Costs of Lead Exposure
and Remediation in Michigan: Update

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A report prepared by the Ecology Center and the Michigan Network for Children's Environmental Health

Acknowledgements

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About the Sponsoring Organizations

Founded in 1970, the Ecology Center is organized for one purpose -- to develop innovative solutions for healthy people and a healthy planet. We believe that the central question of our time is how human beings are going to thrive in the world without destroying the earth's ability to sustain us. In the face of enormous environmental challenges, virtually all sectors of our society are now scrambling to create solutions, and the Ecology Center plays a critical role in advancing the best models. To do that, we do the following:

- Educate consumers to help keep their families healthy and safe
- Push corporations to use clean energy, make safe products, and provide healthy food
- Provide innovative services that promote healthy people and a healthy planet
- Work with policymakers to establish laws that protect communities and the environment

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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Executive Summary

Overview

As an update to our 2014 report "Economic Impacts of Lead Exposure in Michigan," this assessment evaluates the economic impacts of lead poisoning among Michigan children by considering the costs of four well-documented impacts of lead exposure: 1) increased need for 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, 2014, compared to our previous report, which considered the impacts in a 2012 snapshot year.

We note that this research began in 2013 before Flint's water-related lead exposures, and the scope of the work is state-wide. The impacts here are calculated using state-wide elevated blood lead levels in 2014, and associated costs of education, crime, health care, and lifetime earnings in 2014, so these calculations reflect little of the costs associated with Flint's water contamination. Instead, these figures indicate the baseline costs and economic impacts of lead exposure in Michigan, largely associated with lead paint. Based on the literature, we assume lead paint contributes about 70% of children's total lead levels. The additional 30% we assume comes from other sources including water. The significant costs to the residents of Flint and Michigan taxpayers as a result of water contamination in Flint would be additional to the annual costs estimated here.

We estimate the costs of lead exposure in Michigan in 2014 to total nearly $270 million ($112 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 just over 3 years and beyond that provides many years of positive returns. 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. This illustrative analysis suggests that lead abatement would be a worthwhile economic investment, with considerable public health benefits, as well.

Background

This research builds on two important reports, *The Price of Pollution, and Economic Impacts of Lead Exposure in Michigan.* *The Price of Pollution* was released by the Ecology Center and the Michigan Network for Children's Environmental Health in 2010, and examined the annual economic cost of lead poisoning, asthma, cancer, and developmental disabilities.

The Economic Impacts of Lead Exposure in Michigan, published in 2014, delved more deeply into the economic impacts of lead exposure, and compared these costs to the cost of lead abatement in homes.

Costs of Lead Exposure and Remediation: Update is an update of the 2014 report using the latest available full data set from the State of Michigan.

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, most often, 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 $271,000 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 starting at 10 µg/dL and

ADHD treatment) while ignoring other health and developmental impacts of cognitive disability that may require regular and continuing healthcare costs. Additionally, the wider impacts on productivity and stress on family members and caretakers were not considered, nor are other pro-active health measures, such as programs to improve nutrition in response to lead exposure (such as in Flint) included.

Crime

An estimated 10% of juvenile crimes in Michigan were associated with lead exposure, costing an estimated $13.4 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 crime statistics in Michigan, an estimated $64 million annually can be attributed to lead-associated crimes. This includes costs to victims, legal proceedings, incarceration, and lost earnings for both the criminal and victim. These conservative estimates do not quantify additional indirect costs associated with lead-related crime, such as pain and suffering, costs associated with healthcare to address the physical and mental impacts of the crime, and lost quality of life. Inclusion of these costs would substantially increase these figures.

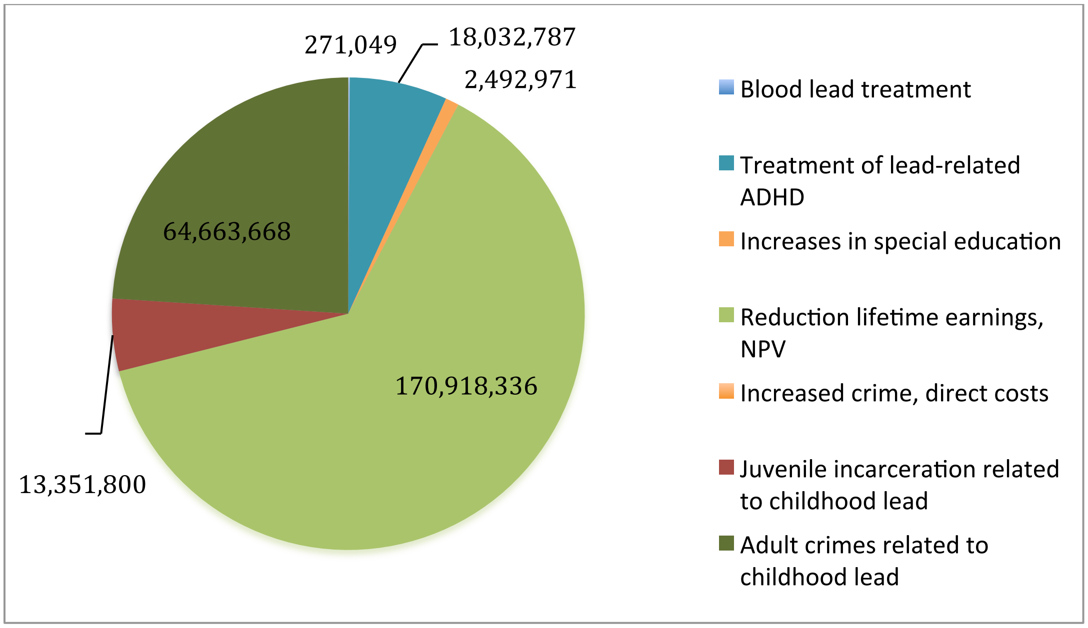
Special Education

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 https://www.dropbox.com/s/o677wcxajz42h96/Dotted-Red-Ball-000020041107_Large.jpg?dl=0an estimated $2.5 million net present value (NPV), lifetime cost for the cohort of 2-year-olds in 2014. 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 $171 million for the 2014 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.

Summary of Costs Associated with Lead Exposure, 2014



Together, the costs of lead exposure totaled nearly $270 million annually, including $112.5 million born by taxpayers.

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 $190 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 $270 million and $112.5 million, respectively. In a lead paint abatement scenario, an investment of $600 million accrues benefits of $190 million annually, paying for itself after just over three years and then accruing cost savings for years to come. The returns per dollar invested from a taxpayer perspective accrue more slowly but are also significant – the $600 million spent on abatement returns $112.5 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.

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 wherever possible 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. For example, we assumed that a child's tested blood lead level in 2014 was that child's 'peak' level (it is this 'peak' level from which the other impacts are measured), when really the peak is at least this high - he or she could well have higher lead levels at other times. We also assumed that among non-Medicaid children, there were no additional elevated BLLs other than those that were tested. This is a hugely conservative assumption, but because 78% of 1 and 2-year olds not receiving Medicaid were not tested, it was difficult to make assumptions about this largely untested group. 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 the 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 further lead abatement is could well be a sound economic, as well as a public health, investment.

Costs of Lead Exposure
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Full Report

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. In 2014, *Economic Impacts of Lead Exposure and Remediation in Michigan* (UMRSC and MNCEH 2014), was published to provide a more thorough assessment of the impacts of lead exposure and costs of potentially reducing these exposures. This report provides an updated version of those calculations, using updated data and the same methodology.

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.

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).

The problem of lead in drinking water has received national attention as a result of the Flint water contamination catastrophe. The costs of that contamination and potential remediation are beyond the scope of this report.

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 effects in 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 Korfmacher (2003). Our approach is to bring together established standards and apply them in a Michigan-specific assessment, producing a one-year (2014) 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. Conservative assumptions at each phase of the assessment are explained in more detail in the "Discussion" section of the paper.

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 Health and Human Services (DHHS) collects data on BLL testing among children in Michigan annually. Through correspondence with DHHS, we obtained results of 2014 testing. In our previous report, we built the method around Michigan's Statewide Testing Plan, which defined "children who should be tested," and we identified the proportion of targeted children who actually were tested and noted the difference in results between targeted children and those that were not part of this targeted group in 2012. "Children who should be tested" was defined as 1 and 2-year-olds who were insured by Medicaid or lived in any of 14 "Target Communities" in Michigan. These 14 Target Communities were urban areas, and about 50% of Michigan's 234,000 1 and 2-year-olds qualified as "children who should be tested." Just under 88,000 1 and 2-year-olds were tested in 2012. Just under 150,000 of Michigan's 700,000 children under 6 were tested.

For this updated 2014 snapshot, the "children who should be tested" designation no longer exists. However, data is available for children insured by Medicaid, and we found that this group makes up most of the "children who should be tested." For example, in the 2012 data, there were 120,000 1 and 2-year-olds "who should be tested" and in 2014 there were 121,000 children on Medicaid. This suggests that the "children who should be tested," who were Medicaid recipients plus targeted communities, were mostly Medicaid recipients. In this assessment, we divide the observations by children receiving Medicaid and those not receiving Medicaid. Although not the same as 2012's "children who should be tested" we believe this is a similar and helpful categorization.

In this study, we chose to focus largely 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 2014, 38% are included in the testing sample, compared to 20% of children under 6 in the testing sample (DHHS 2016).

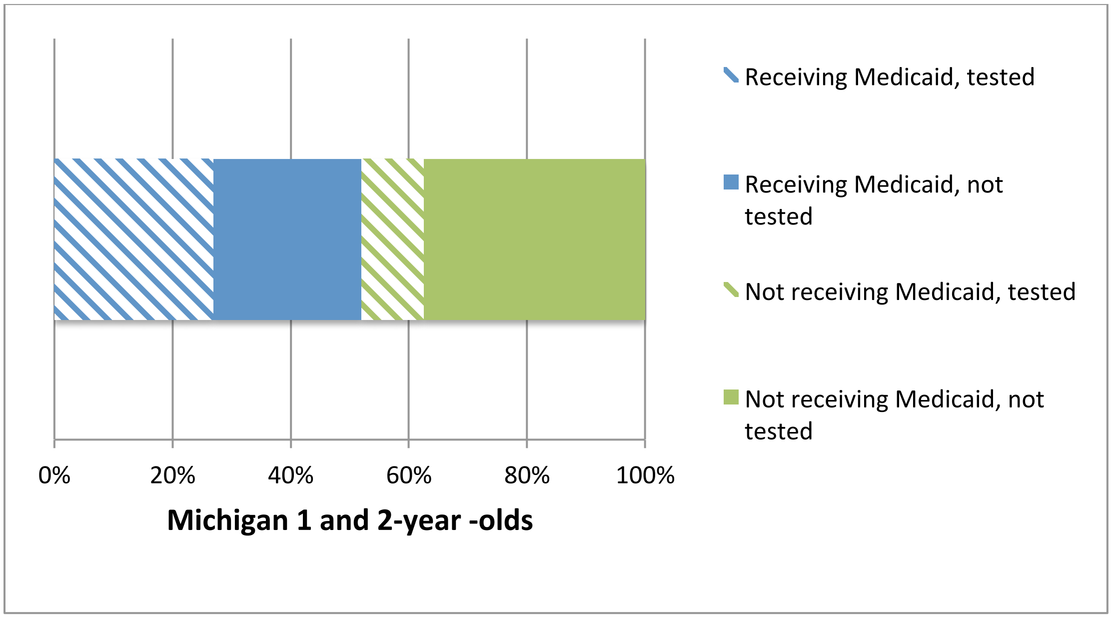
Test results for 1 and 2-year olds, separated by Medicaid status are provided in Table 1. While there is no "safe" amount of blood lead, 5 µg/dL is the CDC "action level" for lead exposure in children (EPA 2013). Figure 1 illustrates the breakdown of all Michigan 1 and 2-year olds by testing and Medicaid status in 2014.

Table 1: Michigan Blood Lead Level Testing for 1 and 2-year-olds, 2014[1]

	Population	Number of children tested	% tested	Children with BLL 5-9 µg/dL	% of those tested	Children with venous BLL >= 10 µg/dL	% of those tested
1 and 2 -yr olds receiving Medicaid	121,568	63,127	51.9%	2170	3.4%	497	0.79%
1 and 2-yr olds not receiving Medicaid	112,535	24,790	22.0%	421	1.7%	53	0.21%
All 1 and 2 yr-olds	234,103	87,917	37.6%	2591	2.9%	550	0.63%

[1] Data from correspondence with DHHS (2016)

Figure 1: 2014 Michigan 1 and 2-year-olds by BLL testing and Medicaid Status



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 Medicaid recipients, and these children are disproportionately in the test sample. Medicaid recipients 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).
- Despite the fact that BLL testing prioritized children receiving Medicaid, only 52% of these children were tested. There may be reason to believe that the 48% of 1 and 2-year-olds receiving Medicaid and not tested might not be receiving recommended health care and therefore may be more generally in a high risk situation, and possibly more at risk to be exposed to lead in the home (therefore, the sample may contain *lower* BLLs than is representative).
- There is a significant difference in test results by Medicaid status (see Table 1). For example, nearly 3.4% of children receiving Medicaid have elevated BLLs of 5-9 µg/dL, while only 1.7% of children not receiving Medicaid test at this elevated level. The difference is even greater at BLLs >10 µg/dL, with rates of 0.79% and 0.21%, respectively. This suggests that Medicaid status may be a helpful prioritization. However, we have a fairly small sample of non-Medicaid 1 and 2-year-olds, so it is difficult to know if these 22% are representative of the non-Medicaid 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 DHHS 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 impacts 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 in 2014, making several conservative assumptions.

Among 1 and 2-year-olds, 52% of children receiving Medicaid were tested, and we assume that the remaining 48% of targeted children would have a similar distribution of test results. Given that so few of the non-Medicaid 1 and 2-year-olds were tested (22%) it is very difficult to extrapolate potential BLLs, so we assume quite conservatively that only those sampled had elevated BLLs and none of the remaining 78% of non-Medicaid 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. We estimate that the tested elevated BLLs represent about 55% of the total population of elevated BLLs.

Table 2: Michigan 1 and 2-year-old BLL Test Results and Projections for Those Untested (Projections in Blue)

Results: Tested Children	Population	Number of Children with BLL 5-9 ug/dL	Rate	Number of Children with Venous BLL >= 10ug/dL	Rate
Children receiving Medicaid	63,127	2,170	3.4%	497	0.8%
Non-Medicaid children	24,790	421	1.7%	53	0.2%
Untested children projected results					
Children receiving Medicaid	58,441	2,009	3.4%	460	0.8%
Non-Medicaid children	87,745	0	0	0	0
TOTAL estimates for all Michigan 1 and 2-year olds	**234,103**	**4,600**	**2.0%**	**1,010**	**0.4%**
Tested children as proportion of total estimate		0.56		0.54	

Table 3: Estimated elevated BLLs for Michigan 1 and 2-year-olds, 2014

	Population	5-9 ug/dL	10-14 ug/dL	15-19 ug/dL	20-44 ug/dL	>=45 ug/dL
Projected results - all Michigan 1 and 2-yr olds	234,103	4,600	618	209	173	10
Assumed distribution of results in the 10+ BLL category[2]	1,010		61%	21%	17%	1%

[2] Derived from the distribution of 10+ BLL results from 2012, data sourced from MDCH (2013), calculated in UMRSC and MNCEH 2014.

For calculations in this assessment 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 associated with elevated BLLs as a child: 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 2014 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. In effect, we are estimating the actual cost of immediate treatment for elevated BLLs in 2014, and we expect similar costs will occur in the following year for those with elevated BLLs in that year – we expect this is a re-occurring cost. 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 2014. 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

Blood Lead Level in µg/dL	# of Children in Michigan Under the Age of 6[3]	Recommended Treatment[4]	Cost of Recommended Treatment (in 2014 USD)[5]	Total Cost
10-20	715	Diagnostic testing, venipuncture, lead assay, nurse-only visit	$87	$61,926
20-45	155	Above treatments, plus eight visits for diagnostic testing, nurse follow-up, environmental investigation of the home	$1,207	$187,152
45-70	14	Above treatments, plus oral chelation	$1,569	$21,971
70+[6]	0	Above treatments, except oral chelation is replaced with intravenous chelation	$4,048.13	0
				$271,049

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.

[3] Data from MDCH (2013)
[4] Source: Gould (2009), derived from CDC recommendations and Kemper *et al* (1998)
[5] Source: Gould (2009), inflated here to 2014 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.

Table 5: Healthcare Costs of Lead-Associated ADHD, 2014

Michigan Children Age 4-15[7]	Estimated 8.4% Diagnosed with ADHD[8]	21.1 % of Cases Associated with Elevated Blood Lead Levels[9]	Healthcare Costs - Medication and Counseling per Child for One Year[10]	Total costs
1,533,486	128,813	27,180	$663.47	$18,032,787

[7] data from CGI Census, estimate for 2012, we assume the same population in 2014
[8] calculations based on data in Bloom *et al* (2010)
[9] Gould (2009), from Braun *et al* (2006)
[10] Inflated from 2006 USD figures in Gould 2009

In sum, we estimate the healthcare costs for immediately treating those under 6 for lead exposure, and for treating lead-associated ADHD among adolescents, to be $18.3 million in 2014.

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 2007, 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. We note that in this study, compared to the 2012 report, a Michigan-specific metric was identified (Weemhof & Staley 2014), and this lowered the estimated cost per year of care to $34,000.

Table 6: Cost of Lead-Associated Juvenile Crime (Incarceration), 2014

Number of Michigan youth in prison [11]	Cost per year of care[11]	Total cost per year	10% attributable to lead[12]
3927	34,000	$133,518,000	$13,351,800

[11] Weemhof and Staley (2014) - figures are for 2013, assumed to be the same in 2014
[12] Standard from Korfmacher (2003)

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.

Table 7: Cost of Adult Crime Linked to Childhood Lead Exposure

	Offenses reported 2014[13]	Proportion of crimes linked to childhood lead[14]	Number of crimes linked to childhood lead	Direct costs per crime[15]	Direct costs of lead linked crimes
Burglaries[16]	173,202	2.9%	5,018	4,709	23,631,033
Robberies	8,206	0.4%	32	26,857	855,981
Aggravated Assaults	23,109	5.1%	1,172	23,912	28,028,384
Rape	9,417	3.7%	348	33,367	11,616,117
Murder	508	2.9%	15	36,532	532,153
TOTAL	214,442				**$64,663,668**

[13] Data from Michigan State Police, Michigan Incident Crime Reporting (2014) http://www.micrstats.state.mi.us/MICR/Reports/Query.aspx
[14] Proportions were calculated based on figures from Gould (2009) derived from Nevin (2000)
[15] From Gould (2009), figures inflated to 2014 values
[16] "Burglaries" includes larceny and motor vehicle theft

The direct costs of crime estimated here total nearly $65 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 healthcare costs to address physical and mental impacts of crime, 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 estimate or include these more indirect 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 reduced 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 nearly $2.5 million in special education costs. These are the lifetime special education costs incurred by the 2014 cohort of 2-year olds, so it is an annual figure we expect to accrue in following years.

Table 8: Costs of special education related to lead exposure – incured by 2-year-old cohort in 2014

2-year-olds with BLL 25+ µg/dL[17]	Cost per year of special education[18]	Total cost for 9 years of special education for 20% of children with blood lead level 25+ µg/dL
74	18,786	$2,492,971

[17] 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.
[18] From Korfmacher (2003), inflated to 2014 values

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 2c yearc olds in 2014. The approach here divides children with elevated BLLs into four categories and then applies the associated loss of IQ points for each BLL category.[19]

[19] 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.

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 2014 figures, assuming each IQ point lost equates to a loss of $21,077 in net present value (NPV) of lifetime earnings

In total, we estimate that more than $170 million in NPV lifetime earnings are lost among Michigan 2c yearc olds with elevated BLLs in 2014. 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.

Table 9: Reduction in lifetime earnings

Maximal blood lead level	Estimated number of 2-year-olds[20]	Associated loss in IQ points for each child[21]	Lifetime earnings loss per child, NPV[22]	Total lifetime lost earnings, NPV
5-10	2300	2.565	54,062	$124,342,600
10-20	414	3.9	82,200	$34,030,800
20-30	36	5.8	122,246	$4,400,856
30 or greater	56	6.9	145,430	$8,144,080
				$170,918,336

[20] See footnote 8 above

[21] 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.

[22] Lifetime earnings loss per child is calculated as the estimated decline in IQ points times the assumed loss in lifetime earnings per IQ point loss in net present value (NPV), derived from Gould (2009).

Summary

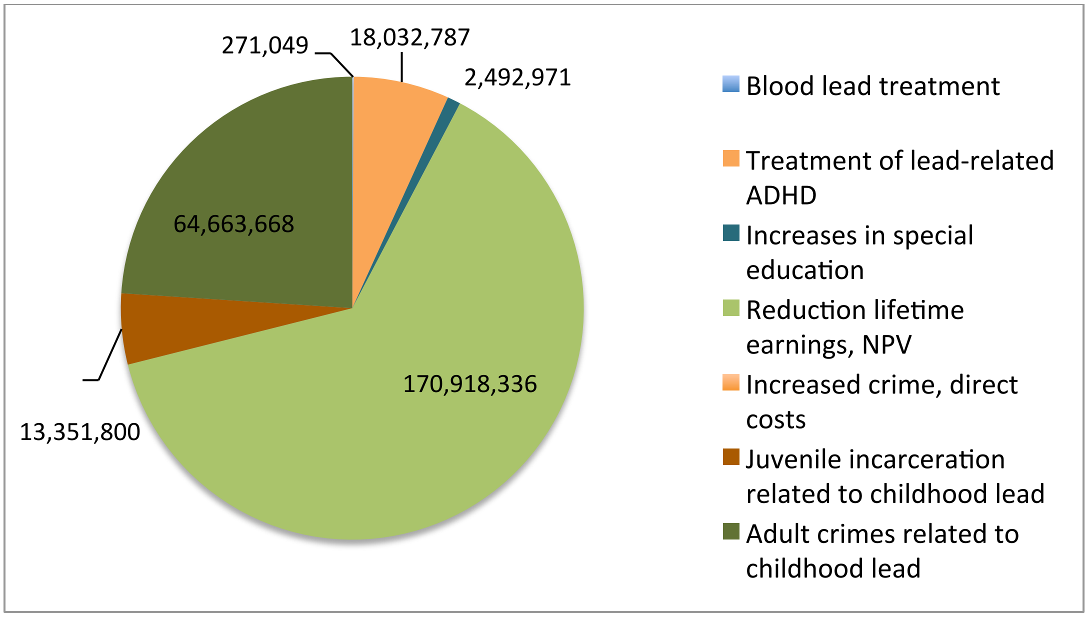
Table 10 summarizes the annual costs of lead exposure described above.

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 10: Summary of Costs Associated with Lead Exposure, 2014

Category	Amount	Costs to Taxpayer	Description of Assumed Taxpayer Costs
Increased in health care			
Blood lead treatment	271,049	243,944	Estimated 90% of children with elevated BLL are on Michigan Medicaid programs
Treatment of lead-related ADHD	18,032,787	16,229,508	Estimated 90% of children with elevated BLL are on Michigan Medicaid programs
Increases in special education	2,492,971	2,492,971	Estimated 100% of costs through public education
Reduction lifetime earnings, NPV	170,918,336	13,673,467	Estimated 8% state and local effective tax rate
		34,183,667	Estimated 20% effective federal tax rate
Increased crime			
Juvenile incarceration related to childhood lead	13,351,800	13,351,800	100% taxpayer cost
Adult crimes related to childhood lead	64,663,668	32,331,834	50% taxpayer cost
TOTAL costs of lead exposure in year (2014)	**269,730,611**	**112,507,191**	

Figure 2: Summary of Costs Associated with Lead Exposure, 2014 Snapshot Estimate



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 from paint. 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,[23] 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 2016). 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 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. The assumed 100,000 high lead risk homes in Michigan is a similar in 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 the poverty line, 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.[24] 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 5,600 1 and 2-year-olds with elevated BLLs (Table 3).

[23] 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.

[24] Author's calculations from data in the President's Task Force (2000)

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. considerably less than $10,000 per unit, as it's no longer the most needy modest interim controls, as described by Gould.

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 Michigan Department of Health and Human Services abated 122 homes, using state general funds, in fiscal year 2014 at an average cost of $6,900 per unit, and in 2015 abated 116 homes at an average cost of $9,950 per unit. U.S. Housing and Urban Development funds abated 326 homes in Michigan in 2014 and 192 homes in 2015, at an average cost of $10,000- $11,000 per unit.[25] We expect the homes abated through these programs would be among those needing the most help – among the most expensive of homes needing remediation. We compare that to a much wider group of 100,000 homes, and we would expect the average cost of remediation to be considerably less than $10,000 per unit, as it's no longer the most needy homes, and some will only need modest interim controls, as described by Gould.

In the illustrative scenario, the lead abatement of 100,000 homes reduces lead exposure by 70%, reducing the annual costs of lead exposure from nearly $270 million to $81 million (a cost savings of nearly $190 million annually). The $600 million in lead abatement would pay for itself after just over 3 years, and then accrue benefit on the order of $190 million annually for many years to come.

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, about $112 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 $78 million annually. After 7-8 years, $600 million in abatement costs would pay for themselves, and

[25] Figures obtained from correspondence with HUD and DHHS

taxpayer savings would then accrue on the order of $78 million annually.

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 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 based much of the estimate on data of BLLs at 2 years of age, assuming that these levels would be the maximal level for each child, although many children may have higher BLLs at other times in their childhood. For many of the impacts measured here we considered impacts starting at BLL 5 or 10 µg/dL, and for special education we considered impacts starting at 25 µg/dL. Though there are not well established metrics for these impacts, there may well be considerable impacts at BLLs lower than our measures (for example, special education or lifetime earnings), and this would increase the costs

considerably. 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: nearly $270 million and $112 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 $190 million annually. From a strictly taxpayer perspective, a $600 million investment in abatement would pay for itself in 7-8 years and then accrue taxpayer savings of $78 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, conceptually, starting with the most needy homes would likely yield disproportionately positive benefits. 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 DHHS) would yield benefits even greater than the average in this scenario.

Recent lead exposures through water in Flint have brought national attention to the impacts of lead exposure. This exposure is tragic, and the response to assist those impacted and to prevent further exposures is critical and has been warranted. A discussion of lead in water contamination is beyond the scope of this report. Still there are also thousands of other Michigan children each year who experience lead poisoning, mostly through lead based paint and dust exposures. The renewed attention on lead contamination should remind us that these exposures are equally worthy of consideration for assistance and prevention. Preventing lead paint exposures could also provide sound economic returns by preventing future costs associated with lead exposures.

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. Furthermore, much of the impacts of lead are disproportionately in urban communities facing other social, educational, and public health challenges, so the impacts of lead on social and cognitive abilities compounds those challenges. Even without this benefit, on an economic basis alone, this assessment suggests that lead abatement is a sound investment.

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