Economic Impacts
Of Lead Exposure and Remediation in Michigan

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A report prepared by the University of Michigan Risk Science Center and the Michigan Network for Children’s Environmental Health
Acknowledgements

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The Michigan Network for Children’s Environmental Health is a coalition of health professionals, health-affected groups, environmental organizations, and others dedicated to a safe and less toxic world for Michigan’s children. Through education, outreach, and advocacy, the MNCEH works to change current policies and practices that result in exposure of children to environmental toxicants. The MNCEH is led by the Ecology Center. For more information about the Michigan Network for Children’s Environmental Health: http://www.mnceh.org/
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Economic Impacts of Lead Exposure and Remediation in Michigan

Executive Summary

Overview

This assessment evaluates the economic impacts of lead poisoning among Michigan children by considering four well-documented impacts of lead exposure: 1) increased health care, 2) increased crime, 3) increased need for special education, and 4) decline in lifetime earnings. By applying methods and metrics from published research to Michigan children, this report illustrates the costs – to the Michigan taxpayer, and to the public more broadly – of lead exposure.

These impacts are estimated for one snapshot year, 2012, and total over $330 million in total costs ($145 million of that is estimated to be passed along to the taxpayer), with a number of conservative assumptions. Compared to estimated costs of lead paint remediation/abatement ($600 million), investment in lead remediation/abatement pays for itself in an estimated 3-6 years and beyond that provides many years of positive returns. After 30 years the average net return on $1 invested in abatement is estimated at $10.50. This illustrative analysis suggests that lead abatement would be a worthwhile economic investment, with considerable public health benefits, as well.

Background

This research follows The Price of Pollution, a study published by the Ecology Center and Michigan Network for Children’s Environmental Health in 2010, which examined the annual economic cost of lead poisoning, asthma, cancer, and developmental disabilities. This new report delves more deeply into the economic impacts of lead exposure, and compares these costs to the cost of lead abatement.

We focus on childhood lead exposure because children are at the highest risk for becoming lead poisoned and are also the most vulnerable to lead’s effects. Childhood lead exposure is associated with a wide range of irreversible, persistent, and costly health effects, including reduced cognitive function (leading to reduced academic achievement and lower IQ), behavioral problems, and aggressive behaviors (including attention-deficit/hyperactivity disorder and delinquent, criminal, or antisocial behavior).

While elimination of leaded gasoline and lead paints have greatly reduced children’s exposure to lead in recent years, there are ongoing exposures to historic sources of
contamination, namely lead-based paint in older homes.

Costs of Lead Exposure

Using established methods and metrics, this assessment applies four well-documented costs of children’s lead exposure in Michigan: increased health care, increased crime, increased special education, and decline in lifetime earnings. These costs are discussed below:

Healthcare

The costs of both the immediate treatment of children with BLLs above 10 μg/dL as well as treatment for lead-associated ADHD were estimated. Immediate treatment (including diagnostic testing, nurse visits, environmental assessment of the home and oral or intravenous chelation) cost an estimated $280,000 annually. Lead-associated ADHD treatment, including medication and counseling, totaled over $18 million annually. We believe these estimates are conservative because they focus on just two metrics (immediate treatment and ADHD treatment) while ignoring other health and developmental impacts that may require regular and continuing healthcare costs. Additionally, the wider impacts on productivity and stress on family members and caretakers were not considered.

Crime

An estimated 10% of juvenile crimes in Michigan were associated with lead exposure, costing an estimated $32 million annually in incarceration alone for lead-associated juvenile crime. Furthermore, adult crimes can be linked to childhood lead exposure, and applying established standards to adult crimes in Michigan, an estimated $73 million annually can be attributed to lead-associated crimes. This includes costs to victims, legal proceedings, incarceration, and lost earnings to both the criminal and victim. These conservative estimates do not quantify additional indirect costs associated with lead-related crime, such as lost wages, pain and suffering, costs associated with physical and mental healthcare, and lost quality of life. Inclusion of these costs would substantially increase the total costs.

Special Education

Because of lead-associated reduction in cognitive ability, an estimated 20% of children with blood lead levels measured at or above 25 μg/dL at age 2 receive special education, for an average of 9 years. This special education costs an estimated $2.5 million net present value (NPV), lifetime cost for the cohort of 2-year-olds in 2010. This estimate does not include indirect costs such as loss of parental productivity in caring for a child with special needs, health and stress impacts on family members, and the costs associated with children whose BLL peaks later than 2 years of age. Additionally, this conservative estimate only considers special education costs for children with BLLs of 25+ μg/dl, when research indicates that impacts at lower levels may also require special educational support.

Decreased Lifetime Earnings

Elevated blood lead levels are correlated with irreversible declines in IQ, which correspond (on average) to reductions in lifetime earnings. Using established standards, loss of lifetime earnings in Michigan were estimated at over $206 million for the 2010 cohort of 2-year-olds. This calculation is conservative as it includes only blood lead levels of 2-year old children, ignoring children whose lead levels may peak at other times.
Additionally, blood lead levels under 5 μg/dL were not considered despite evidence suggesting impacts on IQ at blood lead levels between 2-5 μg/dL. Together, the costs of lead exposure totaled over $330 million annually, including $145 million born by taxpayers.

Summary of costs associated with lead exposure, 2012, in $000s

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Health care - Immediate blood lead treatment</td>
<td>281</td>
</tr>
<tr>
<td>Health Care - Treatment of lead-related ADHD</td>
<td>18,136</td>
</tr>
<tr>
<td>Increases in special education</td>
<td>2,534</td>
</tr>
<tr>
<td>Reduction lifetime earnings, NPV</td>
<td>73,293</td>
</tr>
<tr>
<td>Crime - Juvenile incarceration related to childhood lead</td>
<td>31,969</td>
</tr>
<tr>
<td>Crime - Adult crimes related to childhood lead</td>
<td>206,235</td>
</tr>
</tbody>
</table>

**Costs of Lead Abatement**

In line with published research, we conservatively assume that 70% of lead exposure is associated with lead paint in homes. We illustrate a scenario where 100,000 most at risk homes in Michigan are lead abated, reducing the lead exposure and associated costs by 70% (which creates cost savings of $230 million annually). With an average cost of abatement at $6,000 per unit, this abatement scenario costs an estimated $600 million.

**Discussion**

This assessment indicates that the annual costs of lead exposure – to the public and to the taxpayer - are substantial: more than $330 million and $145 million, respectively.

In a lead paint abatement scenario, an investment of $600 million accrues benefits of $230 million annually, paying for itself after three years and then accruing cost savings for years to come. After 30 years the average net return per dollar spent on abatement is $10.50. The returns per dollar invested from a taxpayer perspective accrue more slowly but are also significant – the $600 million spent on abatement returns $145 million annually.

A $600 million investment in abatement at one time is extremely unlikely. But we believe this is a helpful illustrative scenario, showing the return on investment from lead abatement, and also allowing an estimated average return on investment per dollar of abatement.
This assessment relied on established, published metrics (largely from national studies) and applied them to Michigan. A number of assumptions were made about exposure levels in Michigan, costs of healthcare and education, and lead abatement costs and targeting. We believe the assumptions made were conservative, making this illustrative analysis conservative overall. We quantified only a narrow range of the economic impacts of lead exposure — those impacts that have been well demonstrated and quantified in published literature. Wider impacts, such as productivity for parents of lead poisoned children, wider impacts of lead-associated crime, and lost quality of life were not quantified, and would likely add significantly to the costs estimated here. The assumptions of the number of children with elevated blood lead levels were conservative in a number of respects. With further information on these impacts and on lead exposures in Michigan (for example, more information on untested children), the calculations here could be updated and improved.

These economic returns on investment in lead abatement are all in addition to the value of health and well-being of thousands of Michigan children, and their families, who experience the effects of lead exposure each year. This assessment suggests that the current public investment in Michigan of abating approximately 150 homes per year (at a cost of $1.2 million) is likely an excellent economic investment. Further lead abatement is worthy of consideration as an economic, as well as a public health, investment.
Economic Impacts of Lead Exposure and Remediation in Michigan

Full Report

Summary

This assessment evaluates the economic impacts of lead exposure among Michigan children by considering four well-documented impacts of lead exposure: 1) increased health care, 2) increased crime, 3) increased need for special education, and 4) decline in lifetime earnings. These impacts are estimated for one snapshot year, 2012, and total over $330 million in social costs (including $145 million in taxpayer costs). Compared to the estimated costs of lead paint remediation/abatement ($600 million), this analysis suggests that lead abatement pays for itself in 3-6 years and provides many further years of positive returns. After 30 years the average net return on $1 invested in abatement is estimated at $10.50. This illustrative analysis suggests that lead abatement would be a worthwhile economic investment, with considerable public health benefits, as well.
Background

In 2010 the Ecology Center and Michigan Network for Children’s Environmental Health (MNCEH) published Price of Pollution (MNCEH and the Ecology Center 2010), an economic estimate of environmentally attributable costs of four pediatric conditions – lead poisoning, asthma, cancer, and developmental disabilities. This follow-up report delves more deeply into the economic impacts of lead exposure among Michigan children and the estimated costs of exposure prevention.

Given that priorities for environmental and public health investment are increasingly driven by economic considerations, this assessment is designed to provide an economic context for Michigan’s public health efforts related to lead prevention and remediation. This report was developed through a partnership between the Michigan Network for Children’s Environmental Health (MNCEH) and the University of Michigan Risk Science Center (RSC).

Children are the segment of the population most at risk for lead poisoning and most vulnerable to its effects. While environmental and public health policies such as banning leaded gasoline and lead paint in the 1970s have greatly reduced children’s exposure to lead, historic sources of contamination persist (EPA 2013). Today, children are most commonly exposed to lead as a result of exposure to lead paint in older homes. Because of their natural behaviors, such as hand to mouth activity and crawling and playing on the floor, children may consume paint chips or ingest lead dust (produced from deteriorating surfaces or renovations) through everyday activities, such as opening windows with lead-painted frames (Levin et al 2008).

Adults are much better at expelling lead (through urine and feces) than children, whose bodies absorb a large proportion of the lead ingested, storing it in their bones. Once stored, lead impacts a child’s rapidly developing central nervous system. Lead exposure is associated with reduced cognitive function, leading to reduced academic achievement and lower IQ. Lead exposure is also associated with behavioral problems and aggressive behaviors, including attention-deficit/hyperactivity disorder and delinquent, criminal, or antisocial behavior (EPA 2013, Gould 2009, Lanphear 2005). These effects tend to be linked to a child’s maximal blood lead level (the peak level observed, rather than the average level, although there is also evidence that average levels may be a helpful predictor for older children (Lanphear 2005)), and the impacts of lead on cognitive development are irreversible and persistent (EPA 2013). A recent study indicates an “irreversible pattern of neuronal dysfunction” found in adults that were exposed to lead as children (Cecil at al 2011, p. 403).

Abating lead in contaminated homes (often by repairing or replacing window and door frames or encapsulating/enclosing areas of chipped paint) greatly reduces children’s exposure to lead and the negative health impacts associated with lead poisoning (PTF 2000). However, targeting the right homes for abatement is challenging and can add to the overall cost of successful abatement programs.

Analysis

The assessment in this paper is not novel in approach – the metrics and impacts considered are drawn from established research. This paper draws heavily from Price of Pollution, and reports by Gould (2009) and Korfmancher (2003). Our approach is to bring together established
standards and apply them in a Michigan-specific assessment, producing a one-year (2012) snapshot illustration of the estimated costs of lead exposure and the comparative costs of mitigating that exposure through lead abatement.

Throughout the analysis, conservative assumptions are made wherever possible. For instance, we assumed that the detrimental impacts of lead exposure are on the low side of what research indicates and that costs of abatement are on the high side of demonstrated costs.

In the following section, we estimate lead exposure among Michigan children, as measured by blood lead level (BLL) testing.

We then identify four well-documented impacts and costs of lead exposure: 1) increased health care, 2) increased crime, 3) increased need for special education, and 4) decline in lifetime earnings. We apply these metrics to the assumed lead exposure level among Michigan children, estimating the costs associated with lead exposure in one year. In the final section, we compare these costs to the cost of lead abatement and discuss the economic and public health implications of the results.

Children Exposed to Lead in Michigan
The Michigan Department of Community Health (MDCH) collects data on BLL testing among children in Michigan annually; their 2013 report provides data on 2012 testing (MDCH 2013). The data provide results of children tested under the age of 6 in Michigan, and of the more than 700,000 children under 6 in Michigan, just under 150,000 children were tested in 2012. The majority of children in this sample are age 1 and 2 – the target age for the Statewide Testing Plan – and most testing is among children deemed most likely to be at risk for lead poisoning. The Statewide Testing Plan defines “children who should be tested” as 1 and 2-year-olds who are insured by Medicaid or live in any of the 14 “Target Communities” in Michigan. These 14 Target Communities are urban areas, and thus about 50% of Michigan’s 234,000 1 and 2-year-olds qualify as “children who should be tested”\(^1\).
We chose to focus on the cohort of 1 and 2-year olds for several reasons. Elevated BLLs tend to peak at around age 2 (likely because of crawling and hand-to-mouth behaviors typical at that age) (USPSTF 2006), and peak levels tend to drive the associated health impacts that will be considered in this assessment. The Centers for Disease Control and Prevention (CDC) and American Academy of Pediatrics recommend BLL testing at ages 1 and 2 (CDC 2007). In addition, we can draw better inferences from the larger sample of 1 and 2-year olds (compared to the relatively smaller sample size of all children under age 6). Of the 234,000 children ages 1 and 2 in Michigan in 2012, 37% are included in the testing sample. Among all 718,000 children under 6, 21% were tested in 2012.

Test results for 1 and 2-year olds, separated by “who should be tested” and “other” are provided in Table 1. While there is no “safe” amount of blood lead, 5 μg/dL is the CDC “action level” for lead exposure in children (EPA 2013). Figure 1 illustrates the breakdown of all Michigan 1 and 2-year olds, by testing status and whether prioritized as a child “who should be tested” or not.

Table 1: Michigan Blood Lead Level Testing for 1 and 2-year-olds, 2012

<table>
<thead>
<tr>
<th></th>
<th>Population</th>
<th>Number of children tested</th>
<th>% tested</th>
<th>Children with BLL 5-9 μg/dL</th>
<th>% of population</th>
<th>Children with Venous BLL &gt;= 10 μg/dL</th>
<th>% of population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 and 2-year-old</td>
<td>120,602</td>
<td>68,646</td>
<td>56.9%</td>
<td>3,265</td>
<td>4.7%</td>
<td>445</td>
<td>0.65%</td>
</tr>
<tr>
<td>Children “Who Should be Tested”</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other 1 and 2-year-olds</td>
<td>113,808</td>
<td>19,327</td>
<td>17.0%</td>
<td>322</td>
<td>1.6%</td>
<td>24</td>
<td>0.12%</td>
</tr>
<tr>
<td>All 1 and 2-year-olds</td>
<td>234,410</td>
<td>87,973</td>
<td>37.5%</td>
<td>3,587</td>
<td>4.08%</td>
<td>469</td>
<td>0.53%</td>
</tr>
</tbody>
</table>

Figure 1: Michigan 1 and 2-year-olds by testing status and “who should be tested”
There are some challenges in generalizing from the sample to estimating BLLs for all 1 and 2-year-old children in Michigan:

- Testing (for 1 and 2-year-olds) is aimed at “Target Communities” and Medicaid recipients, and these children are disproportionately in the test sample. These groups are more likely to live in older housing and have lower incomes, factors which often correlate with lead exposure (therefore, the sample may contain higher BLLs than is representative in the overall population).

- Only 57% of the “children who should be tested” were tested, meaning that 43% of children thought to be at high risk for lead poisoning were not tested. There may be reason to believe that those not being tested might be more likely to be exposed to lead, as they are not receiving recommended health care and more generally in a high risk situation (therefore, the sample may contain lower BLLs than is representative).

- There is a significant difference in test results among “children who should be tested” and other 1 and 2 year olds (see Table 1). For example, nearly 4.7% of targeted children have elevated BLLs of 5-9 μg/dL, while only 1.6% of not targeted children test at this elevated level. This suggests that the “children who should be tested” criteria may be a helpful prioritization. However, we have a fairly small sample of “other” 1 and 2-year-olds, so it is difficult to know if these 17% are representative of the “other” 1 and 2-year-old population.

- Maximal or peak BLL corresponds to the impacts in this assessment. While we know the children tested in the MDCH data have actual BLLs at least at the level recorded, many children may have had or will have a higher level at some point. Therefore, the recorded BLLs are at or lower than “peak” BLLs, making the impact estimations that follow conservative. With these data challenges in mind, we estimated rates of elevated BLLs for all Michigan 1 and 2-year-old children, making several conservative assumptions.

Among 1 and 2-year-olds, 57% of targeted children (those thought to be at high risk of lead exposure) were tested, and we assume that the remaining 43% of targeted children would have a similar distribution of test results. Given that so few of the “other” 1 and 2-year-olds were tested (17%) we assume conservatively that only those sampled had elevated BLLs and none of the remaining 83% of “other” children had an elevated BLL. These estimations are shown in Table 2.
We also derived the more specific BLL range estimates in Table 3, as these will be needed for the impact estimations in following sections. Based on the projections in Table 2, we estimated that the tested elevated BLLs represent 59% of the total population of elevated BLLs for each category in Table 3.

Table 2: Michigan 1 and 2-year-old BLL test results and projections for those untested (projections in blue)

<table>
<thead>
<tr>
<th>Tested children - results</th>
<th>Population</th>
<th>Number of children with BLL 5-9 ug/dL</th>
<th>Rate</th>
<th>Number of children with Venous BLL &gt;= 10ug/dL</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Children who should be tested&quot;</td>
<td>68,646</td>
<td>3,265</td>
<td>4.8%</td>
<td>445</td>
<td>0.6%</td>
</tr>
<tr>
<td>&quot;Other&quot; children</td>
<td>19,327</td>
<td>322</td>
<td>1.7%</td>
<td>24</td>
<td>0.1%</td>
</tr>
</tbody>
</table>

| Untested children - projected results | | | | | |
| "Children who should be tested" | 51,956 | 2,471 | 4.8% | 337 | 0.6% |
| "Other" children | 94,481 | 0 | 0 | 0 | 0 |

| TOTAL estimates for all Michigan 1 and 2-year olds | | | | | |
| 234,410 | 6,058 | 2.6% | 806 | 0.3% |

Tested children as a proportion of total estimate | 59% | 58% |

Table 3: Estimated elevated BLLs for Michigan 1 and 2-year-olds

<table>
<thead>
<tr>
<th>Estimated population with highest BLL of:</th>
<th>Population of Michigan Children</th>
<th>5-9 μg/dL</th>
<th>10-14 μg/dL</th>
<th>15-19 μg/dL</th>
<th>20-44 μg/dL</th>
<th>&gt;=45 μg/dL</th>
<th>% with BLL &gt;=5 μg/dL</th>
<th>% with BLL &gt;=10 μg/dL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tested children results</td>
<td>87,973</td>
<td>3,587</td>
<td>382</td>
<td>129</td>
<td>107</td>
<td>6</td>
<td>4.79%</td>
<td>0.71%</td>
</tr>
<tr>
<td>Projected results – All Children</td>
<td>234,410</td>
<td>6,058</td>
<td>651</td>
<td>220</td>
<td>182</td>
<td>10</td>
<td>3.04%</td>
<td>0.45%</td>
</tr>
<tr>
<td>Proportion of all children age 1 and 2</td>
<td>2.58%</td>
<td>0.278%</td>
<td>0.094%</td>
<td>0.078%</td>
<td>0.004%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: Projected results based on estimates in Table 2, assuming that the tested and recorded elevated BLLs represent 59% of the actual elevated BLLs among all Michigan children in each category.
For calculations of 2-year-olds only, we assume that the elevated BLLs in Table 3 would be distributed evenly among 1 and 2-year-olds.

**Costs of lead exposure**

Drawing from established methods and metrics, this assessment estimates four well-documented costs of children’s lead exposure in Michigan:

- Increased health care
- Increased crime
- Increased special education
- Decline in lifetime earnings

**Health care**

We estimate two health care costs for children in Michigan associated with elevated BLLs as a child: the first is the immediate treatment of children who are tested and have results of 10 μg/dL or greater, and the cost of treatment for lead-attributable attention deficit hyperactivity disorder (ADHD).

**Immediate treatment**

The recommended treatment for children whose test results show elevated BLLs and the estimated costs of this treatment (drawn from Gould 2009) are presented in Table 4. Treatment may include diagnostic testing, nurse visits, environmental investigation of the home, and oral and intravenous chelation in extreme cases. The estimated costs of these treatments are applied to the number of children under the age of 6 in 2012 who tested at the corresponding blood levels.

No extrapolation is made to children who were not tested, as those untested would unfortunately not be receiving recommended treatment. Also, these estimates are applied to all children under the age of 6 to reflect the actual health care costs associated with lead exposure among Michigan children in 2012. Because no extrapolation is made to untested children, the sample of children under 6 (rather than 1 and 2 year olds only) is used.

**Table 4: Healthcare costs for children with elevated BLLs**

<table>
<thead>
<tr>
<th>Blood lead level in μg/dL</th>
<th>Number of children in Michigan under the age of 6</th>
<th>Recommended treatment</th>
<th>Cost of recommended treatment (in 2012 USD)</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>10-20</td>
<td>863</td>
<td>diagnostic testing, venipuncture, lead assay, nurse-only visit</td>
<td>$84</td>
<td>$72,803</td>
</tr>
<tr>
<td>20-45</td>
<td>166</td>
<td>above treatments, plus 8 visits for diagnostic testing, nurse follow-up, environmental investigation of the home</td>
<td>$1,171</td>
<td>$194,349</td>
</tr>
<tr>
<td>45-70</td>
<td>9</td>
<td>above treatments, plus oral chelation</td>
<td>$1,522</td>
<td>$13,697</td>
</tr>
<tr>
<td>70+6</td>
<td>0</td>
<td>above treatments, except oral chelation is replaced with intravenous chelation</td>
<td>$3,926</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$280,849</td>
</tr>
</tbody>
</table>
**ADHD treatment**

According to the CDC, an estimated 8.4% of children age 3-17 in the US have been diagnosed with ADHD (Bloom et al 2010). Gould (2009), drawing from Braun et al (2006), estimates that 21.1% of ADHD cases in children aged 4-15 are associated with elevated BLLs. This standard is applied to Michigan, estimating the costs of treating lead-associated ADHD in Table 5.

In sum, the estimated childhood healthcare costs for immediately treating those under 6 for lead exposure, and for treating lead-associated ADHD among adolescents, was just under $18.5 million in 2012.

This estimate is thought to be conservative in that we consider just 2 metrics of increased health care for children associated with elevated BLLs, while other health and developmental impacts also require health care. Also, studies suggest numerous lasting health impacts, as well as wider productivity impacts and stress on family members and caretakers, which are not quantified here (Gould 2009).

**Crime**

Childhood lead exposure has been linked to criminal behavior by juveniles and adults, in the US and internationally (Nevin 2006, Nevin 2000, Gould 2009, Pichery 2011). We assess the costs of juvenile crime by estimating the costs of juvenile incarceration associated with lead exposure. The standard from Korfmacher (2003) is applied in Table 6, assuming that 10% of juvenile delinquency is attributable to lead exposure, totaling an estimated $32 million annual cost of lead-associated juvenile crime.

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**Table 5: Healthcare costs of lead-associated ADHD**

<table>
<thead>
<tr>
<th>Michigan Children Age 4-15&lt;sup&gt;7&lt;/sup&gt;</th>
<th>Estimated 8.4% diagnosed with ADHD&lt;sup&gt;8&lt;/sup&gt;</th>
<th>21.1% of cases associated with elevated blood lead levels&lt;sup&gt;9&lt;/sup&gt;</th>
<th>Health care costs - medication and counseling per child for one year&lt;sup&gt;10&lt;/sup&gt;</th>
<th>Total costs</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,577,790</td>
<td>132,534</td>
<td>27,965</td>
<td>$648.54</td>
<td>$18,136,259</td>
</tr>
</tbody>
</table>

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**Table 6: Cost of lead-associated juvenile crime (incarceration)**

<table>
<thead>
<tr>
<th>Number of Michigan youth in residential facilities (2011, assumed same for 2012)&lt;sup&gt;11&lt;/sup&gt;</th>
<th>Cost per day of care&lt;sup&gt;12&lt;/sup&gt;</th>
<th>Total cost per year</th>
<th>10% attributable to lead&lt;sup&gt;13&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>2085</td>
<td>420.08</td>
<td>$319,691,382</td>
<td>$31,969,138</td>
</tr>
</tbody>
</table>
In addition to juvenile delinquency, lead exposure as a child is linked to crime as an adult. Applying standards established by Gould (2009), drawing from Nevin (2006), Table 7 estimates the direct costs of crimes in Michigan linked to childhood lead exposure. This standard estimates the number of crimes ‘linked to childhood lead’ as crimes averted by a reduction in average preschool BLL by 1 μg/dL. This is a conservative estimate of lead-linked crimes, given that even larger (or especially well targeted) reductions in lead exposure would have even more significant reductions in crime.

The direct costs of crime estimated here total more than $73 million annually and include direct victim costs, legal proceedings, incarceration, and lost earnings to both the criminal and victim (Gould 2009).

For both juvenile and adult crimes, other indirect costs accrue, such as lost wages, pain, suffering, associated physical and mental healthcare costs, and lost quality of life. These would all increase the total costs of lead-related crime substantially. Gould (2009) estimates that these indirect costs total around ten times the direct costs calculated in Table 7. However, in this conservative estimate we do not quantify these less clear costs.

**Special Education**

Childhood lead exposure is associated with declines in IQ and an associated need for special education. A recent Detroit-specific study found an association between childhood lead exposure (exposure before the age of six) and poor academic performance in the third, fifth, and eighth grade (Zhang et al 2013).

Table 8 estimates the costs of special education associated with increased BLLs at 25 μg/dL or above (drawing from the assumed population BLLs in Table 3). Korfmacher (2003), drawing from Schwartz (1994) estimates that 20% of children with blood lead levels of 25 μg/dL or above require special education for an average of 3 years. Sarbaugh-Thompson et al (2008), in a Detroit-specific assessment, estimate that children receiving special education because of lead-related reduction in
Table 8: Costs of special education related to lead exposure – incurred by 2-year-old cohort in 2012

<table>
<thead>
<tr>
<th>Children with BLL 25+ μg/dL</th>
<th>Cost per year of special education</th>
<th>Total cost for 9 years of special education for 20% of children with blood lead level 25+ μg/dL</th>
</tr>
</thead>
<tbody>
<tr>
<td>77</td>
<td>18,219</td>
<td>$2,533,524</td>
</tr>
</tbody>
</table>

cognitive ability receive special education for between 9 and 20 years, depending on the level of cognitive impairments. We assume 9 years of special education for 20% of children measured at 25 μg/dL or above at age 2, which totals an estimated $2.5 million in special education costs. These are the lifetime special education costs incurred by the 2012 cohort of 2-year olds, so it is an annual figure we expect to be accrued in following years.

We believe this estimate to be conservative by only considering special education costs for children with an elevated BLL of 25+ μg/dL, when the impacts at lower levels could also require educational support (Zhang et al 2013, Sarbaugh-Thompson et al 2008). Also, we do not include indirect costs of children with lowered cognitive abilities, including loss of parental productivity in caring for a child with special needs and the health and stress impacts on family members. Furthermore, this assumes a peak BLL at age 2, and no costs are assumed for children whose BLL peaks at a later age.

Decreased Lifetime Earnings

Lead is also associated with reductions in IQ and resulting reductions in lifetime earnings (Canfield et al 2003, Lanphear 2005, Carlisle et al 2009): elevated BLLs are correlated with irreversible declines in IQ, and reduced IQ (on average) leads to reductions in lifetime earnings.

Table 9 applies the standards established in Lanphear et al (2005) and Gould (2009) to estimate lead-associated IQ loss and lifetime earnings loss for Michigan’s 2-year-olds in 2012. The approach here divides children with elevated BLLs into four categories and then applies the associated loss of IQ points for each BLL category.

Table 9: Reduction in lifetime earnings

<table>
<thead>
<tr>
<th>Maximal blood lead level</th>
<th>Estimated number of 2-year-olds</th>
<th>Associated loss in IQ points for each child</th>
<th>Lifetime earnings loss per child, NPV</th>
<th>Total lifetime lost earnings, NPV</th>
</tr>
</thead>
<tbody>
<tr>
<td>5-10</td>
<td>3029</td>
<td>2,565</td>
<td>52,431</td>
<td>$158,818,843</td>
</tr>
<tr>
<td>10-20</td>
<td>435</td>
<td>3.9</td>
<td>79,720</td>
<td>$34,695,771</td>
</tr>
<tr>
<td>20-30</td>
<td>38</td>
<td>5.8</td>
<td>118,558</td>
<td>$4,501,856</td>
</tr>
<tr>
<td>30 or greater</td>
<td>58</td>
<td>6.9</td>
<td>141,043</td>
<td>$8,218,679</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>$206,235,149</td>
</tr>
</tbody>
</table>
The IQ loss associated with each category demonstrates the non-linear nature of the relationship between blood lead and IQ loss. Each additional μg/dL of lead at the lower levels of exposure has a greater impact on IQ than each additional μg/dL at higher levels of exposure. For example, increasing from 5 μg/dL to 10 μg/dL equates to more decline in IQ than increasing from 25 μg/dL to 30 μg/dL. Low level exposures are significant.

Loss of lifetime earnings is calculated using the standard in Gould (2009), inflated to 2012 figures, assuming each IQ point lost equates to a loss of $20,441 in net present value (NPV) of lifetime earnings.

In total, we estimate that more than $206 million in NPV lifetime earnings are lost among Michigan 2-year-olds with elevated BLLs in 2012. We consider only 2-year-olds here as an annual assessment. The following year we expect the next cohort of 2-year-olds to experience similar loss of lifetime earnings because of their elevated BLLs.

In addition to the conservative assumptions made in estimating the BLLs for Michigan’s population in Table 3, this calculation is also conservative in that we base IQ decline on the 2-year old BLL, when BLLs may peak at other times. There is evidence to suggest that IQ loss and earnings loss can occur at levels below 5 μg/dL (Lanphear 2005, Carlisle et al 2009), and this could impact many more children.

### Summary

Table 10 summarizes the annual costs of lead exposure described above. This table also estimates how much of the costs described are born by the taxpayer – an estimated 40% with the assumptions described in Table 10.

<table>
<thead>
<tr>
<th>Description of costs associated with lead exposure, 2012</th>
<th>Amount</th>
<th>Costs to the taxpayer</th>
<th>Description of assumed taxpayer costs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Increases in health care</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Blood lead treatment</td>
<td>280,849</td>
<td>252,764</td>
<td>estimated 90% of children with elevated BLL are on Michigan medicaid programs</td>
</tr>
<tr>
<td>Treatment of lead-related ADHD</td>
<td>18,136,259</td>
<td>16,322,633</td>
<td>estimated 90% of children with elevated BLL are on Michigan medicaid programs</td>
</tr>
<tr>
<td><strong>Increases in special education</strong></td>
<td>2,533,524</td>
<td>2,533,524</td>
<td>estimated 100% of costs through public education</td>
</tr>
<tr>
<td>Reduction lifetime earnings, NPV</td>
<td>206,235,149</td>
<td>16,498,812</td>
<td>estimated 8% state and local effective tax rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>41,247,030</td>
<td>estimated 20% effective federal tax rate</td>
</tr>
<tr>
<td><strong>Increased crime</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juvenile incarceration related to childhood lead</td>
<td>31,969,138</td>
<td>31,969,138</td>
<td>100% taxpayer cost</td>
</tr>
<tr>
<td>Adult crimes related to childhood lead</td>
<td>73,293,337</td>
<td>36,646,668</td>
<td>50% taxpayer cost</td>
</tr>
<tr>
<td><strong>TOTAL costs of lead exposure in year (2012)</strong></td>
<td>332,448,256</td>
<td>145,470,570</td>
<td></td>
</tr>
</tbody>
</table>
Costs of Lead Abatement

By comparison to the costs of lead exposure, we estimate the costs of eliminating exposures to lead by abating lead in homes. We use lead abatement here to describe whatever treatments are needed in a home to reduce or eliminate lead exposures. This may be eliminating the lead, like replacing windows and doors that create lead dust when opened and closed. Or, this may include more interim controls, such as encapsulation or enclosure of the paint in areas where it is chipping or peeling.

We assume that 70% of elevated BLLs are attributable to lead paint exposure in homes, consistent with findings in Levin et al (2008). Therefore, in a scenario of complete abatement of lead paint in homes, we estimate that 70% of the incidence of lead exposure and associated costs above could be eliminated. The remaining 30% (exposure through soil, water and other sources) would remain.

There are many challenges in identifying which and how many homes should be targeted for lead abatement. If targeting were 100% accurate, the costs of lead abatement could be reasonably straightforward. But it is difficult to know which homes with lead paint hazards will actually lead to dangerous exposures in children, especially considering that exposure may occur in a home other than a child’s residence. On the other hand, homes that are successfully lead-abated may lead to many years, and where lead is eliminated, even generations of avoided lead exposures for children.

Gould (2009) compares the benefits of lead abatement with the costs of abating homes likely to be at significant risk of having lead paint hazards, as identified by the President’s Task Force (2000), and we apply...
A similar metric to Michigan. The President’s Task Force (2000) estimated that 2.3 million low-income housing units would be most at risk for lead paint hazards in 2010, and this is roughly 6% of all 38 million houses with lead-based paint (Jacobs et al 2002). This national rate corresponds with the 100,000 housing units in Michigan that have been estimated to be at “high risk” of lead hazards, defined as pre-1960s homes whose occupants live below the poverty level (Scorecard 2013). Our own calculations indicate 100,000 homes is a reasonable proportion of the 2.3 million at-risk housing units nationally. According to the 2012 US Census American Community Survey, 29.5% of the US housing stock, or 34 million units, were built before 1960, while 37.4% of the Michigan housing stock, or 1.4 million units, were built before 1960 (ACS 2012). Therefore, Michigan contains an estimated 4% of the nation’s pre-1960s housing stock. Assuming 100,000 high lead risk homes in Michigan is a similar proportion (4.3%) of the nation’s 2.3 million high lead risk homes, so we consider 100,000 homes as targeted in our scenario. We selected pre-1960s homes as the comparative indicator here because these homes are those thought to be most at risk for lead hazard, although lead paint was available until the 1970s (President’s Task Force 2000).

Targeting for lead abatement is not perfect, not all lead poisoned children live in older homes and not all are below poverty, but these criteria are strong indicators. A low-income child living in older housing is 4 times more likely to be lead poisoned than the average rate for all children in older homes. Similarly, not all homes that contain lead paint present a hazard for children, so effective targeting is an important part of a cost-effective lead abatement approach. In our example, targeting 100,000 homes in Michigan sets a relatively wide margin compared to the estimated 7,000 1 and 2-year-olds with elevated BLLs (Table 3).

We now consider the cost to successfully abate these 100,000 housing units. Gould (2009) estimates the cost of abatement, across the US, to range between $1,200 for a house that requires screening and interim controls to $10,800 for a house that requires risk assessment and full abatement.
Assuming the average cost of lead abatement is $6,000 per unit, the cost to abate all 100,000 high-risk homes in Michigan is an estimated $600 million. We believe an average of $6,000 per home abated would be a high estimate. By comparison, the 140-150 homes abated this year in Michigan by the Department of Community Health are expected to be abated at an average cost of $8,400 each. We expect these would be among the 150 most-in-need homes, as compared to a much wider net in this scenario of the 100,000 most-in-need homes.26

In the illustrative scenario, the lead abatement of 100,000 homes reduces lead exposure by 70%, reducing the annual costs of lead exposure from over $300 million to $70 million (a cost savings of $230 million annually). The $600 million in lead abatement would pay for itself after just 3 years, and then accrue benefit on the order of $230 million annually for many years to come. After just 10 years, the $600 million abatement investment would yield $1.7 billion in net cost savings in Michigan. In other words, each dollar invested in abatement would return about $2.80 in net cost savings over ten years, $6.60 after 20 years, and $10.50 after 30 years. The length of the benefit would depend on the nature of the abatement and how long it lasts, as well as the targeting and the number of children that avoid lead exposure.

From a strictly taxpayer perspective, the break-even point would take longer, as the taxpayer proportion of lead-associated costs is just under half of the total, $145 million annually. Again, we assume in the 100,000 home lead abatement scenario that 70% of exposures, and 70% of the $145 million annual costs are eliminated, which equals taxpayer savings of just over $100 million annually. After 6 years, $600 million in abatement costs would pay for themselves, and taxpayer savings would then accrue on the order of $100 million annually. From the taxpayer perspective, each dollar invested in abatement would return a net benefit of $0.67 after ten years, $2.30 after 20 years, and $4 after 30 years.

This is an illustrative example, as the actual timing of abatement would influence when costs savings would accrue. However, with quite conservative assumptions, the one-year snapshot illustration suggests that abatement is a worthwhile investment economically, in addition to the public health benefits for families whose lead exposure is prevented. The case is strengthened when considering the many years and even potentially generations of exposure and cost savings beyond the one small snapshot illustrated. These findings correspond with estimates in Gould (2009) that investments in lead paint hazard control have rates of return of $12-$155 per every dollar invested.
Discussion

This assessment estimated the social and taxpayer costs of lead exposure in Michigan, and compared these costs to an illustrative lead abatement scenario, in order to explore the economic case for lead abatement in Michigan.

In valuing the cost of health care, special education, crime and lost earnings associated with lead exposure, we relied on established, published metrics (largely from national studies) and applied them to Michigan. A number of assumptions were made about exposure levels in Michigan, costs of healthcare and education, and lead abatement costs and targeting.

We believe the assumptions made were conservative, making this illustrative analysis conservative overall. We quantified only a narrow range of the economic impacts of lead exposure – those impacts that have been well demonstrated and quantified in published literature. Wider impacts, such as productivity for parents of lead poisoned children, wider impacts of lead-associated crime, and lost quality of life were not quantified, and would likely add significantly to the costs estimated here. With further information on these impacts and on lead exposures in Michigan (for example, more information on untested children), the calculations here could be updated and improved.

This assessment indicates that the annual costs of lead exposure – to the public and to the taxpayer - are substantial: more than $330 million and $145 million, respectively. Even with conservative assumptions this assessment indicates that lead abatement would be a worthwhile economic investment. We estimated that all 100,000 of Michigan’s most at-risk homes could be abated for $600 million, an investment that would pay for itself after 3 years and then accrue benefits of $230 million annually. From a strictly taxpayer perspective, a $600 million investment in abatement would pay for itself in 6 years and then accrue taxpayer savings of $100 million annually, for many years to come.

A $600 million investment in abatement at one time is extremely unlikely. But we believe this is a helpful illustrative scenario, showing the return on investment from lead abatement, and also allowing an estimate of average return on investment per dollar of abatement. After 30 years, the net return on $1 of abatement would be an average of $10.50. And the benefits could accrue for longer. Also, if a net return of $10.50 would be the average return across all 100,000 homes abated, with quality targeting of lead abatement, it seems likely that a first grouping of lead abated homes might be among those most in need, delivering a disproportionately positive benefit. It seems reasonable that investing in lead abatement in areas with the highest levels of lead poisoning (highest BLLs by zip code are identified by MDCH (2013)) would yield benefits even greater than the average $10.50 per dollar estimated.

These economic returns on investment in lead abatement are all in addition to the value of the health and well-being of thousands of Michigan children, and their families, who experience the effects of lead exposure each year. Even without this benefit, on an economic basis alone, this assessment suggests that lead abatement is an investment worth considering.
Endnotes

1. The 14 Target Communities are: Battle Creek, Benton Harbor, Dearborn, Detroit, Flint, Grand Rapids, Hamtramck, Highland Park, Jackson, Kalamazoo, Lansing, Muskegon/Muskegon Heights, Pontiac and Saginaw.
2. Data from MDCH (2013).
3. Data from MDCH (2013).
5. Source: Gould (2009), inflated here to 2012 USD.
6. Because the MDCH data category is 45 μg/dL or greater, we conservatively estimate that all Michigan children in this category fall within the 45-70 range, and no children are within the 75+ range.
7. Data from MDTMB (2013).
12. Data from Justice Policy Institute (2009), inflated to 2012 figure.
15. Proportions were calculated based on figures from Gould (2009) derived from Nevin (2000).
16. From Gould (2009), figures inflated to 2012 values.
17. “Burglaries” includes larceny and motor vehicle theft.
18. This calculation assumes children within the 20-44 μg/dL group are evenly distributed, and therefore 19/24 = 79.1% of children in this category have blood lead levels of 25 or greater.
19. From Korfmacher (2003), inflated to 2012 values.
20. For the 5-10 μg/dL category and the 30+ μg/dL category, we make the conservative assumptions that children have the floor levels of measured blood lead (5 μg/dL and 30 μg/dL, respectively). For the 10-20 and 20-30 categories, children are assumed to have an even distribution of blood lead levels across the category.
21. See endnote 8 above.
22. The associated decline in IQ points for the groups of 10 μg/dL or more is from Lanphear et al 2005. The decline associated with the group 5-10 μg/dL applies the standard from Gould (2009) (which is derived from Lanphear et al 2005), with the conservative assumption that all children in the 5-10 μg/dL group tested at 5 μg/dL.
23. Lifetime earnings loss per child is calculated as the estimated decline in IQ points times the assumed $20,441 loss in lifetime earnings per IQ point loss in net present value (NPV), derived from Gould (2009).
24. These figures assumed that 1.4 million homes would no longer be a lead paint hazard because of HUD regulation of Federally-Assisted Housing between 2000-2010.
25. Author’s calculations from data in the President’s Task Force (2000).
26. Figures on cost and number of units abated by Michigan DCH provided in correspondence with DCH.
References

American Community Survey (ACS) (2012). U.S. Census Bureau. Physical Housing Characteristics for Occupied Housing Units. Table S2504.


Report Design by: Tracey Easthope