The Price of Pollution:
Cost Estimates of Environment-Related Childhood Disease in Michigan

A conservative estimate of annual costs for lead poisoning, asthma, cancer and selected neurodevelopmental disabilities

A report prepared by

Michigan Network for CHILDREN'S Environmental HEALTH

June 2010

Acknowledgments

The Price of Pollution: Cost Estimates of Environment-Related Childhood Disease in Michigan was prepared by the Michigan Network for Children's Environmental Health and the Ecology Center. Special thanks to the Studies and Surveys Workgroup of the Michigan Network for Children's Environmental Health for their continued support of this effort.

Our sincere thanks to the following contributors:
Primary author: Aviva Glaser, MS, MPH
Contributors: Tracey Easthope, MPH; Leo Trasande, MD, MPP; Ted Schettler, MD, MPH; William Weil, MD; Genevieve Howe, MPH

The Ecology Center is a Michigan-based nonprofit environmental organization that works at the local, state, and national levels for clean production, healthy communities, environmental justice, and a sustainable future.

This report is based on methodology developed by the National Academy of Sciences, and by Philip Landrigan and colleagues, and published in *Environmental Health Perspectives* in 2002. We thank the authors of this paper for their seminal work:

Landrigan, P.J., C.B. Schechter, J.M. Lipton, et al. 2002. Environmental pollutants and disease in American children: Estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities. *Environmental Health Perspectives* 110(7): 721-728, http://www.ehp.niehs.nih.gov/docs/2002/110p721-728landrigan/abstract.html

This report is also informed by similar state reports including from Washington State, Maine, and Minnesota:

Davies, K. 2005. *Economic Costs of Diseases and Disabilities Attributable to Environmental Contaminants in Washington State*. Collaborative for Health and Environment – Washington Research and information Working Group.

Schuler, K., S. Nordbye, S. Yamin, et al. 2006. *The Price of Pollution: Cost Estimates of Environment-Related Childhood Disease in Minnesota*. Minnesota Center for Environmental Advocacy.

Davis, M.E. *An Economic Cost Assessment of Environmentally-Related Childhood Diseases in Maine*.

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.

Michigan Network for Children's Environmental Health
Ecology Center, 117 N. Division, Ann Arbor, MI 48104

Cover photo: Charles L. Barnes, iStockphoto.com
Layout: Harriet Eckstein Graphic Design

Table of Contents

Abstract

Diseases linked in part or whole to environmental exposures make an important and insufficiently recognized contribution to total pediatric health care, education, and other costs to Michigan. Using methodology previously published by Landrigan et al. (2002),[1] we estimated the costs of four categories of pediatric illness in Michigan that may be partially attributable to chemical pollutants in the environment by applying an environmentally attributable fraction (EAF) model. We found that the best conservative estimate of the annual environmentally attributable costs of lead poisoning, childhood asthma, pediatric cancer, and selected neurodevelopmental disorders in children in Michigan is $5.8 billion (range: $3.65 to $6.68 billion). These costs include both direct and indirect costs wherever possible. Direct costs include such things as prescriptions and hospitalization costs. Indirect costs can include loss of parental wages due to their children's missed schooldays and loss of lifetime earnings due to the premature death of the children. Annual cost estimates for the four specific diseases are estimated as follows:

- Lead Poisoning: $4.85 billion (range: $3.2 to $4.85 billion)
- Childhood Asthma: $88.4 million (range: $29.5 to $103.2 million)
- Pediatric Cancer: $17.3 million (range: $6.9 to $34.6 million)
- Neurodevelopmental Disorders: $845 million (range: $423 million to $1.69 billion)

These cost estimates are conservative, and rely on Michigan-specific data whenever possible.

To put these costs in context, these four environmentally attributable childhood diseases and disorders cost Michigan the equivalent about 1.5% of its Gross Domestic Product every year.[2] It is important to note that these economic costs represent childhood illnesses and loss of earning potential that could be avoided should the environmental exposures be eliminated. The findings of this study demonstrate that reducing environmental exposures to toxic chemicals in children is not only ethical, but also potentially economically advantageous.

Introduction

Every day, children in Michigan are exposed to a wide array of toxic chemicals. At the same time, the burden of childhood diseases is increasing, with rates of asthma, neurodevelopmental disorders, and some cancers on the rise. Researchers are just beginning to explore the extent to which environmental pollutants may be contributing to these changing patterns in pediatric illnesses. Given that environmental epidemiologists have much still to learn, determining the extent of environmentally-attributable costs associated with these diseases presents challenges. Several studies have calculated costs associated with lead poisoning, pediatric asthma, learning disabilities, and developmental disorders in the United States.[3,4,5,6,7,8,9,10,11] However, no known studies have attempted to estimate these costs for the State of Michigan. Estimating the economic costs of environmentally-related diseases in children is critical for directing resources toward appropriate prevention efforts. By preventing environmental exposure to toxicants, the disease burden in children will be reduced, and ultimately, millions of dollars in the state could be saved.

To investigate the environmentally-attributable costs of certain pediatric diseases in the state, we selected lead poisoning, pediatric asthma, select childhood cancers, and a subset of neurodevelopmental disorders (cognitive impairment,[a] autism, and cerebral palsy) because these conditions are serious, relatively common, and likely related at least in part to chemical pollutants in the environment. Outcomes linked strongly to personal or familial choice (*e.g.*, tobacco, alcohol, or drug use) were excluded from the analyses. Therefore, the selected diseases are at least partly preventable through public health efforts and exposure minimization strategies. This report explores the potential economic benefits for such prevention measures.

a. The term cognitive impairment includes what used to be called mental retardation. People who were previously considered to be mentally retarded are now considered severely cognitively impaired. Mental retardation was the terminology used in the Landrigan report.

Methodology

The methodology used throughout this report was developed at the Mt. Sinai School of Medicine and is based primarily on methodology published by Landrigan *et al.* (See appendix for summaries of the Landrigan methodology).[12] This methodology has been the basis of a number of similar state reports, including from Washington State,[13] Maine,[14] and Minnesota.[15] As with the Landrigan *et al.* manuscript, we used an environmentally attributable fraction (EAF) model to estimate the environmentally attributable cost of lead poisoning, asthma, cancers, and neurodevelopmental diseases in American children. This model has been used previously by the Institute of Medicine as well as by Landrigan and colleagues.[16] The EAF has been defined as "the percentage of a particular disease category that would be eliminated if environmental risk factors were reduced to their lowest feasible levels."[17] The general model used by Landrigan and colleagues is the following:

Costs = Disease rate x EAF x Population size x Cost per case

In this equation, EAF represents the environmentally attributable fraction. Expert review panels of prominent scientists and physicians were selected and assembled by Landrigan and colleagues. These panels determined EAFs to be 100% for lead poisoning, 30% for asthma (range 10-35%), 5% for cancer (range 2-10%), and 10% for neurodevelopmental diseases (range 5-20%). The terms "disease rate" and "population size" refer, respectively, to either the incidence or prevalence of a disease and the size of the population at risk. For prevalence and incidence data, we used Michigan data when available. Much of this data comes from the Michigan Department of Community Health. When not available, we applied national data from the U.S. Environmental Protection Agency, Centers for Disease Control and Prevention, as well as from the peer-reviewed literature. Population sizes were determined from the U.S. Census. We used 2009 as the baseline year for the study.

Limitations: To the extent possible, direct and indirect costs were considered in

Photo by Lisa Eastman, iStockphoto.com

this analysis. There are many limitations associated with estimating direct costs, including significant data gaps. Calculating indirect costs increases those limitations and adds the additional difficulty of calculating things that may not be easily quantifiable, such as loss of life and emotional burdens. Therefore, we considered only a small subset set of indirect costs, including loss of earnings potential over a lifetime as a result of premature death, or lost workdays for parents with sick children.

In addition to the limitations above, cost estimates inevitably require a number of assumptions. For instance, loss of lifetime earnings assumes that had a child not died prematurely, that child would live in Michigan through his or her life span. In fact, we know that many young adults move out of the state. Additionally, although national data is used where state-specific data was not available, we know that Michigan is not identical to country-wide averages in some respects, so this can introduce inaccuracies into the estimates. These are examples of some of the assumptions and simplifications required to do this sort of analysis.

It is important to note that these childhood illnesses have more than just economic consequences. Lead poisoning, asthma, cancer, and neurodevelopmental disorders carry with them social and emotional burdens on children and their families that cannot be calculated. This analysis does not attempt to calculate those considerable burdens.

Costs of Childhood Lead Exposure

Lead is one of the most commonly studied neurotoxicants in the world. Childhood lead exposure has long been linked to developmental and neurological consequences. Exposure to lead in young children has been associated with a decrease in IQ and behavioral problems, but lead exposure can also affect nearly every system in the body. To determine the environmentally attributable costs associated with the lead burden in Michigan, we undertook the following analysis.

Calculating the Costs of Childhood Lead Exposure: Michigan Estimate

Environmentally Attributable Fraction EAF: In their 2002 paper, Landrigan and colleagues deemed all cases of lead poisoning to be of environmental origin, primarily from leaded house paint and residual lead from gasoline in soil, making the environmentally attributable fraction (EAF) 100%.

Size of Population: For the purposes of the study, the population at risk is assumed to be a single cohort of five year-old children. This age group was chosen as the population at risk because this is the age when children typically enter school, and the age at which the neurological damage caused by lead often first is noticed. Additionally, abatement or medical treatment beyond that age will not reverse brain damage or restore lost intelligence. Therefore, a child may have lifelong decrease in function as a result of the exposure. According to the 2000 U.S. Census, there were 73,193 5 year-old boys in Michigan and 69,307 5 year-old girls. While this does not necessarily reflect the 2009 population, the Census Bureau estimates only a 0.3% cumulative population increase for the state between 2000 and 2009, making the actual number of 5 year-olds in 2009 not likely to be significantly different from the number in 2000. So, we used the 2000 Census number as our estimate of the current cohort of 5 year-old boys and girls in Michigan.[18]

Photo by Caracterdesign, iStockphoto.com

Disease Rate: We received Michigan-specific data on blood lead levels of 5 year-old children in the state from the Michigan Department of Community Health.[19] The mean blood lead level for children 5 years of age (at time of testing) in 2009 was 2.29 µg/dL (micrograms per deciliter of blood). The number of 5 year-old children tested was 9,140. In comparison, the most recent national data available is from the 2007-2008 NHANES survey, which found the mean blood lead level of 5 year-old children to be 1.5 µg/dL.[20] This difference between Michigan and the rest of the country is not surprising. As of 2006, Michigan was ranked 7th in the nation for number and percentage of children confirmed to have lead poisoning.[21] In 2007, Michigan was ranked 6th worst in the nation.[22] In certain areas in Michigan, such as Detroit, children are consistently at higher risk for elevated blood lead levels than the rest of the state.[23] However, because Michigan targets at-risk children for testing (which may overestimate mean blood lead levels), we use both the Michigan and the national NHANES blood levels for our calculations.[b]

Cost per Case: In their 2002 study, Landrigan and colleagues assumed that an increase of 1.0 µg/dL blood lead was associated with a mean loss of .25 IQ points, based on the work by Schwartz et al. Since Landrigan's study was published, Canfield et al. (2003) found a loss of 0.46 IQ points per 1.0 µg/dL.[24] More recent studies

b. The true average lead levels in 5 year-old children in Michigan may be slightly higher or lower than the estimate provided by MDCH, due to MDCH's method of database storage, in which: Any reported value that is less than zero is stored in the database as a 1. Additionally, some labs have a detection limit, usually around 2, 3 or 4 µg/dL. Results below the detection limit are generally reported as "<2", "<3" or "<4". Those are stored as 1, 2 or 3 respectively. Additionally, because Michigan targets at-risk children for testing, this sample may not be representative of the state. Despite these uncertainties, we believe that using Michigan-specific data is important given Michigan's higher than average lead levels in children. We also include estimates using national data as a comparison.

suggest there may be even greater losses associated with lead exposure.[25] For this study, we use Canfield's estimate of loss of IQ points, and Salkever's estimate of loss of lifetime earnings (1 IQ point drop = 2.39% decrease in lifetime earnings). To estimate the expected lifetime earnings of a 5 year-old, Landrigan used 1997 data from the Bureau of Labor Statistics. We referred to a 2004 study by Max et al. which calculated the present value of lifetime earnings in 2000 of men and women in different age brackets.[26] Through communications with the authors, we were able to get (updated) 2005 present values of lifetime earnings for 5 year-olds (boys: $1,352,986; girls: $1,063,916).[27] We used the Bureau of Labor Statistics' Index of Hourly Compensation to update these estimates to 2009 dollars using a factor of 1.12[c] (boys: $1,515,344; girls: $1,191,586).[28]

Table 1. Estimated annual loss of future lifetime earnings due to pediatric lead poisoning in Michigan, for 2009 cohort.

Environmentally attributable fraction (EAF)		
Calculation of Economic Losses		
For boys:		
For girls:		
Present value of loss of future lifetime earnings due to pediatric lead poisoning in Michigan =	**$4.85 billion**	**$3.19 billion**

c. 1.12 was calculated using the BLS Index of Hourly Compensation. (2005 annual : 163.824; 2009 2nd Quarter: 183.059 (most recent available)); thus we inflated the 2005 numbers by a factor of 183.059/163.824 = 1.12.

Results and Discussion

Results: The present value of Michigan's economic losses attributable to lead exposure in the 2009 cohort of 5 year-olds ranges from $3.19 (using U.S. blood lead levels) to $4.85 billion (using Michigan blood lead levels) per year in loss of future lifetime earnings (See Table 1 for calculations).

Discussion: It is important to note that the estimate of economic losses in Michigan that are attributable to childhood lead exposure quantify only part of the true societal costs due to lead poisoning in children. Our analysis assumes that the only cost associated with reduced IQ is loss in lifetime earnings. Two things are important to note in this regard. First, this calculation assumes that those children affected by childhood lead poisoning will stay in the state of Michigan and continue working. Obviously, this is not the case for all children. Secondly, the economic burdens of reduced IQ go far beyond the loss of future earnings. An average loss of 1.05 IQ points in Michigan children means that some of the most highly exposed children will have much more dramatic drops in IQ. These children will need special education and increased care from parents, resulting in additional economic costs to the state.

Moreover, recent research has revealed that elevated lead levels in children are associated with behavioral problems,[29] including an elevated risk for delinquent behavior and arrests.[30] In fact, a 2008 prospective study found that childhood lead concentrations are associated with increased rates of total arrests as well as increased rates of arrests involving violent offenses.[31] These indirect yet very significant consequences were not taken into account in our study. Lead is also associated with other functional losses that could be economically significant. Thus, actual societal costs to the state from lead poisoning in children are likely to be much greater than estimated here.

Costs of Childhood Asthma

Asthma is a chronic disease that causes the airways to become sore and swollen. Children have smaller airways than adults, which makes asthma especially serious for them. Nationwide, 9 million children suffer from asthma. The prevalence and burden of asthma continues to increase in the US, and in Michigan. To determine the environmentally attributable costs associated with the pediatric asthma burden in Michigan, we undertook the following analysis.

Calculating the Costs of Childhood Asthma: Michigan Estimate

Population at risk: For calculations of direct medical costs of asthma, we used the population of children under age 18 in Michigan as our population at risk.

Disease Rate: Data for pediatric asthma hospitalizations and mortality in Michigan was provided by the Michigan Department of Community Health. We used data for the number of children hospitalized due to asthma in Michigan from 2008; in that year, there were 4,325 hopitalizations of children (age 0-17) due to asthma.[32] Data on asthma mortality was also provided by the Michigan Department of Community Health. For the years 2003-2007, the average number of pediatric deaths per year due to asthma was 12 per year. The average number of male pediatric asthma deaths during this time period was 7 per year, and for females it was 5 per year.[33] We assume the same disease rates for 2009.

Cost per Case and Cost Calculations: When possible, we calculated costs of pediatric asthma in the state using current, Michigan-specific data. However, much of the data was not available. When it was not possible to get current, Michigan-specific data, we instead relied on cost calculations done by Landrigan and colleagues. We updated them to be as current and applicable to the state as possible.

- To calculate direct medical costs due to hospitalizations, we used data for inpatient stays from the Michigan Department of Community Health. The average cost of an asthma hospitalization in Michigan in 2008 for children (1-17 years) was $7,358.[34] Using the Bureau of Labor Statistics Inflation Calculator, we calculated this to be $7,332 in 2009 dollars. We multiplied this by the number of asthma hospitalizations in 2008 (4325) to determine that the direct annual costs of hospitalizations due to asthma in Michigan are $31.71 million. We assumed that the number of hospitalizations has not changed since then.

- To calculate the indirect costs of asthma in Michigan due to premature deaths, we used MDCH's data on asthma mortality in boys and girls. We then took 2005 average lifetime earnings for boys and girls, using national lifetime earnings for 10-14 year-olds as an estimate (boys: $1,493,428 and girls: 1,174,235)[35] and updated to 2009 dollars using an inflation factor of 1.12[d] (boys: $1,672,639 and girls: $1,315,143). We then multiplied these numbers by the number of premature deaths due to asthma in the state every year:

  o Boys: 7 premature deaths/year x $1,672,639 = $11,708,473

  o Girls: 5 premature deaths/year x $1,315,143 = $6,575,715

  o Total: $18,284,188.

- To calculate medical costs due to physicians' services and medications, and

Photo by Damir Cudic, iStockphoto.com

d. 1.12 was calculated using the BLS Index of Hourly Compensation. (2005 annual : 163.824; 2009 2nd Quarter: 183.059 (most recent available); thus we inflated the 2005 numbers by a factor of 183.059/163.824 = 1.12.)

Table 2: Estimated annual costs of pediatric asthma of environmental origin in Michigan, year 2009.

Medical and indirect costs	U.S. dollars
Medical costs	
Hospitalizations	
Inpatient stays	31.71 million
Outpatient visits	6.78 million
Emergency room visits	14.21 million
Physicians' services	
Inpatient	2.3 million
Outpatient	20.5 million
Medications	123 million
Subtotal: medical costs	**$198.5 million**
Indirect costs	
School days lost (lost workdays for parents)	78 million
Premature deaths (lost lifetime earnings)	18.3 million
Subtotal: indirect costs	**$96.3 million**
Total costs of pediatric asthma (medical costs + indirect costs)	**$295 million**
EAF	30%
Environmentally attributable costs of pediatric asthma (EAF x total costs)	$88.4 million
EAF percentage range	10-35%
EAC estimated range	$29.5-103.2 million

outpatient and emergency room hospitalizations, as well as indirect costs due to the number of school days lost, we used a methodology similar to Davies' 2005 report of economic costs of environmentally attributable diseases in Washington State.[36] In that study, costs of pediatric asthma in Washington are calculated by updating the cost estimates derived by Landrigan and colleagues to 2004 dollars and multiplying by the percentage that the state comprises of the U.S. population.[e] According to the U.S. Census, Michigan comprises 3.29% of the U.S. population.[37] Landrigan's cost estimates are (as reported, and updated to 2009 dollars):

e. It is important to note that this type of calculation assumes that there is no difference in age distribution between Michigan and the rest of the country, and that costs of healthcare in Michigan are comparable to that of the rest of the country. In 2004, Michigan healthcare spending per capita was slightly lower than the national average (Source: www.statehealthfacts.org)

- Physician inpatient services: $54 million in 1997, $72 million in 2009
  - Multiplied by 3.29% = $2.3 million

- Physician outpatient services: $625 million in 1997, $835 million in 2009
  - Multiplied by 3.29% = $20.5 million

- Medications: $2.81 billion in 1997, $3.76 billion in 2009
  - Multiplied by 3.29% = $123 million

- Outpatient hospitalizations: $154 million in 1997, $206 million in 2009
  - Multiplied by 3.29% = $6.78 million

- Emergency room visits: $323 million in 1997, $432 million in 2009
  - Multiplied by 3.29% = $14.21 million

- Indirect Costs due to number of school days lost: $1.78 billion in 1997, $2.38 billion in 2009
  - Multiplied by 3.29% = $78 million

Results

Using the above methodology, the estimate of the annual costs to Michigan of childhood asthma attributable to environmental contaminants is $88.4 million in 2009 dollars, with a range of $29.5 to $103.2 million (see Table 2).

Photo by Gloria-Leigh Logan

Costs of Childhood Cancer

Cancer is the leading cause of death by disease among U.S. children 1 to 14 years of age. Leukemias and cancers of the brain and central nervous system account for more than half of the new cases of pediatric cancer. Over the past 20 years, there has been an increase in the incidence of children diagnosed with all forms of invasive cancer. To determine the environmentally attributable costs associated with the pediatric cancer burden in Michigan, we undertook the following analysis.

Calculating the Costs of Childhood Cancer: Michigan Estimate

Population at risk: We considered all children under the age of 18 in Michigan as our population at risk.[f]

Disease Rate: We used the most up-to-date and Michigan-specific data available to estimate disease rates in the state. The most recent data available on incidence of childhood cancer in Michigan was from the Michigan Department of Community Health's website. In 2004, 323 Michigan children were diagnosed with cancer. Fifty-two children in Michigan died of cancer in 2005.[38] As these were the most recent data available, these are the statistics we used for our 2009 cost calculations.

Cost per Case and Cost Calculations:

- Because there have not been any studies calculating costs of childhood cancer cases in Michigan, we had to rely on Landrigan's calculations. Landrigan calculated a national cost per case of childhood cancer as $623,000 in 1997. In 2009, this would be a cost per case of $833,000 due to inflation.[39]

- To calculate the costs of pediatric cancer cases in Michigan, we multiplied

f. Note: Landrigan and colleagues used only children under age 15 as the population at risk.

the cost per case by the number of children diagnosed per year: **$833,000 x 323 = $269 million**

- Landrigan estimated the cost of premature deaths due to childhood cancer to be $1.8 billion for the U.S. population. We know that 52 Michigan children died in 2005 of cancer; we assume this to be our annual mortality rate due to pediatric cancer. To calculate the indirect costs of these premature deaths due to lost lifetime earnings, we estimated an equal number of death for boys and girls.[g] We then took 2005 average lifetime earnings for boys and girls, using the Bureau of Labor Statistics' lifetime earnings for 10-14 year-olds as an estimate (boys: $1,493,428 and girls: 1,174,235)[40] and updated to 2009 dollars using an inflation factor of 1.12[h] (boys: $1,672,639 and girls: $1,315,143). We then multiplied the number of premature deaths due to pediatric cancer for boys and girls in the state by average lifetime earnings. It is important to note that these calculations estimate unrealized lifetime earnings of children, not costs to families. Premature deaths of children impose enormous social, emotional, and economic burdens on families.

    - o Boys: 26 premature deaths x $1,672,639 = $43,488,614
    - o Girls: 26 premature deaths/year x $1,315,143 = $34,193,718
    - o Total: $77.7 million

- Thus, the annual costs of pediatric cancer in Michigan, including cost of premature death due to childhood cancer can be roughly approximated as

Table 3: Estimated costs for pediatric cancer of environmental origin in Michigan; annual cost using 2009 cohort.

Cost per case of pediatric cancer	$833,000
Number of cases diagnosed each year	323
Total treatment costs of pediatric cancer (cases x cost per case)	$269 million
Lost wages due to premature death due to cancer	$77.7 million
Total costs of pediatric cancer in Michigan (treatment costs + lost wages)	**$346.7 million**
EAF	5%
Environmentally attributable costs of pediatric cancer	
(EAF x total costs)	**$17.3 million**
EAF percentage range	2-10%
EAC estimated range	$6.9-34.6 million

g. According to July 2008 U.S. census estimates, there were 1,223,358 boys in the state and 1,166,840 girls, which is a ratio of 1.05 to 1, which is practically a 1:1 ratio.
h. 1.12 was calculated using the BLS Index of Hourly Compensation. (2005 annual: 163.824; 2009 2nd Quarter: 183.059 (most recent available); Thus we inflated the 2005 numbers by a factor of 183.059/163.824 = 1.12.)

$269 million + $77.7 million = $346.7 million.

- Applying the environmentally attributable fractions (EAF) of 2, 5, and 10%, we calculated the environmentally attributable costs (EAC) as shown in Table 3.

Results

Using the above methodology, the estimate of the annual costs of childhood cancer attributable to environmental contaminants in Michigan can roughly be approximated as $17.3 million in 2009 dollars, with a range of $7 to 35 million.

Costs of Childhood Neurodevelopmental Disorders

Neurodevelopmental disorders are characterized by a variety of behavioral, communication, or cognitive problems. While a range of neurodevelopmental disorders affect children, we chose to focus on autism, cerebral palsy, and mental retardation (referred to here as cognitive impairment[i]) because these conditions have been linked in part to environmental exposures, and because they have been previously investigated by other researchers. To determine the environmentally attributable costs associated with the select childhood neurodevelopmental burden in Michigan, we undertook the following analysis.

Calculating the Costs of Select Childhood Neurodevelopmental Disorders: Michigan Estimate

Population at risk: The relevant population at risk is all children born each year in Michigan. The most recent data on number of births in Michigan comes from the Michigan Department of Community Health. In July of 2008, there were 127,680 children under 1 year of age in Michigan.[41] We assume that this number is not substantially different from annual births in 2009.

Disease Rate: Michigan-specific incidence data were not available for neurodevelopmental disorders. Consequently, national incidence rates for cognitive impairment, autism, and cerebral palsy were applied:

- **Cognitive impairment:** The incidence rate is 12 cases per 1,000 births, as found by Bhasin et al. in 2006.[42] Thus, of the 2009 Michigan birth

i. The term cognitive impairment includes what used to be called mental retardation. People who were previously considered to be mentally retarded are now considered severely cognitively impaired. Mental retardation was the terminology used in the Landrigan report.

j. As of December 1, 2009, 23,494 students age 0-26 were identified as having cognitive impairment. The total number of students in Michigan was 1,639,851; thus, the rate of cognitive impairment in Michigan was roughly on par with the national rate.

cohort, we would expect 1,532 cases of cognitive impairment.[j]

- Cerebral Palsy: A 2008 study found that the national incidence rate of cerebral palsy is 3.6 cases per 1,000 births.[43] Thus, of the 2009 Michigan birth cohort, we would expect 460 cases of cerebral palsy.

- **Autism:** In 2009, there were 14,760 students with autism spectrum disorder enrolled in special education in Michigan public schools.[k] As there were 1.64 million children in the Michigan school system in 2006,[44] this is an incidence rate of slightly greater than 1 in 150 cases, which is the CDC's estimate of the national rate of autism spectrum disorders.[45] Therefore, in the 2009 Michigan birth cohort, we would expect 851 cases of children with autism spectrum disorder.

Cost per Case Estimates: We were unable to get Michigan-specific data on cost per case of autism, cerebral palsy, and cognitive impairment in children. Thus, like Landrigan and colleagues, we relied on the work of Honeycutt et al. We updated Landrigan's cost per case estimate to 2009 dollars using the Bureau of Labor Statistics Consumer Price Index Inflation Calculator for all costs except productivity losses due to morbidity. For productivity losses, we used the Bureau of Labor Statistics (BLS)'s Index of Hourly Compensation to update the costs, as this is a more relevant estimate of wage inflation.[l] We did find Michigan-specific costs of special education and we include them later; but do not appear in Table 4.

We then took these updated lifetime costs per case of the three neurodevelopmental disorders, multiplied them by the number of expected incidents of these disorders in the 2009 Michigan birth

Table 4: Lifetime costs per case of three neurodevelopmental conditions or disorders, 2009.

	Cognitive impairment	Autism	Cerebral Palsy
Physician visits	$22,893	---	$43,902
Prescription drugs	$4,172	---	$4,713
Hospitalization	$35,334	$5,931	$23,171
Assistive Devices	$3,642	$155	$3,614
Therapy and Rehabilitation	$15,475	$2,252	$19,276
Long-term care	$112,178	$43,905	$5,834
Home and auto modifications	$1,083	$763	$2,469
Home care	$1,213,360	$1,369,076	$1,180,197
Productivity losses due to morbidity	$913,468	$765,839	$757,760
Total lifetime costs per case	**$2,321,605**	**$2,187,921**	**$2,040,936**

k. This includes only those students who were in special education. Autism spectrum disorder also includes high functioning children who may not be assigned to special education. These children are unlikely to have high medical costs.
l. In 1997, the annual Index of Hourly Compensation by the BLS was 113.055. In the second quarter of 2009 (the most recent data available), it was 183.059 . Thus an inflation factor of 183.059/113.055 was applied (1.62).

Table 5: Estimated lifetime costs of neurodevelopmental disorders of environmental origin for children born in 2009 in Michigan.

	Cognitive Impairment	Autism	Cerebral Palsy
Total lifetime costs per case, not including special education	$2,321,605	$2,187,921	$2,040,936
Annual new cases	1,532	460	851
Lifetime costs per annual cohort, not including special education (cost per case x new cases)	$3.56 billion	$1.01 billion	$1.74 billion
Adjustment of costs to avoid double counting	-2.5%	—-	15%
Adjusted lifetime costs per annual cohort, not including special education	$3.47 billion	$1.01 billion	$1.47 billion
Total costs, select neurobehavioral disorders, not including special education	$5.95 billion ($ 3.47 b.+ $1.01 b + $1.47 b)		
Annual cost estimate of special education in Michigan	+ $2.5 billion		
Total costs of select neurodevelopmental disorders in MI	= $8.45 billion		
EAF	10%		
Total environmentally attributable costs	**$845 million (10% of $8.45 billion)**		
	$423 million – 1.69 billion		

cohort. We used the downward adjustments employed by Landrigan for lead and cerebral palsy (as explained in the Appendix) to avoid double counting. These were 2.5% for lead and 15% for cerebral palsy. Landrigan used a 34% downward adjustment for autism to account for those children with autism who are also mentally retarded. However, the Michigan Department of Education uses only one primary disability category per child; thus, children are categorized as either having autism or cognitive impairment, but never both. This study does not, therefore, include a downward adjustment for autism.

Michigan-specific costs of special education were taken from a June 2008 expenditure report from the Michigan Department of Education.[46] According to the report, total state expenditures for special education were 2.42 billion for the 2006-2007 school year. Every year for the last 20 years, state expenditures for special education have risen between 2% and 12%, with an average of around 3-4% for the last few years. To be conservative, we applied a 2% increase for 2 years to estimate that costs of special education expenditures in Michigan were approximately $2.5 billion. We recognize that this includes all special needs programs, and thus the total costs will overestimate costs of only cognitive impairment, autism, and cerebral palsy. However, because there are many neurobehavioral disorders that have been linked to environmental exposures, including ADD and ADHD, and because the EAF applies to all neurobehavioral disorders, we believe that the total attributable cost estimates will still be fairly conservative. While there are some children in special education without neurobehavioral disorders, they represent only a small percentage of children in special education—1.36% of students in special education in Michigan have a hearing impairment, 0.39% have a visual impairment, and 1.51% have a physical impairment.[47]

Results

Based on the above calculations, and using the environmentally attributable fraction (EAF), the costs to society for three neurobehavioral disorders for the 2009 Michigan birth cohort can be roughly approximated as $845 million, with a range of $423 million – 1.69 billion.

Photo by Suprijono Suharjoto, iStockphoto.com

Appendix: Costs of Environmentally Attributable Diseases in the U.S. – Landrigan Approach

U.S. Costs of Childhood Lead Poisoning

EAF: Landrigan and colleagues deemed all cases of lead poisoning to be of environmental origin, making the environmentally attributable fraction (EAF) 100%.

Size of Population: The estimate of population size was based on a single cohort of children in 1997 (the year for which the estimates were done), all age 5 years old. This age group was chosen as the population at risk because this is the age when children typically enter school, and the age at which the neurological damage caused by lead often first is noticed. Additionally, abatement or medical treatment beyond that age will not reverse brain damage or restore lost intelligence. Therefore, a child may have lifelong decrease in function as a result of the exposure. To find the number of 5 year-old children in the country, Landrigan used data from the U.S. Census.

Disease Rate: To estimate the prevalence of lead poisoning, Landrigan used data from the CDC's National Health and Nutrition Examination Study (NHANES). The mean blood lead level for 5 year-old children in the U.S. from 1991-1994 was 2.7 µg/dL.

Cost per Case: Landrigan's model for calculating the economic costs of pediatric lead poisoning, which is based in part on previous published studies by Schwartz[48] and Salkever,[49] assumes that IQ scores decrease with increasing blood lead levels in a dose-response manner. Those decrements in IQ scores are in turn associated with decreased wages and lifetime earning power. Specifically, Landrigan used Schwartz's finding that 1 µg/dL of blood lead is associated with a 0.25 decrease in IQ points, and Salkever's finding that the loss of 1 IQ point is associated with a 2.39% loss of lifetime earnings. Lifetime earnings were taken from estimates from the Bureau of Labor Statistics of average

Table 6. Estimated annual loss of future lifetime earnings due to pediatric lead poisoning, United States, for 1997 cohort of 5 year-olds.

Total annual loss of future lifetime earnings due to pediatric lead poisoning =	

expected lifetime income for 5 year-old boys ($881,027) and girls ($519,631).

Results: Landrigan and colleagues estimated the total annual economic losses due to lead exposure to be $43.4 billion for the year 1997 (See Table 6 for calculations).

U.S. Costs of Childhood Asthma

EAF: Landrigan and colleagues, through consultations with a panel of experts, estimated that 30% of acute exacerbations of childhood asthma are environmentally-related. The range for the environmentally attributable fraction (EAF) was deemed to be 10-35%, and environmental causes included only non-biological, outdoor pollutants such as emissions from stationary and mobile sources.

Population at risk*:* Landrigan used all children under 18 as the population at risk. Cost estimates are based on the aggregate cost of asthma in children under 18 years of age, multiplied by the EAF.

Disease Rate: To estimate the prevalence of asthma, Landrigan used data on childhood asthma prevalence from the National Health Interview Survey and data on asthma mortality in children from the CDC. According to this data, there were 247 deaths each year from childhood asthma.

Cost per Case: To estimate the costs of childhood asthma, Landrigan considered both the direct and indirect costs related to asthma. Direct health care costs included hospital care (inpatient, outpatient, and emergency care), and physician services (inpatient, outpatient, and medications). Indirect costs included number of school days lost and lost productivity due to premature death. These cost estimates were developed using the approach of Chestnut et al. (2000) and Weiss et al. (2000).

Results: Landrigan and colleagues estimated the total annual national economic costs of childhood asthma attributable to environmental exposures in the U.S. to be $2 billion for the year 1997 (See Table 7).

Table 7: Estimated annual costs of pediatric asthma of environmental origin in the United States, using 1997 cohort.

Medical and indirect costs	U.S. dollars
Medical costs	
Hospitalizations	
Inpatient stays	634 million
Outpatient visits	323 million
Emergency room visits	154 million
Physicians' services	
Inpatient	54 million
Outpatient	625 million
Medications	2.81 billion
Subtotal: medical costs	**$4.6 billion**
Indirect costs	
School days lost (lost workdays for parents)	1.78 billion
Premature deaths (lost lifetime earnings)	193 million
Subtotal: indirect costs	**$2 billion**
Total costs of pediatric asthma (medical costs + indirect costs)	**$6.6 billion**
EAF	30%
Environmentally attributable costs of pediatric asthma (EAF x total costs)	$2.0 billion
EAF percentage range	10-35%
EAC estimated range	$0.7-23 billion

U.S. Costs of Childhood Cancer

EAF: Landrigan and colleagues, through consultations with a panel of experts, estimated the fraction of cases of the major categories of childhood cancer that may be associated with environmental exposures. The panel was only able to agree that the actual environmentally attributable fraction (EAF) would be at least 5-10% and less than 80-90%. Because of the many uncertainties associated with childhood cancer, the EAFs used were at the conservative end and were: 2, 5, and 10%.

Population at risk: Unlike the calculations for asthma and lead poisoning, which considered a single cohort as the population at risk, Landrigan based national childhood cancer calculations on number of new cancer diagnoses per year for all U.S. children under age 15. This was done because there is a broad range of ages of onset for different childhood cancers.

Disease Rate: For childhood cancer, the relevant disease rate is incidence because it cannot be anticipated that environmental cleanup will ameliorate the morbidity or mortality of children who now have cancer.[50] To estimate the incidence of

Table 8. Estimated annual costs of pediatric cancer of environmental origin in the United States, using 1997 cohort.

Medical and indirect costs	**U.S. dollars**
Medical costs (per primary case)	
Inpatient stays	189,600
Outpatient visits	20,400
Laboratory	263,200
Physicians' services	35,900
Subtotal: medical costs	**$509,000**
Indirect morbidity costs (per primary case)	
Lost parental wages	13,500
Loss of IQ	60,500
Subtotal: indirect morbidity costs	**$74,000**
Total morbidity costs per primary case	583,000
Morbidity costs of secondary cases	40,000
Morbidity costs per case for primary and subsequent secondary cancer	**$623,000**
Total annual morbidity costs of childhood cancer	
Medical and indirect morbidity costs	4.8 billion
Costs of premature deaths	1.8 billion
Total morbidity costs	**6.6 billion**
EAF	5%
Environmentally attributable costs of pediatric cancer	332 million
EAF percentage range	2-10%
EAC estimated range	132-663 million

Photo by Maya Kovacheva, iStockphoto.com

pediatric cancer, Landrigan used data from the national Cancer Institute's Surveillance Epidemiology and End Results database. According to this data, there are 7,722 new cases of childhood cancer each year in the U.S.

Cost per Case: Landrigan notes that data on the costs of childhood cancer are not easily available, particularly because the majority of childhood cancer patients participate in randomized clinical trials for which there are no costs to patients, and poorly recorded costs to hospitals. To estimate the costs of childhood cancer, Landrigan considered both the direct and indirect costs related to cancer. Direct medical costs included inpatient care, outpatient care, laboratory services, and physician's services. Indirect costs included lost parental wages, loss of IQ, secondary cancer cases, and costs of premature deaths. Costs were estimated based on records from the Mount Sinai Medical Center as well as published data on costs of laboratory services. They also considered the morbidity costs of secondary cases of cancer, as children with cancer are at greater risk of secondary malignancy. Costs associated with decreased IQ were calculated because certain cancer treatments involve radiation that can affect IQ. Lost wages due to premature death were calculated by multiplying the estimated loss of lifetime earnings by the number of pediatric deaths.

Results: Landrigan and colleagues estimated total annual U.S. direct medical costs and indirect economic losses from pediatric cancer attributable to environmental exposures to be $332 million for the year 1997 (See Table 8).

U.S. Costs of Neurodevelopmental Disorders

EAF: A committee convened in 2000 by the U.S. National Academy of Sciences estimated that 3% of all neurodevelopmental disorders in children are caused directly by exposures to environmental toxicants. An additional 25% of disorders are caused by interactions between environmental factors and genetic susceptibility in children. Based on this estimate, Landrigan and colleagues used an EAF of 10%, with a range of 5-20%. This conservative estimate was meant to avoid the inclusion of neurodevelopmental disorders due to alcohol, tobacco, or drug use. Because a significant number of cases of autism and cerebral palsy are also associated with mental retardation, Landrigan avoided double counting these cases by imposing a downward adjustment of 34% of attributable cases of autism and 15% of attributable cases of cerebral palsy. Additionally, to avoid double-counting mental retardation costs due to lead exposure, Landrigan used a downward adjustment of 2.5%.

Population at risk: Landrigan used all children born in the U.S. in the year 1997 as the population at risk.

Disease Rate: Disease rates for mental retardation, autism, and cerebral palsy were taken from a 2000 CDC study.[51]

Cost per Case: Cost estimates of mental retardation, autism, and cerebral palsy were taken from a study by Honeycutt et al.[52] published in 2000. These cost estimates for the three disorders considered both the direct and indirect costs. Direct health care costs included physician visits, prescriptions drugs, hospitalization, therapy, home care, special education services, and more. Indirect costs were calculated as productivity losses due to morbidity.

Results: Landrigan and colleagues estimated the total annual economic losses due to pediatric neurobehavioral disorders of environmental disorders to be $9.2 billion, with a range of $4.6-$18.4 billion. These costs refer to the added lifetime costs for each birth cohort. Mental retardation accounted for the majority of these costs.

Table 9: Lifetime costs per case of three neurodevelopmental diseases in the U.S., 1997.

	Mental Retardation	Autism	Cerebral Palsy
Physician visits	$17,127	—	$32,844
Prescription drugs	$3,121	—	$3,526
Hospitalization	$26,434	$4,437	$17,335
Assistive Devices	$2,725	$116	$2,704
Therapy and Rehabilitation	$11,577	$1,685	$14,421
Long-term care	$83,923	$32,846	$4,365
Home and auto modifications	$810	$571	$1,847
Home care	$907,742	$1,024,237	$882,932
Productivity losses due to morbidity	$563,869	$472,740	$467,753
Total lifetime costs per case	**$1,617,328**	**$1,536,632**	**$1,427,727**

Endnotes

1 Landrigan, P.J., C.B. Schechter, J.M. Lipton, et al. 2002. Environmental pollutants and disease in American children: Estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities. *Environmental Health Perspectives* 110(7): 721-728, http://www.ehp.niehs.nih.gov/docs/2002/110p721-728landrigan/abstract.html.

2 U.S. Department of Commerce, Bureau of Economic Analysis. 2009. Gross Domestic Product By State. http://www.bea.gov/regional/gsp/action.cfm,

3 Schwartz J. Societal benefits of reducing lead exposure. Environ Res 66:105-124 (1994).

4 Weiss KB, Gergen LK, Hodgson TA. An economic evaluation of asthma in the United States. *New Engl J Med* 326:862-866 (1992).

5 Smith D, Malone D, Lawson K, Okamoto L, Battista C, Saunders W. A national estimate of economic costs of asthma. *Am J Respir Crit Care Med* 156:787-793 (1997).

6 Farquhar I, Sorkin A, Weir E. Cost estimates for environmentally related asthma. In: *Research in Human Capital and Development*, Vol 12 (Farquhar I, Sorkin A, eds). Stamford, CT:JAI Press, 1998;35-46.

7 U.S. EPA. 1999. Cost of asthma. In: Cost of Illness. Washington, DC:U.S. Environmental Protection Agency, 1999. Available: http://www.epa.gov/oppts/coi [cited 7 May 2004].

8 Chestnut LG, Mills DM, Agras J. National Costs of Asthma for 1997. (EPA Contract 68-W6-0055) Boulder, CO: Stratus Consulting Inc., 2000.

9 Weiss KB, Sullivan SD, Lyttle CS. Trends in the cost of illness for asthma in the United States, 1985-1994. J *Allergy Clin Immunol* 106:493-499 (2000).

10 Schwartz J, Pitcher H, Levin R, Ostro B, Nichols AL. Costs and Benefits of Reducing Lead in Gasoline: Final Regulatory Impact Analysis. EPA-230/05-85/006. Washington, DC:U.S. Environmental Protection Agency, 1985.

11 U.S. EPA. Economic Analysis of Toxic Substances Control Act Section 403: Hazard Standards. Washington, DC: U.S. Environmental Protection Agency, 1998.

12 Landrigan, P.J., C.B. Schechter, J.M. Lipton, et al. 2002. Environmental pollutants and disease in American children: Estimates of morbidity, mortality, and costs for lead poisoning, asthma, cancer, and developmental disabilities. *Environmental Health Perspectives* 110(7): 721-728, http://www.ehp.niehs.nih.gov/docs/2002/110p721-728landrigan/abstract.html.

13 Davies, K. 2005. Economic Costs of Diseases and Disabilities Attributable to Environmental Contaminants in Washington State.

Collaborative for Health and Environment-Washington Research and information Working Group.

14 Schuler, K., S. Nordbye, S. yamin, et al. 2006. The Price of Pollution: Cost estimates of Environment-Related Childhood Disease in Minnesota. Minnesota Center for Environmental Advocacy.

15 Davis, M.E. An Economic Cost Assessment of Environmentally-Related Childhood Diseases in Maine.

16 Institute of Medicine. 1981. Costs of Environment-Related Health Effects: A Plan for Continuing Study. Washington, DC. National Academy Press.

17 Smith KR, Corvalin CF, Kjellstrom T. How much global ill health is attributable to environmental factors? Epidemiology 10:573-584 (1999).

18 U.S. Census Bureau. Census 2000 Data for the State of Michigan. http://www.census.gov/census2000/states/mi.html

19 Personal communication, MDCH. February 2010.

20 U.S. EPA. December, 2009. Blood Lead Level. http://cfpub.epa.gov/eroe/index.cfm?fuseaction=detail.viewInd&lv=list.listByAlpha&r=188246&subtop=208.

21 Rosenman, KD et al. 2008. The 2007 Annual Report on Blood Lead Levels on Adults and Children in Michigan. http://www.michigan.gov/documents/mdch/07Lead_all_287172_7.pdf.

22 Michigan Childhood Lead Poisoning Prevention and Control Commission. Plan to Eliminate Childhood Lead Poisoning in Michigan. June 2007.

23 Michigan Department of Community Health (MDCH). 2005. Childhood Lead Poisoning Prevention Program 2005 Data Report. http://www.michigan.gov/documents/2005_CLPPP_Data_Report_156298_7.pdf. United States Environmental Protection Agency (EPA). Detroit River-Western Lake Erie Basin Indicator Project. INDICATOR: Lead Poisoning in Detroit, Michigan. Last updated on May 3rd, 2007. http://www.epa.gov/med/grosseile_site/indicators/leadtable.html#figure2.

24 Canfield RL, Henderson CR, Cory-Slechta DA, Cox C, Jusko TA, Lanphear BP. 2003. Intellectual impairment in children with blood lead concentrations below 10 micrograms per deciliter. *N Engl J Med* 348:1517-1526.

25 Carlisle, JC, KC Dowling, DM Siegel, and GV Alexeeff. 2009. A blood lead benchmark for assessing risks from childhood lead exposure. *Journal of Environmental Science and Health Part A* 44:1200-1208. http://esequips.org/sitebuildercontent/sitebuilderfiles/carlisledowlingetaljesh2009.pdf.

26 Max, W, DP Rice, et al. 2004. Valuing Human Life: Estimating the Present Value of Lifetime Earnings, 2000. UC San Francisco: Center for Tobacco Control Research and Education. Retrieved from: http://escholarship.org/uc/item/82d0550k.

27 Personal communication with Wendy Max, PhD. February 11, 2010.

28 Personal communication with Wendy Max, PhD. February 11, 2010.

29 Chen, A, B Cai, KN Dietrich, et al. 2007. Lead exposure, IQ, and behavior in urban 5-7 year-olds: Does lead affect behavior only by lowering IQ? *Pediatrics* 119(3): e650-e658.

30 Needleman, HL, C McFarland, RB Ness, et al. 2002. Bone lead levels in adjudicated delinquents: A case control study. *Neurotoxicology and Teratology* 24(6):711-717.

31 Wright, JP, KN Dietrich, MD Ris, et al. 2008. Association of prenatal and childhood blood lead concentrations with criminal arrests in early adulthood. *PLoS Med* 5(5): e101.

32 Michigan Inpatient Database, 2008, Michigan Department of Community Health. Provided by Wasilevich, E. Michigan Department of Community Health, May 2010.

33 Michigan Death File, 2003-2007, Michigan Department of Community Health. Provided by Wasilevich, E. Michigan Department of Community Health, May 2010.

34 HCUP State Inpatient Database 2008, Agency for Healthcare Research and Quality (AHRQ), based on data collected by the Michigan Health & Hospital Association and provided to AHRQ. Provided by Wasilevich, E. Michigan Department of Community Health, May 2010.

35 Wendy Max, personal communication. February 11, 2010.

36 Davies, K. July 2005. Economic Costs of Diseases and Disabilities Attributable to Environmental Contaminants in Washington State. Collaborative for Health and Environment – Washington Research and Information Working Group.

37 U.S. Census Bureau. Accessed February 2010. Michigan Quickfacts. http://quickfacts.census.gov/qfd/states/26000.html.

38 State of Michigan Office of the Governor. 2008. Childhood Cancer Awareness Month Resolution. http://www.mi.gov/gov/0,1607,7-168-25488-199130--,00.html.

39 U.S. Bureau of Labor Statistics. 2010. CPI Inflation Calculator. http://data.bls.gov/cgi-bin/cpicalc.pl.

40 Wendy Max, personal communication. February 2010.

41 Michigan Department of Community Health. 2009. Michigan Population Trends by Age, 1990-2008. http://www.mdch.state.mi.us/pha/osr/CHI/POP/DP00_A2A.ASP.

42 Bhasin, TK, S Brocksen, RN Avchen, et al. 2006. Prevalence of four developmental disabilities among children aged 8 years- metropolitan Atlanta developmental disabilities surveillance program, 1996 and 2000. *Surveillance Summaries* 55(SS01): 1-9. http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5501a1.htm.

43 Yeargin-Allsopp, M., K Van Naarden Braun, NS Doernberg, et al. 2008. Prevalence of cerebral palsy in 8 year-old children in three areas of the United States in 2002: A multisite collaboration. *Pediatrics* 121:547-554.

44 Michigan Department of Education. Michigan compliance Information System. 4/9/07. Personal Communication.

45 Centers for Disease Control and Prevention. 2007. Prevalence of autism spectrum disorders. Surveillance Summaries. *Morbidity and Mortality Weekly Report* 56(SS-1). http://www.cdc.gov/mmwr/pdf/ss/ss5601.pdf.

46 Michigan Department of Education. June 2008. Special Education General Expenditure Charts. 1977- 2007. http://www.michigan.gov/documents/mde/1977-2007SpecEducExpenditureCharts_234346_7.pdf.

47 Michigan Department of Education. 2010. Data Portrait: Special Education State-ISD Summary Report, December 2009. Version 6.0.

48 Schwartz J, Pitcher H, Levin R, Ostro B, Nichols AL. Costs and Benefits of Reducing Lead in Gasoline: Final Regulatory Impact Analysis. EPA-230/05-85/006. Washington, DC:U.S. Environmental Protection Agency, 1985.

49 Salkever DS. Updated estimates of earnings benefits from reduced exposure of children to environmental lead. Environ Res 70:1-6 (1995).

50 Zahm SH, Devesa SS. Childhood cancer: overview of incidence trends and environmental carcinogens. Environ Health Perspect 103(suppl 6):177–184 (1995).

51 Buxbaum L, C Boyle, M Yeargin-Allsopp, et al. 2000. Etiology of mental retardation among children ages 3-10: The Metropolitan Atlanta Developmental Disabilities Surveillance Program. Atlanta, GA: Centers for Disease Control and Prevention.

52 Honeycutt A, L Dunlap, H Chen, et al. 2000. The Cost of Developmental Disabilities. Task Order No. 0621-09. Revised Final Report. Research Triangle Park, NC: Research Triangle Institute.