estimate contains two components: 1) the baseline high school graduation rate in New Jersey, and 2) the projected increase in high school graduation if childhood blood levels were reduced to < 1 µg/dL for each and every child in New Jersey.

There is a good deal of controversy over the correct measure of high school graduation rates.[31] To avoid this issue, this report uses a standardized "on time" high school graduation rate, defined as the percentage of children graduating within four years of entering the 9th grade. Under the present circumstances, it can be expected that about 84% of New Jersey children will ultimately graduate from high school on time.[21]

To estimate the improvement in high school graduation under the < 1 µg/dL scenario, this report uses an estimate derived from measures of dentine lead levels on academic success in the scientific literature.[22] That is, the risk of failing to graduate from high school is thought to increase 4.5% for every point of IQ lost to childhood lead exposure. Because this number is from a single source and because New Jersey has unusually high on-time graduation rates, we used a number of conservative assumptions to ensure that we are not overestimating the impact of childhood lead exposure on high school graduation rates. These are described in the technical appendix.

[i] The present study relies upon the effect of childhood lead exposure on high school graduation, and high school graduation on reduced mortality (**Figure 1**). This was done because the scientific literature linking high school graduation to reduced mortality is superior to that linking childhood lead exposure to premature mortality.

Estimating lifetime costs and health outcomes

Details of the analysis are provided as a technical appendix. The basics of the analysis are briefly discussed in this section.

The medical literature contains many studies examining the various costs associated with childhood lead exposure. This literature was reviewed to obtain an estimate of the *annual* cost of childhood lead exposure for different levels of exposure. Annual data were obtained for special education costs, direct medical costs, juvenile delinquency costs, adult crime costs, adult earnings, and adult welfare costs.[ii] In addition, annual information on adult health status and longevity was calculated using national datasets (see technical appendix). To ensure that the costs used in the analysis are meaningful, they were all adjusted to constant 2008 dollars.

These *annual* costs were then entered into a mathematical model that estimates costs over the *lifetime* of New Jersey residents. This model adds up the annual costs for children with a blood lead level < 1 µg/dL, and for those in the status quo scenario, through the age of 65 after taking into account premature mortality. Costs are not counted after age 65 for a number of reasons. First, people generally retire at age 65. Second, the crime rate in this population is extremely low. Finally, when thinking about these future costs, it is important to apply a concept called discounting. Typically, people tend to value money in hand now over the promise of receiving money in the future. For this reason, a certificate of deposit tends to pay interest in exchange for the right to hold money for an extended period. In economic analyses, a 3% discount rate is typically applied.

Certain costs are treated differently at different ages. For instance, crime costs vary greatly by age, and tend to dissipate rapidly by age 40. The mathematical model used for these calculations takes such variations in costs into account.

A note about "QALYs"

One quality-adjusted life year (QALY) is a common way scientists talk about health. One QALY represents a year of perfect health. A QALY is a year of life that has been adjusted using a "health-related quality of life" score, or HRQL score. The HRQL score falls on a scale of 0 to 1, with 0 equal to death and 1 equal to perfect health. This score is used to adjust a year of life using multiplication. For example, if a person with heart disease has an HRQL score of 0.5, then that person is thought to have about half the health of a perfectly healthy person. If he or she lives 10 years, then we would say that the person has lived 5 QALYs (10 years • 0.5).

Lifelong costs

The annual costs and health effects mentioned above must then be translated into lifelong costs. To estimate the overall net lifetime benefit associated with changing the status quo to the < 1 µg/dL scenario, we must add up all of the annual costs over the average lifetime of children in each cohort. These average lifetime costs are presented as an aggregate—the sum of each category of costs (such as earnings or crime costs) over the entire lifespan of the average lead exposed or unexposed child.

Findings

Annual costs to New Jersey society

In this section, we use the term "costs" to describe the excess costs associated with childhood lead exposure. Recall from the "Two scenarios" section above that these annual excess costs associated with

[ii] See the technical appendix for more details on the analysis and for a complete list of references.

childhood lead exposure constitute the difference in the costs and benefits produced by the average New Jersey child in the < 1 μg/dL scenario and the status quo scenario.

Direct medical costs

Of the 684,000 children aged 0 to 6 years in New Jersey, 588,000 have blood lead levels greater than or equal to1 μg/dL (**Table 1**). Unlike most other costs, the first annual cost in **Table 1**, direct medical costs, is only incurred for New Jersey children with blood lead levels greater than or equal to 10 μg/dL. The reason for this is that medical guidelines suggest that children be monitored only if their blood levels cross this threshold.[28]For levels up to 20 μg/dL, costs amount to around $78 per child (not shown in the table), but leap to $17,969 for children with a blood lead level higher than 70 μg/dL.[iii] The table shows the average undiscounted cost ($286) for children with blood lead levels greater than or equal to 10 μg/dL within New Jersey.[23, 28]However, these costs do not include the time parents spend taking their children to the doctor, costs associated with transportation, or loss of wages due to missed work, so real world costs for these children are likely to be substantially higher. Omitting these uncertain costs ensures that the estimates are as conservative as possible.

Special education costs

Table 1 also shows annual special education costs among lead poisoned children in New Jersey. These annual costs only occur for an average of three years. We used very conservative estimates of $1,083 over one year for the subset of New Jersey children with a blood lead level of ≥ 25 μg/dL annually for all children residing within New Jersey.[22] Despite the fact that lead lowers IQ in children with much lower blood lead levels, and that it is associated with conduct and attention deficit disorders at lower blood lead levels,[5, 6, 14] it is conservatively assumed that children with lower blood lead levels will not incur further costs.

Crime costs

The annual medical and special education costs are incurred in childhood over a fixed period. For instance, medical costs are only incurred over a single year for the average lead exposed child, and special education costs are only incurred over three years.[22] However, other annual costs are incurred on a recurring basis. For instance, childhood lead exposure increases violent criminal tendencies (bottom of **Table 1**). Once children aged 0 to 6 years currently residing in New Jersey reach adolescence and adulthood, it could be expected that they would commit an average of approximately 1 additional violent crime per 1000 persons (0.001 more violent crimes per person) per year than they would have if none had been exposed to lead. These crimes would come at an undiscounted societal cost of slightly over $62 per person per year.

Annual costs associated with reduced high school graduation

Table 2 shows annual differences in graduation rates, costs, and health outcomes for high school dropouts and high school graduates in New Jersey. All other things being equal, high school graduation rates are predicted to increase to around 97% if none of these children had a blood lead level > 1 μg/dL. We tested the predicted increase in high school graduation rates over a wide range of values so that the reader can get a sense of how error in this estimate might impact the overall results of this analysis. This is discussed in

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[iii] The hospital cost was obtained from a database of virtually all childhood hospitalizations within New Jersey. This hospitalization database reports what the hospital charged (approximately $35,000 per hospitalization). However, for technical reasons, social costs are significantly lower than the amount charged. Therefore, these charges were converted to costs. The technical details surrounding why charges must be converted to costs and the formulas used to make the conversion can be found in Muennig, P. *Cost-Effectiveness Analysis in Health*. San Francisco: Jossey-Bass, 2007.

the section, "Effects of major assumptions on predicted savings."

Each of these additional high school graduates could reasonably be expected to realize an increase in earnings from $17,471 to at least $32,550 per additional New Jersey high school graduate per year. Of course, these savings would be realized far in the future, so their present value is significantly lower. For high school graduates relative to dropouts, health-related quality of life score, which is a commonly used measure of illness in health research, improves from 0.8 to 0.84. Likewise mortality for high school graduates falls to 83% of the value of high school dropouts.

Annual costs to the state government of New Jersey

The above annual costs would be realized for New Jersey society as a whole (everyone in New Jersey regardless of who pays). While policymakers are certainly concerned with the health and well-being of their constituents, budgetary constraints sometimes necessarily limit considerations to net revenue flows within the state budget. The New Jersey state analysis provides such data. This analysis includes only those costs associated with childhood lead exposure that are borne by the state itself.

Table 2 presents the state-specific costs of childhood lead exposure in New Jersey that are associated with taxation and Medicaid. For every additional high school dropout arising from childhood lead exposure, taxes realized by the state government of New Jersey on citizens' reduced earnings would fall from $1,139 to $245. The state would also pay $1,365 more per additional dropout in Medicaid expenses. Of course, these savings would be realized far in the future, so their present value is significantly lower.

Juvenile delinquency costs: a special case

The annual costs to New Jersey society and the state government of New Jersey add up to larger changes over an individual's lifetime. These changes were estimated from the age of 18 to 65 using the model described above.

One important cost, juvenile crime costs in New Jersey, however, should be singled out for closer inspection since it is incurred before the age of 18. The juvenile delinquency cost presented here is neither an annual cost nor a lifetime cost. It is a snapshot of costs incurred between the ages of 14 and up to 18.

Juvenile justice costs generally begin to accrue at age 14. In this sub-analysis, costs are only considered between the ages of 14 and up to 18 before entering the adult justice system. Given data limitations, the study was unable to account for differences in the mix of violent crimes committed in this age group relative to that of other age groups. With this limitation in mind, the model predicts that costs amount to $26.3 million dollars per cohort of children aged 0 to 6 years from the perspective of New Jersey society as a whole. As with other analyses, this estimate is conservative. While a strong case can be made that *all* crime costs should be included, the evidence linking childhood lead exposure to crime is strongest for *violent* crime costs, so only the latter were included.[2, 3, 24]

Lifetime benefits to New Jersey society

Were all children to have a blood lead level less than 1 µg/dL, reductions in annual monetary costs discussed above would add up to large savings over the lifetime of each New Jersey child. When thinking about these future costs, it is important to apply a concept called discounting described above.

In economic analyses, a 3% discount rate is typically applied to the annual benefits.[40] Thus, benefits at age 8 are worth 3% less than benefits realized at age 7.

The annual savings above add up to $31,000 in savings over each child's lifetime at a 3% discount rate (**Table 3**). This amounts to $21 billion across the entire cohort of children aged 0 to 6 years. It would also produce 0.1 additional QALYs per child within New Jersey, which amounts to 67,000 QALYs for all New Jersey children aged 0 to 6 years.

These QALYs have monetary value, estimated at approximately $93,000 per QALY.[41] This makes it appropriate to count the value of a QALY among the overall savings, a process called "monetization." When the value of a monetized QALY is added, the net benefit increases to almost $40,000 per child or approximately $27 billion across all children (final column of **Table 3**).

Lifetime benefits to the state government of New Jersey

These net benefits to New Jersey society will also lower government spending by approximately $14,000 per child over his or her lifetime. This amounts to $9 billion in reduced costs across the entire cohort of children aged 0 to 6 years. While the state of New Jersey certainly has reason to value improved health and productivity of its citizens, it only realizes these fiscal benefits on its budget sheet in the form of increased taxes and reduced expenditures. Therefore, QALY gains are not included in the government perspective.

Effects of major assumptions on predicted savings

Other than direct medical and special education costs, the projected benefits to both New Jersey society and the state of New Jersey are not realized until the children reach age 18. Recall that the process of discounting begins in childhood (at the average age of 3 in the age 0 to 6 years cohort). Over this period, the effect of discounting adds up to large changes in the estimates of future values. For this reason, the projected benefits are highly dependent on the discount rate. Undiscounted net benefits reach over $140,000 per child when monetized QALYs are included.

The other major assumption surrounds the impact of childhood lead exposure on high school graduation rates. Above, it was noted that New Jersey ranks exceptionally high in terms of on-time high school graduates, as compared to other states.

Table 2. The expected differences in earnings, income taxes paid, Medicaid use, and health outcomes associated with high school graduates and high school dropouts in New Jersey.

	Dropouts	Graduates
Societal Analysis		
Annual Income Earned[a]	$17,471	$32,550
Health-Related Quality of Life[b]	0.80	0.84
Mortality Risk[c]	1	0.83
State Analysis		
Medicaid Costs[d]	$1,365	$0
Annual Taxes Paid[e]	$245	$1,139

[a]Earnings were obtained from an extensive literature review and analysis of data from the U.S. Bureau of the Census.[37] Earnings for the United States were adjusted to New Jersey values using data from the U.S. Bureau of the Census by multiplying the national by the ratio of earnings in New Jersey to earnings in the United States.[38]
[b]Based on the EQ-5D and scaled 0 to 1, with zero equal to a state of death and 1 equal to a state of perfect health. These figures represent the mean of age-specific EQ-5D scores between the ages of 18 and 90 in 1-year intervals. See the technical appendix for more information.
[c]Represents the mean risk based upon the 1-year age-specific values employed in the model. The risk, 0.83, implies that high school graduates have 83% the mortality rate of high school dropouts. See the technical appendix for more details on how this analysis was conducted.
[d]Proportion of Medicaid expenditures paid by the State of New Jersey per high school dropout.
[e]Taxes were estimated by calculating expected taxation on the estimated earnings using tax simulation software provided by the National Bureau for Economic Research.[37]

This makes it all the more challenging to account for the impact of childhood lead exposure on high school graduation rates; the mathematical models used to make these predictions work best when applied to states much closer to national averages. To help ensure that this problem does not lead to overstated estimates, we conservatively assumed that the real world effect of childhood lead exposure upon high school graduation rates in New Jersey would be about half that observed for the nation as a whole. The assumption is made only to ensure that the analysis was as conservative as possible. We therefore also tested the estimates over a wide array of values.

Even if the impact of childhood lead exposure on high school graduation rates were sufficiently low to only increase on-time high school graduation rates in New Jersey from 84% to 90%, we would still realize lifetime societal benefits of nearly $15,000 for each and every child within New Jersey or over $10 billion. Thus, we can be fairly certain that large benefits will be realized by reducing childhood lead exposure regardless of the challenges associated with estimating improvements in high school graduation.

Summary of findings

Although average blood lead levels in children today are a fraction of what they were two decades ago, childhood lead exposure remains a significant societal problem. One single cohort of 0-6 year-olds would conservatively contribute at least $27 billion dollars more to New Jersey society over their lifetimes if their blood lead levels were reduced to < 1 µg/dL. As additional children are born into a world with a lower baseline lead exposure, the benefits would multiply.

Reducing childhood lead exposure would also save lives and reduce human suffering. Children with lower cognitive ability end up with less education. They are, therefore, less likely to have a job that provides health insurance, less likely to drive a safe car, and more likely to engage in harmful behavioral risk factors, such as smoking or consuming illegal drugs.[36] This not only makes New Jersey less competitive economically, it also creates unhealthy, impoverished neighborhoods. Reducing childhood blood lead levels to < 1 µg/dL would produce approximately 67,000 additional years of healthy life among each cohort of children aged 0 to 6 years in New Jersey (see **Table**

Table 3. The expected benefits to New Jersey children of reducing lead exposure to below 1 µg/dL based on the current cohort of New Jersey children aged 0 to 6. Benefits are presented over the lifetime of the average New Jersey child and for all children combined. Monetary benefits, quality-adjusted life years (QALYs) gained, and total monetary benefits (the money returns to reducing childhood lead exposure plus the economic value of the QALYs gained)

	Monetary Benefits Excluding QALYs	Number of QALYs Gained	Total Monetary Benefits
Societal, New Jersey			
Per Child	$30,573	0.1	$39,913
All Children	$20,618,461,563	67,440	$26,917,501,719
State, New Jersey[a]			
Per Child	$13,512	-[b]	$13,512
All Children	$9,112,506,219	-	$9,112,506,219

[a] The societal benefit is the total savings to society regardless of the source of the money. The state benefits are only felt on the state budget, and are a subset of the societal benefits.
[b] The state analysis does not include quality-adjusted life years.

3). This is the rough equivalent of 1,100 full, healthy lives.[42] The economic value of these lives is included in the overall monetary calculations, and healthy life accounts for $6 billion of the $27 billion in overall monetary benefits.

The societal benefit is the total savings to society regardless of the source of the money. The state benefits are only felt on the state budget, and are a subset of the societal benefits. Thus, the state benefits are included in the societal benefits. For the state government of New Jersey, the benefits are lower primarily because monetary returns take the form of taxes rather than earnings. Nevertheless, reducing sources of environmental lead exposure such that no child would have a blood lead level ≥ 1 μg/dL would reduce costs to the state by at least $9 billion dollars. That means that in today's dollars, the state would realize a benefit of $9 billion dollars if all children presently under the age of 6 years had blood lead levels below 1 μg/dL. As with societal costs, the costs multiply as additional children are born and exposed to unnecessarily high lead levels.

Ensuring a worthwhile investment

The purpose of this report is to provide an estimate of the cost ceiling at which an investment in reducing childhood lead exposure in New Jersey would produce returns on the investment. Only the benefits of reducing childhood lead exposures are considered; the costs of different policies needed to accomplish this goal are not analyzed.

It is important to ensure that this ceiling for projected returns on any investment made in reducing childhood lead exposure is as conservative as possible. To ensure that policymakers can be confident that the money invested in reducing sources of childhood lead exposure is well spent, a number of very conservative assumptions were made, and uncertain benefits were excluded. Excluding such benefits better ensures that the estimated savings represent the minimal plausible benefits. The primary source of uncertainty in this analysis is the extent to which lead exposure impacts high school graduation rates. We used an estimate derived from the scientific literature.[22] However, this is the only estimate we know of. There are also challenges associated with applying this estimate to New Jersey, which has an unusually high on-time high school graduation rate. Still, even if the graduation gains are reduced from 97% to 90%, the model still estimates $10 billion in societal benefits.

Other estimates of the impact of childhood lead exposure on earnings are within the range of those employed here after considering differences in the scope of outcomes observed.[8, 22, 43] The most recent of these estimates includes a similar scope of benefits and estimates national gains of $250 billion.[44] Extrapolating from the nation as a whole to our state estimates, this figure is lower than our estimate. However, it does not include monetized health gains, and uses inputs that are not adjusted for inflation.

Our analysis did not include benefits that might plausibly be realized if childhood blood lead levels are successfully reduced. For instance, reducing childhood lead exposure may prevent certain long-term medical costs associated with osteoporosis and hypertension.[3] However, because rigorous data on this benefit are not available, these potential benefits were not included. Thus, this approach better ensures that returns on investments in reducing childhood lead exposures will be realized.

Conclusions

As scientific knowledge deepens, society sometimes comes to realize that problems previously believed to be solved actually still remain. Childhood lead exposure is a strong case in point. Public health officials rejoiced as two major sources of exposure—leaded gasoline and lead-based household paint—were permanently removed from consumer products in the 1970s and 1980s. While this celebrated achievement resulted in significant reductions of lead exposure, lead continues to be used unnecessarily in numerous products. The soil becomes contaminated from industries that still use lead, including those in which it is not an essential ingredient. Some other sources of exposure arise from the pre-regulatory era. For instance, lead continues to be found in older homes and in soil contaminated with lead.[15] Lead is even used in some traditional home remedies to treat childhood illnesses, as well as in some jewelries, cosmetics, toys and candies.[15]

Now that science has shown that even low levels of childhood lead exposure can cause lasting neurological damage, the time has come re-think policies for reducing childhood lead exposures in order to reprioritize limited fiscal resources.

Technical Appendix

This technical appendix describes the methods used in the report in more technical and detailed terms.

Standards Used

All costs are presented in constant 2008 dollars and discounted at a rate of 3% in accordance with the Panel on Cost-Effectiveness in Health and Medicine.[40]

Data are analyzed from two perspectives. The societal perspective includes all costs and all benefits regardless of who pays or receives them. The state perspective includes only those costs and benefits applicable to the State of New Jersey. The societal benefit is most appropriate for policy decisions, but the state perspective assists in budget projections. The Panel on Cost-Effectiveness in Health and Medicine recommends the societal perspective for all base-case analyses.

Literature Review

Lead plausibly produces a wide variety of direct and indirect social effects. These include impacts on medical costs, schooling costs (e.g. special education or grade retention), teen pregnancy, low-birth weight babies, child abuse, crime, earnings, welfare utilization, and adult health (ranging from heart disease to osteoporosis).[13, 22]

In deciding which costs to include, a “levels of evidence” approach was employed. In this approach, data obtained from randomized controlled trials were given highest priority. However, data obtained from instrumental variable analyses, prospective data with appropriate controls, and natural experiments exploiting variations in exposure were included when 1) multiple studies employing at least two different methodological approaches produced congruent findings and 2) there is plausible biological evidence for the observed effect. The literature was reviewed using PubMed and Google Scholar. PubMed reviews were conducted using appropriate MeSH searches. Google Scholar searches were conducted by key word using multiple iterations of the keywords pertinent to each area of inquiry (e.g., the effects of childhood lead exposure on crime).

Enumeration of Cases

The number of lead poisoned children were obtained by blood lead level strata, generally defined as: 0 to < 1, 1 to < 10, 10 to < 15, 15 to < 20, 20 to < 25, 25 to <45, 45 to < 70, and 70 and over.

State surveillance data from the New Jersey Department of Health and Senior Services, for those children who had BLL tested in 2006, were used to obtain the number of children exposed within each blood lead level stratum. Because surveillance data are not available for every child, the numbers were corrected using 1) the total number of children aged 0 to 6 years residing within New Jersey and 2) the number of children for whom blood lead levels were sampled. The correction factor was calculated as the ratio of the total number of children in New Jersey divided by the total number of children sampled.

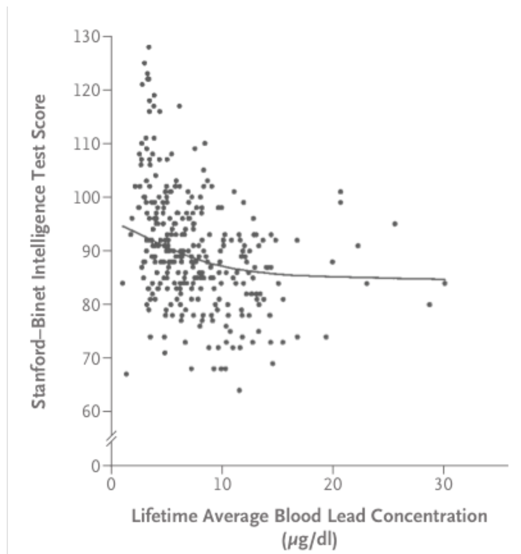
While data are available for 23% of all children, screened children may be more likely to live in families with health insurance or other confounding factors. If so, they may be more or less likely to be screened, thereby potentially skewing the results. To help ensure that the results from surveillance data were roughly representative of the New Jersey population as a whole, we used the combined 1999-2006 National Health and Nutrition Examination Survey (NHANES), a nationally-representative sample of the non-institutionalized civilian population in the U.S., to review the proportionate distribution of children within each strata.[45] If the distribution of children within each blood lead strata is similar between the NJ state surveillance data and the NHANES, then there is a lower likelihood that the NJ state data are skewed in some way. The NHANES and New Jersey distributions were very similar, suggesting that the state surveillance data were reasonably representative of the state blood lead profiles of the state as a whole. This conclusion is drawn from the very low likelihood that skewed state data would match the national distribution of blood lead levels purely by chance.

IQ

The relationship between childhood lead exposure and IQ is curvilinear, with a steep slope between 1 µg/dL and 10 µg/dL followed by a significantly less steep linear increase thereafter (Figure 2).[5] Thus, the social costs associated with the effect of childhood lead exposure on educational attainment were estimated by separating blood lead levels into strata (0 to < 1, 1 to < 10, 10 to < 15, 15 to < 20, 20 to < 25, 25 to <45, 45 to < 70, and 70 and over), and then estimating the effect size within each strata.

The studies used to estimate IQ values hold maternal socio-economic status, parental IQ, and the Home Observation for Measurement of the Environment (HOME) score constant. For persons with blood lead levels increasing from 1 µg/dL to 10 µg/dL, a 7.4 point change in IQ was used.[5] This value was obtained from a single, prospective study examining the non-linear effects of blood lead level concentrations on IQ that contained 172 children with low levels of exposure. Other studies tend to examine the linear relationship between IQ and blood lead levels greater than 10 µg/dL. Two reviews of the literature found the slope of the relationship between childhood blood lead levels and IQ to be -0.323[11] and -0.185.[46] This former estimate includes studies of children with lower blood lead levels, and so is biased by the steeper lead-IQ association among children with low-level (<10 µg/dL) exposures. To define the slope of the relationship for childhood blood lead levels > 10 µg/dL, the latter value was used.

Appendix Figure 1. Average childhood blood lead levels (µg/dL) and IQ score (U.S. mean = 100).



Earnings

Previous assessments of the impact of childhood lead exposure on earnings used estimates of both the direct impact of IQ on earnings and the indirect effect of IQ on earnings through educational attainment.[22, 43, 47] However, the literature on the direct effect of IQ on earnings, while large, is less rigorous than that of educational attainment on earnings.[48, 49]

The economics literature contains estimates of returns derived from randomized controlled trials, instrumental variable analyses, and twin studies.[49-53] While all of the important studies on the schooling and earnings relationship have their flaws, they collectively add up to convincing evidence of a 10 to 17% return associated with a year of schooling.[49] The present analysis relied upon a recent and extensive review of the economics literature coupled with a recent analysis of Current Population Survey data to derive the earnings increases associated with producing one additional high school graduate.[37]

Most, though certainly not all, childhood lead exposures occur among children from lower socio-economic status families.[13] These children face a wide range of social obstacles unrelated to lead exposure or educational attainment, and these obstacles may limit the child's full earnings potential. Earnings used in the base case analysis conservatively include only those of students who complete high school but exclude the earnings of those who go on to complete college.

Crime costs

The direct effect of lead exposure on IQ and criminal activity has been documented using prospective cohort studies with appropriate controls (e.g., maternal IQ, socio-economic status, and home environment score). It has also been documented in studies exploiting geographic and temporal variations in anti-lead regulations.[2, 24] Lower IQ and those neurobehavioral changes that may predispose the individual to crime (e.g., weak executive control) also impact educational attainment.[13, 22] Randomized controlled trials and instrumental variable analyses, among other rigorous study designs, show a consistent link between educational attainment and 1) earnings (and thus means-tested welfare program utilization), 2) crime, and 3) health outcomes.[49, 54-56] Finally, lower educational achievement coupled with disruptive behaviors plausibly result in grade retention and special education use.[4, 5, 7, 8, 57, 58] Therefore, the final model included costs associated with treating lead exposure in children, special education, income, crime (both juvenile and adult), and welfare use (Figure 1 in the main report).

Crime costs were estimated two ways. First, they were estimated based upon a prospective study following lead-exposed children through adulthood and then examining data on the crimes committed.[24] These data were used in the societal analysis. Second, because state costs associated with crime are only available from the education literature, the state analysis relied on estimates of the indirect effect of lead exposure on criminal activity via its impact on high school graduation rates.[31, 32] These costs were used in the state analysis.

There is strong evidence of a link between educational attainment and criminal activity.[52, 54, 59] These data were derived from randomized controlled trials and natural experiments.

There is also evidence for a direct effect of childhood lead exposure on crime arising from 1) the neurobiology literature, which shows that childhood lead exposure leads to a loss of executive control and increased impulsivity,[3, 9, 13] 2) spatial and temporal data using variation in exposure as a measure, which shows that at least 56% of the variation in crime rates can be explained by childhood lead exposure,[2, 3] and 3) prospective follow up data with appropriate controls, which show an increase in the arrest rate of 7% to 40% per 5 µg/dL increase in blood lead level (depending on the measure of childhood lead exposure used).

In the latter study, the most appropriate measure of childhood lead exposure—the mean blood level between ages 0 and 6 years—is only statistically significant for violent criminal activity. The present analysis uses these prospective follow-up data to estimate the relationship between violent criminal activity and mean childhood lead exposure.

Approximately 73%-92% of crimes occur between the ages of 18 and 40 with a spike at age 18 to 25. Uniform Crime Reports data were used to estimate variations violent crime rates across different ages.[32] The cost per crime was obtained from a review of the academic literature.[30]

Crime costs were calculated as follows. First, arrest ratios by mean childhood blood lead levels were obtained.[24] Second, reported crimes were conservatively assumed to be equal to the number of crimes committed. This likely produces an underestimate because some crimes are not reported to the authorities, and thus not recorded in the data. Third, because future crime costs are calculated among children born today, it was necessary to use projected crime rate data to 2027.[2] Fourth, the marginal change in each of the four types of violent crime costs (murder, rape, assault, robbery) at each stratum of childhood lead exposure was calculated as follows:

$$CR \cdot RR - CR$$

where, CR = the adjusted rate of crime expected in 2027, and RR = the risk ratio for increased criminal activity at each of the lead-specific blood levels used in the study. These excess rates were then simply multiplied by the crime category-specific cost.

Public sector (state) crime benefits were determined from the indirect effect of childhood lead exposure on adult crime, i.e. through the evaluation of improved high school graduation rates.[31]

Welfare costs

Welfare programs in the United States are means-tested. As a result welfare utilization is dependent on earnings. To the extent that educational attainment impacts earnings, we would expect declines in welfare utilization with increasing educational attainment.

Only changes in Medicaid utilization costs could be reliably measured.[39] Therefore, only Medicaid costs were included in the state analysis. These costs include all costs for which the State of New Jersey is responsible, and exclude costs covered by the Federal government.

High school graduation

The analytical model focuses most future costs upon the indirect effect of childhood lead exposure on high school graduation. Some of this effect likely arises from the impact of lead upon IQ and some arises from the impact of lead on behavior.[13] There is only one estimate of the effect of childhood lead exposure upon high school graduation rates.[9, 22] While there are estimates of the direct effect of childhood lead exposure on earnings, the literature uses older studies, missing the majority of the work on the earnings production function of high school graduation over the past 15 years.[22]

We used this estimate, which suggests that 1 IQ point lost as a result of lead exposure leads to a 4.5% drop in high school graduation. Thus, the 7 point IQ loss associated with <10 μg/dL/dl of lead exposure would theoretically be expected to reduce high school graduation by 7*0.045 = 0.33. Given a mean IQ of 100, this large fall off in graduation seems intuitive; a subject with an IQ of 90 would have high school graduation reduced by 45% and a subject with an IQ of 80 should have virtually no chance of graduating from a regular high school.

To ensure that the findings were as conservative as possible, we used a slope of 0.185, the lowest slope from two meta analyses in the scientific literature for the lead-IQ association.[22, 46] Moreover, we assumed that the relationship between lead-induced IQ changes and high school graduation rates is approximately half of the slope observed in the medical literature.[22] Conservative assumptions here are especially important because New Jersey has an unusually high on-time graduation rate. We solicited advice from various experts in childhood lead exposure and education to confirm that our estimates and assumptions were reasonable.

Health benefits

The health benefits of additional educational attainment are well documented,[55, 56, 60] and may arise from possessing a quality job that provides health insurance, enhanced social networks, lower behavioral risk factors, nepotistic connections, improved decisionmaking skills and higher income.[36]

Instrumental variable analyses of the education-mortality relationship produce larger effect size estimates than OLS regression, which suggest that regression produces conservative estimates.[55, 56] To enhance modeling of quality-adjusted life expectancy, this analysis uses regression-based estimates of morbidity (quality-adjusted life years, or QALYs) and mortality. One QALY is equivalent to a year of life in perfect health.[40]

Mortality models were constructed using data from the National Health Interview Surveys (NHIS, 1997-2000) linked to mortality data via the National Death Index (NDI), with follow-up through the end of 2002 (the most recent follow-up publicly available).[61, 62] HRQL models were constructed using the EuroQol (EQ-5D) from the 2000-2002 Medical Expenditure Panel Surveys (MEPS).[63] The HRQL measure completed by MEPS subjects is the EuroQol-5D,[64] which is QALY-compatible and captures subjects' mobility, self-care, usual activities, pain/discomfort and anxiety/depression. Both mortality and HRQL scores were calculated by Peter Franks and Dan Tancredi of UC Davis.

To derive the age-specific mortality risks and mean HRQL scores, US rates for high school graduates were used as a standard population under the assumption that they would be similar to rates within New Jersey. (New Jersey-specific data were not available.) This allows for the removal of possible confounding due to between-group differences in covariate distributions. Two sets of estimated regression coefficients were applied to each member of this standard population and then averaged these predictions to derive risk-factor specific estimates of age-specific mortality and HRQL.

Regression analyses were conducted using Stata (version 10.0, Statacorp, College Station, TX), adjusting for the complex survey designs of the NHIS and MEPS. All regression models adjusted for age, log age (to address non-linear age effects), sex, region of the country (Northeast, South, Mid-West, West), and survey year (as a series of dummy variables).

Mortality regression coefficients were estimated by a multiplicative hazards parametric regression model of age-at-event failure time data, specified as a log-linear model using Poisson regression.[65, 66] In order to better estimate the impact of time-varying age on the baseline hazard, this model used person years as the unit of analysis, with each subject contributing an observation for each full or partial year of follow-up.

Markov model

A Markov model was used to compare life expectancy, HRQL scores, direct medical costs, special education costs, earnings, crime costs, and welfare costs over the lifetime of the 684,000 children aged 0 to 6 years in New Jersey. In the model, mortality effects, salary benefits, crime costs, and welfare costs begin to accrue only after the age of 18. Thus, while the cost of the intervention is presented in today's dollars, most future benefits are not realized until age 18 onward. They are continuously discounted over 15 years before they begin to accrue. Complete model outputs, including the QALYs produced, are listed in Table 4.

The model contains two arms: 1) reduction of childhood blood lead levels to < 1 µg/dL and 2) the status quo. The only differences between the "< 1 µg/dL" arm and the "status quo" arms are: 1) the high school graduation rates and 2) the crime costs are only incurred in the status quo arm of the model. The model is described in more detail elsewhere.[67]

Results

In the report, the data presentation was simplified for a lay audience. The complete cost-effectiveness table (Table 3 in the report) is presented as Table 4.

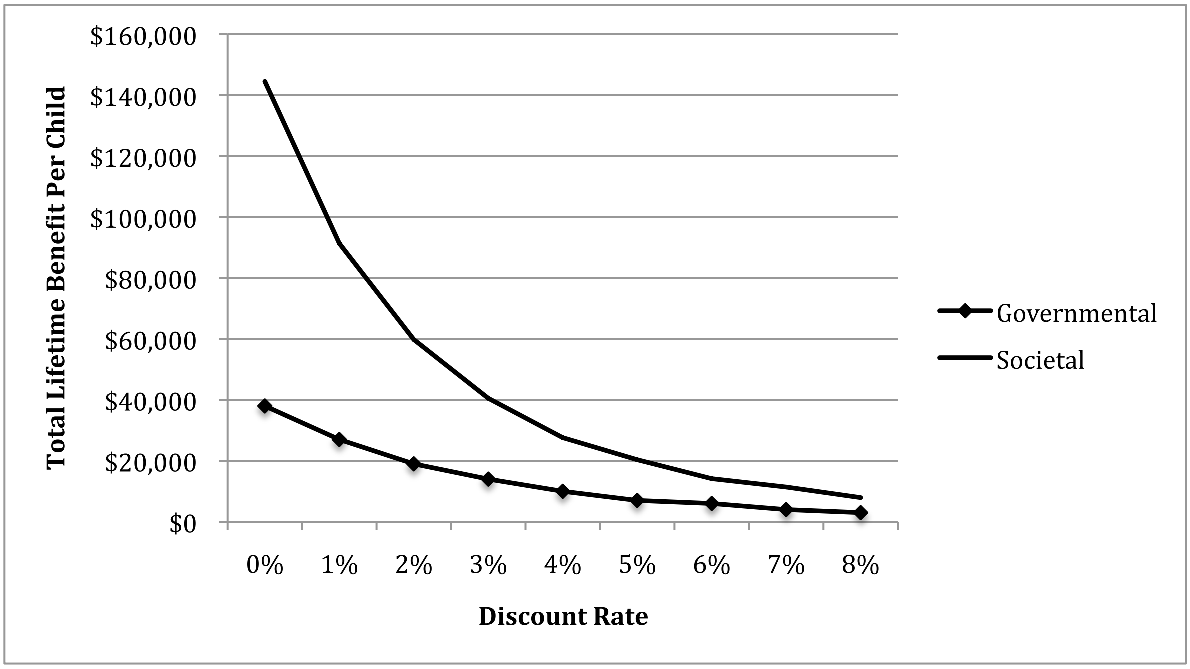
Table 4. Lifetime monetary benefits, gains in quality-adjusted life years (QALYs), and the monetized net benefit (QALYs valued in dollars added to the lifetime monetary gains) associated with reducing blood lead levels in all New Jersey children to less than 1 µg/dL. Results are presented per child and for all children aged 0 to 6 years currently residing in New Jersey. (BLL = blood lead level.)

	Monetary Benefits	Marginal Monetary Benefit	Total QALYs	Number of QALYs Gained	Net Benefit
Societal, New Jersey					
Per child					
Status Quo	$463,523		15.5 QALYs		
BLL < 1 µg/dL	$494,096	$30,573	15.6 QALYs	0.1 QALYs	$39,913
All Children		$20,618,461,563		67,440	$26,917,501,719
State, New Jersey*					
Per child					
Status Quo	$656		-		
BLL < 1 µg/dL	$14,169	$13,512	-	-	$9,112,506,219
All Children		$9,112,506,219			$9,112,506,219

Sensitivity Analysis

Other than direct medical and special education costs, the projected benefits to both New Jersey society and the state of New Jersey are not realized until the children reach age 18. Thus, the projected benefits are highly dependent on the discount rate. Undiscounted net benefits reach over $140,000 including monetized QALYs. These benefits drop in a curvilinear fashion as the discount rate is increased on both the QALYs gained and the monetary benefits (Figure 3).

Figure 3. The effect of changes in the discount rate on the lifetime benefits per child projected for New Jersey government (dotted line) and New Jersey society as a whole (straight line). For example, at a discount rate of 0%, lifetime benefits per child to the state government of New Jersey total nearly $40,000.



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