The Price of Pollution

Cost Estimates of Environment-Related Childhood Disease in Minnesota

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For more than 30 years, the Minnesota Center for Environmental Advocacy has been the legal and scientific voice protecting and defending Minnesota's environment. As a statewide environmental advocacy group, we work in the courts, the legislature and state agencies to develop and implement environmental change.

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About this publication

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

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Executive Summary

The burden of many childhood chronic diseases is increasing, as evidenced by rising rates of asthma, developmental problems, birth defects, and some types of cancer. A large body of research indicates that environmental factors are important contributors. Numerous studies have demonstrated an association between air pollutants and respiratory diseases, including childhood asthma. Increased cancer risk is associated with children's exposure to benzene and 1,3-butadiene in outdoor air, drinking water contaminants and pesticide use in and around the home. In addition, children whose parents work with agricultural or industrial chemicals have a higher cancer risk. The devastating effects of lead exposure on children's brain development are well established, including lowered intelligence, shortened attention span, decreased coordination, aggressive behavior, and learning disorders. These effects are evident even at blood lead levels below 10 μg/dL, the level considered "safe" by the Centers for Disease Control and Prevention (CDC). Exposure to mercury, dioxins, polychlorinated biphenyls (PCBs), plasticizers, certain pesticides, organic solvents and air pollution have been shown to increase the risk of birth defects. Finally, exposure to lead, mercury, dioxins, PCBs, toxic flame retardants and some pesticides have been linked with increased risk of neurobehavioral disorders, even at low-level exposures.

This study quantifies some of the economic impacts of these environmental contributors to childhood asthma, cancer, lead poisoning, birth defects and neurobehavioral disorders in Minnesota. It is based primarily on the methodology set forth by Landrigan[1] but also utilizes updated methods from studies by Davies[2] for Washington state and Massey and Ackerman[3] for Massachusetts. We applied actual Minnesota data on rates of disease and costs, whenever those data were available. When they were not available, we extrapolated from national data. We used Landrigan's "environmentally attributable fraction" methodology to estimate the portion of costs for these childhood diseases that could conservatively be attributed to environmental pollutant exposures.

The best estimate of total costs of environmentally attributable childhood diseases in the state of Minnesota is $1.569 billion per year, with a range of $1.393 to $1.890 billion. Cost estimates for specific diseases are:

- Childhood asthma: $30.6 million
- Childhood cancers: $8.2 million
- Lead poisoning: $1.223 billion
- Birth defects: $4.5 million
- Neurobehavioral disorders (excluding lead): $303 million

These cost estimates are very conservative, so the impacts on individuals, society and taxpayers are likely much greater. This information has value for public policy because it requires we account for long-term costs to society, a perspective too often left out of policy analyses. Since environmental contributors to childhood diseases are largely preventable, public policies that prevent exposures and pollution provide significant benefits for individuals and for society. We recommend the implementation of policies to reduce or eliminate some of the key environmental contributors to childhood illnesses in Minnesota, such as: phasing out remaining products with mercury, phasing out the use of toxic flame retardants, providing additional resources for lead abatement, improving disease tracking and biomonitoring, reducing pesticide useage and automobile emissions and finally, reforming chemical regulation to prevent children's exposure to the most problematic chemicals.

Our findings demonstrate that there is not only a moral imperative to reduce the impacts of these preventable childhood diseases, but it also makes good economic sense. Investing in policies that protect public health will pay off in the long term and help ensure a healthy future for Minnesota's children.

Background

The burden of many childhood chronic diseases is increasing, as evidenced by rising rates of asthma, developmental problems, birth defects and some types of cancer.[4] While the causes of these diseases are complex and multifactorial, a large body of research points to environmental factors as important contributors.[5] This study quantifies some of the economic impacts of environmental contributors to these diseases in Minnesota.

Childhood diseases and their subsequent adult impacts caused or aggravated by exposure to environmental pollutants impose a huge economic cost on society. These costs include expenditures for health care and other treatments for children, and in most cases, they include additional costs in adulthood for cancer treatments, lost productivity, etc. Landrigan *et al.* very conservatively estimated that certain childhood environmental diseases cost the U.S. as a whole an estimated $54.9 billion per year in dollars (1997$).[1] Estimates of the cost of environmental diseases for individual states have also found tremendous economic impacts. A Washington state study estimated a cost of $1.875 billion[2] and a Massachusetts study estimated $1.6 billion for childhood diseases.[3] A study of costs for the state of Montana, which also included adults, estimated $404.6 million per year.[6] Using similar methods, this study estimates the costs to Minnesota for childhood diseases only.

Previous Studies

In 2002 Landrigan[1] published a landmark study estimating the annual costs to the nation as a whole from childhood lead poisoning, asthma, cancer, and neurobehavioral disorders. Using statistics on the rates of these diseases, they employed a panel of experts to estimate the annual costs. They then estimated the proportion of cases for which the disease is likely to be caused or aggravated by environmental conditions, i.e. the "environmentally attributable fraction" (EAF). The basic EAF equation they utilized, with some variations, was:

Costs = (disease rate) * (EAF) * (population size) * (cost-per-case)

Several state-level studies have applied Landrigan's basic model. Davies estimated costs for adult and childhood diseases in Washington state. The Washington study covered asthma, cancer, lead, cardiovascular disease, birth defects and neurobehavioral disorders.[2] Massey and Ackerman's study of Massachusetts included asthma, cancer, lead, birth defects and neurobehavioral disorders for children only.[3] Seninger conducted a similar study for Montana, which included the same diseases as Massachusetts, but for both adults and children.[6]

Two recent studies focused specifically on costs from mercury exposure. Trasande *et al.*[7] estimated the costs of mercury pollution on the neurodevelopmental health of children. Using estimates of the impacts of IQ reduction due to methyl mercury exposure and its consequent reduction in adult productivity, this study found a nationwide impact of $8.7 billion per year. Of this, $1.3 billion were attributable to mercury pollution from coal-fired power plants. (In 2004$, the cost would be $9.54 billion nationwide and $1.43 billion for coal-fired power plants.) A subsequent study by Trasande estimated the costs related to increases in mental retardation attributable to mercury pollution at $2 billion per year, $239 million of which are attributable to coal-fired power plants.[8] (In 2004$, $2.19 billion is the nationwide cost and $262 million is attributed to coal-fired power plants.) Based on Minnesota's proportion of new births (1.78 percent), the state's share of costs for neurodevelopmental effects and mental retardation is estimated at $208.8 million in 2004$, with about $30 million attributable to coal-fired power plants alone.

Minnesota Mercury Cost Estimates

If we apply Trasande's estimates of mercury costs to Minnesota, based on Minnesota's proportion of new births (1.78 percent), the state's share of costs for neurodevelopmental effects and mental retardation is estimated at $208.8 million in 2004$, with about $30 million attributable to coal-fired power plants alone.

Study Methodology

This analysis estimates the costs for the following childhood diseases: asthma, childhood cancer, birth defects, lead poisoning and neurobehavioral disorders. For the most part, we proceeded with Landrigan's[1] framework, but we also incorporated updated methods from more recent studies.

Environmentally attributable fractions (EAFs): This study utilizes the same EAFs used in the 2002 Landrigan study, though they are conservative and likely to underestimate the proportion of some or all of these diseases that are actually related to environmental exposures.

Definition of environmental factors: For the purposes of this study, environmental factors are defined as pollutants, both naturally occurring and anthropogenic, in air, water and soil. Examples include: chemicals, metals, pesticides and other toxic substances to which humans may be exposed. This definition of environmental factors does not include: genetic factors, diet, smoking, alcohol consumption, sexual behavior, infectious disease, accidents or injuries.

Disease incidence/prevalence and cost data: We utilized actual Minnesota data on disease rates and costs whenever available. If state-specific data were not available, we extrapolated from national estimates, using census data to estimate the Minnesota proportion of the U.S. population under age 18 (1.78 percent).[9] Data sources for each disease are:

- Asthma: National cost-per-case data and Minnesota-specific asthma prevalence.
- Cancer: National cost-per-case data and Minnesota-specific cancer incidence.
- Lead: National data on loss of lifetime earnings and prevalence of lead poisoning.
- Birth defects: National incidence and cost information.
- Neurobehavioral disorders: National incidence and cost data, except for Minnesota-specific costs for special education services.

Costs not included: This study does not account for additional costs incurred for social services and criminal justice services or for lost wages and productivity for parents who miss work to care for their children. It thus represents a very conservative estimate of the total cost impact. For example we do not include the costs of many adverse social outcomes that have been associated with IQ reductions, including: poverty, out-of wedlock birth, low-weight births, welfare recipiency, dropping out of high school and involvement in the criminal justice system.[10]

Inflation factor: The study utilizes the Department of Labor's Consumer Price Index Inflation Calculator (available at www.bls.gov/cpi/home.htm) to calculate cost estimates in 2004$.

Complete details on the methods, assumptions and data sources used to derive cost estimates are described in the disease-specific sections that follow.

Disease-Specific Cost Analyses

Costs of Childhood Asthma

Background: Asthma attacks are caused or aggravated by a variety of factors. Air pollutants in both indoor and outdoor environments are important causal factors. Following Landrigan's[1] framework, we set out to derive an estimate of the environmentally attributable costs of childhood asthma in Minnesota.

Numerous studies have demonstrated an association between air pollutants and respiratory diseases, including childhood asthma.[11,12,13,14] Pollutants such as particulate matter, ozone and nitrogen dioxide have been identified as risk factors for asthma attacks. Children are especially susceptible. If not treated immediately, asthmatic children are often hospitalized or brought to an emergency room.

Costs and prevalence: Landrigan *et al.*[1] did not derive their estimate of national asthma costs on a cost-per-case basis as they did with the other diseases. Rather, they used an existing estimate of total national costs and then multiplied it by the EAF.

We derive a cost-per-case estimate whenever possible, as Massey and Ackerman did in their Massachusetts study. They used the U.S. Environmental Protection Agency (EPA) Cost of Illness Handbook[15] figures for annual costs per case, updated from 1999$ to 2002$. Then they used Massachusetts' prevalence data and the EAFs to calculate the annual cost of the environmentally attributable fraction:

(prevalence, as # of cases) * (annual cost-per-case) * (EAF)

Summary of Data and Assumptions

- MN childhood asthma prevalence = 7.9%
- 101,665 children with asthma in MN
- Annual costs = $1,003 per case
- EAF = 0.30; range 0.10 to 0.35

We inserted Minnesota prevalence data into this equation, keeping Landrigan's EAFs and updating the cost figures to 2004$. Our first step was to obtain reliable prevalence data for asthma among Minnesota children. According to the Minnesota Department of Health (MDH),[16] 7.9 percent of Minnesota children aged 0 to 17 years have been diagnosed with asthma in their lifetime. MDH refers to this percentage as the lifetime asthma prevalence. This percentage can be used to estimate the number of cases:

(percentage of children with asthma) * (number of children less than 18 years)

Assuming that the proportion of children less than 17 years with asthma would be very similar to the proportion of children less than 18 years with asthma, we can apply the percentage to 2000 population data:[17]

(7.9%) * (1,286,894) = 101,665 children with asthma in Minnesota

Minnesota cost estimate: Our next step was to apply the annual cost-per-case data and update EPA's cost figures from 1999$ to 2004$.

Annual cost for ages 4 to 5 years = $761.16 in 1999$ = $863.04 in 2004$

Annual cost for ages 6 to 17 years= $904.90 in 1999$ = $1,026.02 in 2004$

Since EPA's estimates were separated into costs for ages 4 to 5 years and costs for ages 6 to 17 years, and MDH lifetime asthma prevalence is for all children less than 17 years, we averaged the costs out over the whole time period:

[($863 * 2 years) + ($1,026 * 12 years)] / (14 years) = $1,003 per case for ages 4 to 17 years.

Then we applied this as the estimated cost-per-case for all cases less than 18 years:

(101,665 cases) * ($1,003 per case) = $101,969,995 total cost for all MN cases

Applying the EAFs of 0.10, 0.30 and 0.35 yielded the following results:

* EAF 0.10 = $10,197,000

* EAF 0.30 = $30,590,999

* EAF 0.35 = $35,689,498

The environmentally attributable costs of childhood asthma in Minnesota are estimated at $30.6 million per year, with a range of $10.2 to $35.7 million.

Since we report on costs for children age 4 and older, this is likely to be an underestimate. There is evidence that asthma hospitalization rates are high among children under 4 years old. For example, Hennepin County (MN) Health Department reported that in 2000, boys under 4 years old had the highest asthma hospitalization rate of any age group, at six per 1,000 people.[18]

Costs of Childhood Cancer

Background: The most frequently occurring childhood cancers nationwide and in Minnesota are leukemias, brain and other central nervous system cancers and lymphomas.[19,20] MDH reports that childhood cancer rates in Minnesota are similar to national rates, except for childhood lymphomas, which are higher than average in Minnesota.[21]

There are many different carcinogenic chemicals in the environment contributing to cancers among both children and adults. In estimating the proportion, or EAF, of cancers that can plausibly be attributed to the environment, Landrigan's panel of experts came up with EAFs of 0.02, 0.05 and 0.10. These EAFs are conservative since there is a great deal of uncertainty surrounding environmental risk factors for cancer. In addition, they do not account for environmental exposures occurring during childhood which can lead to cancer decades later. Nevertheless, Landrigan's EAFs are in the same range as Doll and Peto's[22] frequently cited 1981 estimates of the proportion of cancers that are attributable to "pollution." Doll and Peto placed their EAF at 1 percent to 5 percent, but cautioned that the impacts of environmental pollutants on the incidence of cancer are "peculiarly difficult" to quantify, so "the upper limit of 5%…is therefore rather arbitrary." [22]

Children can be exposed to a wide variety of carcinogenic pollutants in the environment. Numerous studies have found an increased risk of childhood cancer from pesticide exposures.[23, 24] While children in farming regions may be exposed to pesticides more frequently[25,26] several studies have reported a significantly increased risk for leukemia and cancers of the brain and nervous system among children exposed to pesticides in and around the home.[27,28] Children whose parents work with pesticides in various agricultural applications also have an increased risk for cancer through direct exposures and through "take-home" exposures to pesticides on the parents' clothes, shoes, etc.[29,30]

Increased risk for childhood cancer has also been linked to exposure to other types of industrial chemicals on the clothing of parents in occupations where those chemicals are used.[31,32] This type of exposure adds to an increased cancer risk from chemical pollutants released to the ambient environment. Studies have shown an association between elevated rates of childhood cancer and chemicals such as benzene and 1,3-butadiene in outdoor air.[33,34,35] Other studies have identified some associations between drinking water contaminated with carcinogenic industrial chemicals and childhood leukemia,[36,37,38] but causality is difficult to establish conclusively.

Costs: Landrigan derived an estimate of national costs for childhood cancer on a cost-per-case basis, using the following equation:

(annual incidence) * (cost per case) * (EAF)

Where annual incidence = 7,722 cases per year among children less than 15 years old, and the cost-per-case = $623,000 in 1997$

(7,722 cases per year) * ($623,000 per case) = $4.8 billion in 1997$

Landrigan also added costs of mortality: a lump cost of $1.8 billion. This is described as "the costs of premature loss of life due to primary and secondary cancer in this cohort of children." This brought the total costs to $6.6 billion annually. Applying EAFs of 0.02, 0.05 and 0.10, the resulting estimates are $132 million, $332 million and $663 million per year, respectively.

Minnesota cost estimate: To estimate the economic costs of childhood cancer in Minnesota, we followed Landrigan's methodology. MDH reports an average of 162 newly diagnosed childhood cancers among children less than 15 years of age.[21] As mentioned, Landrigan also added costs of mortality: a lump cost of $1.8 billion or roughly $233,100 in additional costs per case in 1997$. We updated Landrigan's estimates of treatment and mortality costs to 2004$. We inserted these figures in Landrigan's equation:

(162 diagnoses/year) * ($1,007,584 cost per case) = $163,228,608

Applying the EAFs of 0.02, 0.05 and 0.10 yielded the following results:

EAF 0.02 = $3,264,572

EAF 0.05 = $8,161,430

EAF 0.10 = $16,322,861

The costs of environmentally attributable childhood cancers in Minnesota are estimated at $8.2 million per year, with a range of $3.3 to $16.3 million.

Summary of Data and Assumptions

- MN annual incidence = 162 childhood cancer diagnoses per year
- Total costs per case derived from Landrigan *et al.* = $733,238 (treatment costs) + $274,346 (mortality costs) = $1,007,584 per case per year in 2004$

Costs of Lead Poisoning

Background: Lead causes numerous serious health effects. However, neurodevelopmental effects feature most prominently in economic analyses and include lowered intelligence, shortened attention span, decreased coordination, aggressive behavior and learning disorders.[39] These effects are possible even at blood lead levels below the regulatory threshold or level considered "safe" (10 μg/dL) by the Centers for Disease Control and Prevention (CDC).[40]

Our estimate of costs associated with the full range of behavioral and cognitive effects of lead poisoning in Minnesota is based on the very conservative methodology used by Landrigan. To capture the overall costs due to lead poisoning Landrigan relied on a 1985 EPA economic forecasting model of "lost lifetime earning power" due to lead-related decrement in intelligence (IQ score). This model ascribes to a "birth cohort" (a group of children born in a given year) an average amount of money they would be expected to earn in a lifetime. Of note, neither direct (e.g., special education), nor indirect costs (criminal justice, etc.) for lead-related mental retardation were included in the neurobehavioral disorder cost calculation section to avoid double counting. In fact, Landrigan subtracted a "lead attributable" fraction of 2.5 percent of mental retardation cases. Following Landrigan, we assume an EAF of 100 percent, as all cases of lead poisoning are judged to be of environmental origin.

Costs: The annual lost lifetime earnings due to lead poisoning are calculated as follows:

(mean blood lead level of 5-year-old child) * (loss of IQ points per unit blood lead) * (loss of lifetime earning per IQ point) * (number of boys and girls, respectively) * (EAF of 100 percent)

We used the CDC's latest National Health and Nutrition Examination Survey (NHANES) data for average blood lead levels of 1- to 5-year-olds.[41] MDH data on blood lead levels are available only for a fraction of Minnesota children and hence cannot be averaged to a "statewide population mean." We assumed a slightly higher IQ loss from lead than Landrigan, based on a recently published study,[40] where a blood lead level of 1 μg/dL translates into a loss of 0.46 IQ points. Thus a blood lead level of 1.9 μg/dL means a loss of 0.874 IQ points. According to Landrigan's methodology we assumed that a loss of one IQ point equals the loss of 2.39 percent lifetime earnings; hence a loss of 0.874 IQ points equals a loss of 2.09 percent lifetime earnings. Lifetime earnings data for both genders are from the Bureau of Labor Statistics,[z] adjusted for 2004$: for boys it is $1,036,890 and for girls it is $612,010. Minnesota's 2004 birth cohort consisted of 35,988 boys and 34,626 girls.[42]

Minnesota cost estimate:

Lost lifetime earnings for MN boys: (2.09%) * ($1,036,890) * (35,988) * (EAF 1.0) = $779,895,984

Lost lifetime earnings for MN girls: (2.09%) * ($612,010) * (34,626) * (EAF 1.0) = $442,901,477

Lost lifetime earnings for MN boys and girls together: ($779,895,984) + ($442,901,477) = $1,222,797,462

Lost lifetime earnings due to lead poisoning in Minnesota are estimated at $1.223 billion per year.

Summary of Data and Assumptions

- Average blood lead level of 1-5 year olds in U.S. 1999-2002: 1.9mg/dL
- Loss of 0.46 IQ points per 1mg/dL blood lead
- 2.39 percent loss of life time earning per IQ point
- Lifetime earnings lost for boys $1,036,890 and for girls $612,010 (2004$)
- Minnesota's 2004 birth cohort: 35,988 boys and 34,626 girls
- EAF = 1.0

Costs of Birth Defects

Background: According to the March of Dimes, approximately 150,000 babies born in the U.S. each year are affected by birth defects—one out of every 28 newborn babies. They state: "A birth defect is an abnormality of structure, function or metabolism (body chemistry) present at birth that results in physical or mental disability, or is fatal. Several thousand different birth defects have been identified. Birth defects are the leading cause of death in the first year of life."[43] Both genetic and environmental factors can cause birth defects but the causes of most are unknown. Birth defects are categorized as structural/metabolic (e.g., spina bifida), congenital infections (e.g., cytomegalovirus) or other causes (e.g., environmental toxins). While some birth defects are inherited, many are caused by factors such as nutritional deficiencies, maternal alcohol or drug use and exposure to environmental toxins. Exposure to mercury, dioxins, PCBs, plasticizers, certain pesticides, organic solvents and air pollution have conclusively been linked with an increased risk of birth defects.[4,44] Only a fraction of the known birth defects are recognized at birth and recorded on the birth certificate. An even lower fraction is entered into Minnesota's recently established birth defect surveillance system.

Costs: A 1995 CDC study[45] estimated the annual costs of only 18 birth defects* at $8 billion in 1992$ for a single year's birth cohort. This study further broke down the direct health care costs at $2.1 billion and indirect costs at $5.9 billion. Indirect costs include developmental services, special education and lost productivity. Inflated to 2004$ the total cost rises to $10.8 billion. In order to avoid double-counting costs for cerebral palsy, which is already included in "neurobehavioral disorders" (the next section of this report) and to deduct the costs for Down syndrome, a condition not attributable to environmental factors, we deducted the costs for these two conditions from the CDC's total cost figure:

($10.8 billion) - ($5.754 billion)† = $5.046 billion

Smith *et al.*[46] estimate that approximately 5 percent to 10 percent of all birth defects are associated with environmental and occupational exposures to chemicals during pregnancy. We used a best estimate EAF of 5 percent, with a range of 5 to 10 percent.

Summary of Data and Assumptions

- The rate of birth defects in Minnesota is comparable with national rates.
- Minnesota proportion of U.S. population under age 18 = 0.0178
- CDC's estimate of total annual costs for 16 of 18 birth defects in 2004$: $5.046 billion ($3.72 billion in direct and $1.33 billion indirect in 2004$).
- EAF = 0.05 range 0.05 – 0.10

* Cerebral palsy, spina bifida, truncus arteriosus, single ventricle transposition, double outlet right ventricle, teratology of fallot, tracheo-esophageal fistula, colorectal atresia, cleft lip or palate, atresia/stenosis of small intestine, renal agenesis, urinary obstruction, upper limb reduction, lower limb reduction, omphalocele, gastroschisis, diaphragmatic hernia and Down syndrome

† Per Waitzman *et al.*, 1992 costs for cerebral palsy were $2.426 billion and $1.848 billion for Down syndrome. Inflated to 2004$, they are $3.266 billion and $2.488 billion respectively, for a total of $5.754 billion.

Minnesota cost estimate: Because Minnesota-specific information on incidence and costs of birth defects is unavailable, we applied the Minnesota proportion of annual U.S. births to the CDC's annual cost estimates to arrive at a Minnesota cost estimate, as did Davies in her Washington study.

Best estimate: ($5.046 billion) * (0.05) * (0.0178) * (EAF 0.10) = $4,492,720

EAF 0.05 = $4,492,720

EAF 0.10 = $8,989,000

Direct: ($3.720 billion) * (0.05) * (0.0178) = $3,310,800 (range $3,310,800 – $6,621,600)

Indirect: ($1.330 billion) * (0.05) * (0.0178) = $1,183,700 (range $1,183,700 – $2,367,400)

The costs of environmentally attributable birth defects in Minnesota are estimated at $4.5 million per year, with a range of $4.5 million to $9 million.

There are several reasons why the above is a very conservative estimate of environmentally attributable birth defects. First, we assume the incidence of birth defects in Minnesota is similar to the rate nationally. However, Minnesota is an agricultural state and there is evidence that the birth defect rates are higher in some regions.[47] Second, to be more conservative, we deducted all costs related to Down syndrome, even though the EAF may already account for the fact that this condition is not caused by environmental factors. Down syndrome is a chromosome abnormality that may result in mental retardation. Our estimate is also conservative because many birth defects are not identifiable at birth and therefore not captured by birth certificate data. Finally, the national incidence rates we used include only 18 of thousands of possible birth defects.

Costs of Neurobehavioral Disorders

Background: The National Academy of Sciences (NAS) estimates that 3 percent of neurobehavioral disorders in American children are caused directly by exposure to environmental toxins; an additional 25 percent are caused by interactions between environmental factors, defined broadly, and the individual's genetic susceptibility.[48] Exposure to chemicals and metals during the fetal and early childhood stages of development can interfere with normal brain development and function. Lead, mercury, dioxins and PCBs have been studied extensively and shown to cause neurobehavioral disorders. Other metals, including cadmium and manganese, as well as organic solvents and pesticides have also been linked with neurobehavioral disorders.[49,5] Scientific evidence increasingly demonstrates the danger of even low-level exposure to environmental neurotoxicants. Concerns over the relatively lower levels of mercury, PCBs, perfluorocarbons and dioxin found in fish from Minnesota lakes and rivers have prompted the MDH to issue fish consumption advisories for pregnant women, women who could become pregnant and children under age 15.[50]

Costs: Landrigan *et al.*[1] address the costs for three neurobehavioral disorders: mental retardation, autism and cerebral palsy. They derive annualized lifetime cost estimates by multiplying incidence data from the CDC[51] by lifetime cost-per-case estimates developed by Honeycutt *et al.*[52] Landrigan applied three downward adjustments to avoid double counting: 2.5 percent to mental retardation incidence due to lead exposure, 34 percent to autism costs and 15 percent to cerebral palsy costs to account for co-existing mental retardation.

Landrigan's lifetime cost estimates incorporate both direct and indirect costs, including physician visits, prescription drugs, hospitalization, assistive devices, therapy and rehabilitation, long-term care, home and auto modifications, special education services, home care and productivity losses due to morbidity. Not included are costs for social services and criminal justice, as well as lost wages and diminished productivity of parents whose work is impacted by the needs of their children.

Because we later added in Minnesota-specific costs for special education, we recalculated annualized national lifetime cost figures for cerebral palsy, mental retardation and autism, omitting special education costs from Landrigan's equation.

We used the annual costs for special education by the Minnesota Department of Education for the 2003-2004 school year. These cover classroom instruction beyond the basic per pupil instructional costs, but do not include additional administrative, transportation and other expenses incurred by special education programs. The figures include costs for the three disorders considered in the Landrigan study, as well as other qualifying neurobehavioral and physical disorders. Like Massey and Ackerman[3] in their study of environmentally attributable childhood illness in Massachusetts, we reasoned that while special education includes services to children with physical disabilities distinct from neurobehavioral disorders, the fact that large numbers of children with true neurobehavioral disorders are not tested or offered special education counterbalances this issue.

Summary of Data and Assumptions

- Total MN expenditures for special education, 2003-2004 = $1,179,601,075* in 2004$
- Landrigan's estimate of total national neurobehavioral costs = $92.02 billion in 1997$, or $108.3 billion in 2004$. The 10 percent EAF portion = $10.8 billion; range 5 percent - 20 percent or $5.4 – $21.6 billion.
- Landrigan's estimate of total national neurobehavioral costs minus costs for special education = $104.11 billion in 2004$
- Minnesota proportion of U.S. population under age 18 = 0.0178
- EAF = 0.10; range 0.05 – 0.20

Minnesota cost estimate: We estimated costs of the environmentally-attributable portion of neurobehavioral disorders in Minnesota children by combining lifetime cost estimates determined by Landrigan[1] with Minnesota-specific special education costs. We apportioned Minnesota's share of Landrigan's national costs using U.S. Census figures. We then added Minnesota-specific data on special education costs back into the calculation and used Landrigan's EAFs (10 percent best estimate with a range of 5 percent to 20 percent) to determine Minnesota's total annualized lifetime costs attributable to environmental neurotoxicants (other than lead).

Minnesota annualized lifetime costs, minus special education

[(Landrigan national estimate in 2004$, minus special education) * (Minnesota proportion of U.S. population)] = ($104.11 billion) * (0.0178) = $1.85 billion

Best estimate of 10 percent = $185 million

Range 5 percent to 20 percent = $92.5 - $370 million

Minnesota annual special education costs

Actual Minnesota special education expenditures for state FY 2003-2004 = $1,179,601,075

Best Estimate of 10 percent = $118.0 million

Range 5 percent to 20 percent = $59 – $236 million

Estimate of total Minnesota annual costs of neurobehavioral disorders attributable to environmental causes:

(MN lifetime costs) + (MN special education costs) = Total MN costs

($185 million) + ($118 million) = $303 million (range $151.5 – $606 million)

EAF 0.05 = $151.5 million

EAF 0.10 = $303 million

EAF 0.20 = $606 million

The costs of environmentally attributable neurobehavioral disorders in Minnesota are estimated at $303 million per year, with a range of $151.5 to $606 million.

Our figure is close to the Minnesota cost estimate obtained by apportioning National Heart, Lung and Blood Institute (NHLBI) data according to Minnesota's share of the national population. NHLBI estimated the total national cost of diseases of the nervous system at $159.4 billion in 2004$, with direct costs totaling $140.3 billion and indirect costs totaling $19.1 billion. If we apply the Minnesota proportion of the U.S. population to these figures and use an EAF best estimate of 10 percent, with a range of 5 to 20 percent, the Minnesota estimate is $280 million (range $140–560 million).†

* 2004 Total Expenditures, MN Department of Education: School District Financial Profiles, at http://education.state.mn.us/mde/Accountability_Programs/Program_Finance/Financial_Management/School_District_Financial_Profiles/index.html

† The NHLBI data sources were: Centers for Medicare and Medicaid Services (CMS), National Center for Health Statistics (NCHS), U.S. Census Bureau and the Institute for Health and Aging, University of California, San Francisco. (NHLBI FY 2005 Fact Book, Ch. 4: Disease statistics, p.55. Available at: www.nhlbi,gov/about/factpdf.htm)

Summary of Findings

The best estimate of total costs of environmentally attributable childhood diseases in the state of Minnesota is $1.569 billion per year, with a range of $1.393 to $1.890 billion. Cost estimates for specific diseases are:

- The environmentally attributable costs of childhood asthma in Minnesota are estimated at $30.6 million per year, with a range of $10.2 to $35.7 million.
- The costs of environmentally attributable childhood cancers in Minnesota are estimated at $8.2 million per year, with a range of $3.3 to $16.3 million.
- The costs of environmentally attributable lead exposures in Minnesota are estimated at $1.223 billion per year, due to lost lifetime earnings.
- The costs of environmentally attributable birth defects in Minnesota are estimated at $4.5 million per year, with a range of $4.5 to $9 million.
- The costs of environmentally attributable neurobehavioral disorders in Minnesota are estimated at $303 million per year, with a range of $151.5 to $606 million.

Summary of Costs of Childhood Diseases Attributed to Environmental Causes in Minnesota

Condition	Best estimate (2004$)	Range (2004$)
Asthma	$30.6 million	$10.2 - 35.7 million
Cancer	$8.2 million	$3.3 - 16.3 million
Lead poisoning	$1.223 billion	$1.223 billion
Birth Defects	$4.5 million	$4.5 - 9 million
Neurobehavioral disorders	$303 million	$151.5 - 606 million
TOTAL	$1.569 billion	$1.393 - 1.89 billion

Discussion/Recommendations

This study quantifies some of the economic impacts of childhood diseases linked to environmental exposures. It is a very conservative estimate of actual costs using minimum expenditures, so the impact on individuals, society and taxpayers is likely much greater than our estimates. This analysis has value for crafting public policy, as it accounts for costs often left out of policy analyses. Too often short-term costs are considered while long-term economic impacts are ignored. Economic analyses such as this add another dimension to the core public health value of disease prevention. Environmental contributors to childhood diseases are largely preventable, but public health must be a top priority. The following are policy initiatives designed to reduce or eliminate some of the key environmental contributors to childhood illnesses in Minnesota.

Mercury reduction from coal plants. Coal plants are responsible for more than 50 percent of the mercury emissions in Minnesota. Nationally they account for roughly 42 percent. As the largest single source of mercury emissions, regulation of mercury emissions from coal plants should be a top public health priority. The 2006 Minnesota Legislature took the lead in the nation by passing legislation requiring the three largest coal plants in the state to reduce mercury emissions by 90 percent by 2014, ahead of the federal schedule for mercury reduction.

Mercury products. While Minnesota has successfully reduced mercury emissions from many products and from certain forms of incineration (not crematoria), it is still legal to sell many mercury-containing devices for which non-mercury alternatives are available, including blood pressure devices, thermostats, barometers and some pharmaceuticals. Legislation to phase out the remaining mercury-containing products is needed. The 2006 Minnesota legislature took a step in the right direction by passing a bill that requires utility companies to inform their customers that fluorescent light bulbs contain mercury and to provide information on how to dispose of spent light bulbs as hazardous waste, to prevent pollution from improper disposal.

Lead programs. High soil concentrations of lead in backyards and playgrounds are the legacy of nearly a century of using lead paint and leaded gasoline. An estimated 1 million Minnesota homes built before 1978 contain lead paint.[53] While many of them are in urban areas, some rural areas are also affected.[54] While the main focus of MDH's 2010 Elimination Plan[55] is preventing children from ever being exposed to lead through the reduction or elimination of sources of lead in their environment, federal grants for lead hazard reduction (e.g., Department of Housing and Urban Development) to state and local agencies are running out. The following policies would help address the lead poisoning problem:

- Fund lead abatement
- Provide more incentives for property owners to reduce or prevent lead hazards.
- Reestablish the Minnesota Department of Health's "Legislative Study Work Group" for lead
- Reduce the blood lead threshold for public health intervention in Minnesota from 15 to 10 μg/dL

Pesticides. Minnesota children can be exposed to pesticides in homes, schools and parks. Children who live in rural areas of the state are at even higher risk because they can be exposed to pesticides drifting from agricultural applications or on the clothing of parents who work on farms. An MDH study found numerous pesticides in the blood and urine of children living in both rural and urban areas, including the nervous system toxin chlorpyrifos, which was detected in samples from 92 percent of children.[56] In addition, drinking water wells in rural and suburban Minnesota often contain multiple pesticides and dangerous levels of nitrates.[57] It is critical that Minnesota implement more serious controls on the use of pesticides shown to be known or probable carcinogens, hormone disruptors or nervous system toxins. Several policy changes would reduce health risks from pesticides:

- Establish a system to enable the public, medical professionals and researchers to know what pesticides are applied in Minnesota, when, where and in what quantity. This information is not public at present.
- Provide farm workers and their families with advance notification of pesticide applications.
- Phase out the cosmetic use of pesticides on lawns, gardens and parklands.
- Establish a more comprehensive statewide monitoring network for pesticides and other pollutants in groundwater.

Toxic flame retardants. Polybrominated diphenyl ethers (PBDEs) are flame retardants that are widely used and unlabelled in electronics, textiles and other consumer products. The most common commercial classes are penta, octa and deca-BDE. PBDEs are chemically similar to PCBs, which were banned in 1977 due to their toxicity and persistence in the environment. Like PCBs, PBDEs are now known to be toxic, persistent and accumulate in the environment and in the human body. PBDEs also accumulate in breast milk, which is an especially serious concern. Levels in the Minnesota environment and fish are some of the highest ever detected.[58] While strong fire safety standards are necessary, safer flame retardants are available and should be required. As an emerging problem class of chemicals, PBDEs should be phased out in all commercial uses in the U.S. and globally. Eight states and Europe have already banned penta-BDE and octa-BDE and several states are seeking a phase out of deca-BDE. The Minnesota Legislature has considered, but not yet passed a bill to phase out penta-BDE and octa-BDE by 2008 and use of deca-BDEs in electronics and textiles by 2010.

Biomonitoring and Public Health Tracking. A major limitation of this report was the lack of Minnesota-specific data on environmental pollutant exposures and on rates of disease conditions such as birth defects and neurological disorders. Chronic diseases have become more common than infectious diseases, yet population-based data on these conditions is often scarce. Although Minnesota now has a fledgling birth defect registry, it has just four years of data and covers the Twin Cities metropolitan area only. Future studies would benefit from improving the collection and integration of exposure and disease data. Biomonitoring—the measurement of chemicals in body fluids and tissues—is vital to understanding actual exposure levels. Integrating this exposure data with more complete information on rates of diseases caused or aggravated by pollutants would enable Minnesota to focus its regulatory programs and disease prevention efforts on actual risks to public health and would also generate solid information for the public on environment and health. It is critical that Minnesota establish biomonitoring and public health tracking programs, as other states have done, to contribute to the growing nationwide environmental health-tracking network. These state and national tracking systems will enable our public health system to recognize and respond to early warnings of environmental health problems.

Reducing exposures to diesel and automobile emissions. Poor air quality exacerbates asthma and other respiratory diseases and has been shown to increase risk for cancer. Hence, exposures to both diesel and gasoline exhaust should be minimized through public education and public polices that better protect children. A public awareness campaign could encourage people to not leave their cars and trucks idling. Vehicular emission testing could be reintroduced in Minnesota and ordinances regarding broken mufflers strictly enforced. Finally, public policies on transportation should focus less on automobiles and more on mass transit that can move more people with less pollution. Minnesota should also continue to reduce air pollution from industrial and energy-production point sources.

Chemical policy reform. The widespread dispersion of chemicals in our environment and their subsequent insidious effects on human health speaks to the failure of the current regulatory systems to protect public health. Nothing short of complete reform of the U.S. chemical policy system will achieve significant results. The European Union has initiated a system of chemical evaluation and regulation known as Registration, Evaluation and Authorisation of Chemicals or

REACH, which is designed to keep the most persistent, bioaccumulative and toxic (PBT) chemicals out of the environment. Such a system is needed in the U.S. In addition to phasing out PBTs, the regulatory system should:

- Require safer substitutes and solutions
- Ensure that the public and workers have full information and participate in policy-making
- Act on early warnings
- Require comprehensive safety data for all chemicals
- Take immediate action to protect communities and workers

Our economy and our modern lifestyle do not need to depend on the use of toxic chemicals. We can adopt a sustainable vision for our world and our future, one that considers "downstream" effects by designing products for an entire lifecycle. We can design products based on human need rather than corporate profits. For example, "green chemistry" is emerging as a promising new field for developing products and processes that do not endanger human health and ecosystems.

In summary, this study quantifies some of the economic impacts of environmental contributors to childhood diseases. It does not account for the significant human toll, as individuals and families grapple with developmental problems, birth defects and life-threatening cancer or asthma on a daily basis. In any public policy discussion, the health of our children should be of paramount concern. We hope that this analysis will help inform future policy discussions.

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