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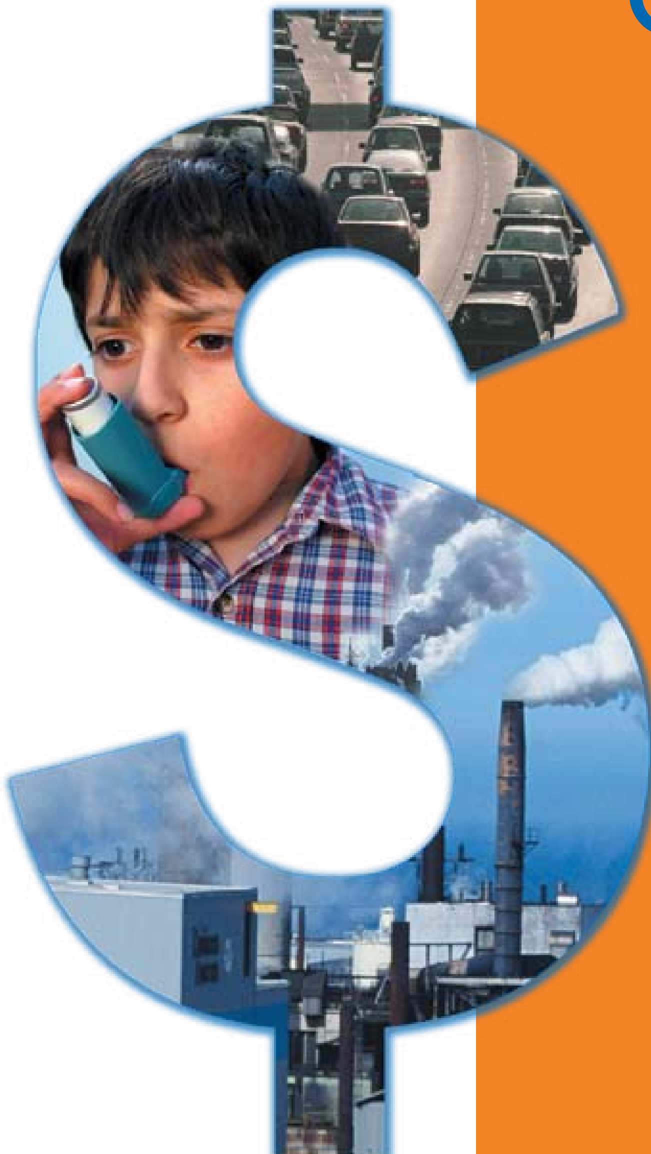

The Price of POLLUTION

Cost Estimates of Environmentally-Related Disease in Oregon

FEBRUARY 2008

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The Oregon Collaborative on Health and the Environment (CHE-OR) is an active network of organizations and individuals who share the basic goal of improving human health by reducing exposure to toxins in our bodies and the environment. CHE-OR moves the environmental health movement forward in Oregon by furthering productive debate and cooperative efforts, fostering productive action on human environmental health issues, and disseminating the best scientific information about these concerns. CHE-OR is a regional working group of the national Collaborative on Health and the Environment, which consists of over 2800 individual and organizational partners in 43 countries and 48 states.

The Oregon Environmental Council safeguards what Oregonians love about Oregon – clean air and water, an unpolluted landscape and healthy food produced by local farmers. For nearly 40 years we've been a champion for solutions to protect the health of every Oregonian and the health of the place we call home. We work to create innovative change on three levels: we help individuals live green; we help businesses, farmers and health providers thrive with sustainable practices; and we help elected officials create practical policy. Our vision for Oregon includes solving global warming, protecting kids from toxins, cleaning up our rivers, building sustainable economies, and ensuring healthy food and local farms.

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ACKNOWLEDGEMENTS

We gratefully acknowledge the assistance of the many people who worked to develop and support this project. This was a collaborative project between the Oregon Environmental Council and the Collaborative for Health and Environment, Oregon Chapter (CHE-OR).

The CHE-OR Research and Media Workgroup consists of: Pamela Brody-Heine (Principal, Eco Stewardship Strategies), Cheyenne Chapman, JD, LLM (Chemicals Policy Program Director, Oregon Center for Environmental Health), Molly Chidsey (Pollution Prevention Specialist, Multnomah County), Stephanie Farquhar, PhD (Associate Professor, School of Community Health, Portland State University), Renee Hackenmiller-Paradis, PhD, MPH (Program Director, Oregon Environmental Council), Sara Leverette (Outreach Program Director, Oregon Environmental Council), Catherine Thomsen, MPH (Project Lead, California Breast Cancer Research Program), Maye Thompson, PhD, RN, (Oregon Nurses Association), and Sara Wright, MPH (Environmental Health Program Director, Oregon Physicians for Social Responsibility).

In addition we would like to thank Sarah Doll who initiated this project, Stephanie Bernell, PhD, Associate Professor at Oregon State University who reviewed the methodology, and Jonathan Ingar, MD who reviewed the manuscript.

We are especially grateful for generous support from the Northwest Health Foundation which enabled the completion of the report.

The conclusions and recommendations in this report are those of the author and sponsoring organizations (Oregon Environmental Council and CHE-OR) and do not necessarily reflect the views and opinions of the project funders, Oregon State University, advisors, reviewers, or participants. The author and sponsors accept all responsibility for any errors or omissions in this work.

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EXECUTIVE SUMMARY

People develop disease and disabilities from many reasons. Some, like the common cold and malaria, are infectious and spread through viruses and bacteria. Many diseases and disabilities are due to genetics and are passed down from parents. Others are caused by pollutants and chemicals that we are exposed to in our professions, communities, schools, and homes. These diseases are called environmentally attributable diseases, because they are caused by health risks, such as lead, diesel, and mercury, in our surroundings, or environment. Environmentally attributable diseases are costly and frequently preventable.

Many environmentally attributable diseases place financial and social burdens on the citizens of Oregon. These include asthma, cancer, cardiovascular disease, birth defects, lead poisoning and neurobehavioral problems. According to the U.S. Environmental Protection Agency, a number of studies link the environment with disease and disability. For example, there is a strong correlation between air pollutants and asthma and between exposure to certain chemicals, such as benzene and certain pesticides, and the development of cancer (U.S. EPA, 2003). Another well established finding is the dangerous effect of lead exposure on children's neurological development including learning difficulties, lower IQ, and impaired cognition. Exposures to mercury, air pollution, and organic solvents have been linked to a wide range of birth defects, including heart defects, spina bifida, and cleft lip and palate.

Due to the many reasons that disease and disabilities develop, many diseases can in part be attributed to environmental exposures while also having non-environmental contributors. This study quantifies the economic cost of the environmentally-attributable components of asthma, cancer, cardiovascular disease, lead exposure, birth defects, and neurobehavioral disorders in Oregon. Estimates of those impacts are presented for both adults and children in those categories that span the age spectrum, and are presented for children only in those diseases and disabilities that primarily affect children. This report does not estimate the emotional and personal tolls that these diseases have on Oregonians and their families.

Based on our calculations, the estimate of the total costs of environmentally attributable disease and disability in the state of Oregon for adults and children combined is at least $1.57 billion annually with a range of $1.25 to 2.00 billion. The estimate of the total costs of environmentally attributable disease in the state of Oregon for children alone is $1.10 billion per year, with a range of $984.40 million to 1.29 billion.

Cost estimates per year for specific diseases are:

- Adult + Childhood asthma: $30.0 million
- Childhood asthma: $27.7 million
- Adult cardiovascular disease: $342.5 million
- Adult + Childhood cancer: $131.0 million
- Childhood cancer: $9.2 million
- Childhood lead exposure: $878.0 million
- Birth defects: $2.8 million
- Neurobehavioral disorders: $187.1 million

It is critical that Oregon legislative officials and decision makers implement policies to reduce environmental contributors to these diseases and disabilities. Subsequently, we recommend the following policy items: creation of a lead monitoring program in Oregon; research and outreach about effective alternatives to the most toxic pesticides; creating a birth defects registry; establishing a functional bio-monitoring and public health tracking system in Oregon; and adequately funding our state agencies such as Department of Environmental Quality and the Department of Human Services.

Ultimately, the environmental threats to the health of Oregonians—and the costs associated with the negative health impacts of these threats—will not be reduced until a common-sense chemical regulatory system is established that ensures only the safest chemicals are used in consumer products, manufacturing, and production. This comprehensive approach to chemical policy reform helps to ensure that our children's children do not inherit the health issues created today by certain hazardous chemicals and pollutants.

The primary methodologies used in this study are taken from the national estimates formulated by Landrigan, Schechter, Lipton, Fahs, and Schwartz (2002), and from state specific studies conducted by Massey and Ackerman (2003) in Massachusetts, by Davies and Hauge (2005) in Washington state, and by Schuler, Nordbye, Yamin, and Ziebold (2006) in Minnesota. We use Oregon data on rates of disease and costs whenever those data were available. In other cases, our cost estimates were extrapolated from national data.

INTRODUCTION

In contrast to many infectious diseases, many chronic diseases are increasing in prevalence. Most chronic diseases are those not caused by microbial agents such as viruses, bacteria, protozoan, and fungi. The increased incidence of chronic diseases is evidenced by rising rates of asthma, developmental problems, birth defects and some types of cancer (U.S. Environmental Protection Agency [EPA] 2003)[1]. While the causes of these diseases are complex and multi-factorial, a growing body of research confirms that environmental factors are important contributors (Schettler, Stein, et al., 2000). Environmental contributors are chemicals, frequently made by man or introduced by man into unintended parts of the environment, which are linked to negative health impacts. Examples of environmental contributors include lead, mercury, certain pesticides, diesel and gasoline exhaust, and PCBs.

The purpose of this study is to estimate how much money is spent in Oregon annually to pay for environmentally attributable diseases, which are largely preventable.

The growing burden of chronic diseases is imposing a significant economic cost on society. These costs include expenditures for health care and costs associated with lost productivity and diminished earning potential. Landrigan et al.(2002) conservatively estimate that certain childhood environmental diseases cost the U.S. an estimated $54.9 billion per year in 1997 dollars. This number does not include the emotional or social tolls that environmentally attributable diseases, such as childhood cancer or learning disabilities, have on individuals, families, and society as a whole.

The purpose of this study is to estimate how much money is spent in Oregon annually to pay for environmentally attributable diseases, which are largely preventable. The estimates in this study are based on conservative assumptions, providing a low end approximation of the actual economic impact of pollution-related disease and disability. Implementing policies that reduce exposures to environmental pollutants would lead to reduced healthcare costs in Oregon and significantly benefit the economy and the health of current and future Oregonians. It is up to us to leave a legacy of health to Oregon's children.

[1] Between 1980 and 1995, the percentage of children with asthma doubled. The frequency of childhood cancer has increased from 128 to 161 cases per million children between 1975 and 1998.

PREVIOUS STUDIES

In 2002, Landrigan et al. published a study estimating annual costs for childhood lead poisoning, asthma, and cancer. As part of this study, the authors established “environmentally attributable fractions” (EAFs), the proportion or fraction of each disease or disability that can be reasonably attributed to exposure to environmental contaminants. These EAFs were then used to estimate the cost burden of these diseases and disabilities attributable to toxins in the environment. The EAFs used in the Landrigan et al. study were developed by a panel of experts using data from the National Academy of Sciences. Utilizing these EAFs, Landrigan et al. estimated the total national environmentally attributable fractional costs for lead poisoning, asthma, cancer and developmental disabilities in children to be $54.9 billion/year in 1997 dollars.

Massey and Ackerman (2003) used the Landrigan model to evaluate the environmentally attributable costs of childhood cancer, asthma, neurobehavioral disorders, lead poisoning, and birth defects in Massachusetts. While both Landrigan et al. and Massey & Ackerman used similar methodology, they differed in the sources of health information and economic assumptions used.

Several other studies have utilized the methodology of both Landrigan et al. and Massey & Ackerman to evaluate the environmentally attributable costs of childhood and adult disease and disability in Washington (Davis & Hauge, 2005), Montana (Seninger, 2005), and for children only in Minnesota (Schuler et al., 2006).

STUDY METHODOLOGY

This analysis estimates the costs for the following diseases: adult and childhood asthma, adult cardiovascular disease, adult and childhood cancer, childhood lead exposure, birth defects, and childhood neurobehavioral disorders. For most of the analysis, we used Landrigan's framework, but we have also incorporated updated methods from more recent studies, including Massey & Ackerman (2003) and Schuler et al. (2006).

Environmentally attributable fractions (EAFs): This study utilizes the same EAFs used in the 2002 Landrigan et al. study. While there is growing scientific evidence that exposure to environmental contaminants plays a role in many diseases and disabilities, the precise proportions attributable to environmental contaminants will probably never be known. To take account of this uncertainty, the environmentally attributable fractions (EAFs) used in this study are conservative and are expressed as ranges, or environmentally attributable fraction ranges (EAFR). For each cost calculation, we provide a best estimate of the costs for the proportion of disease and disability attributable to environmental contaminants. The best estimate uses the consensus EAF arrived at by the panel of experts in the Landrigan et al. study to determine the estimated costs. The EAFRs are utilized to reflect the range of uncertainty in the underlying assumptions and beliefs of the consensus panel. The reasoning for EAFR and the best estimate for each disease and disability is discussed in the relevant section below.

The population of Oregon is approximately 1.22% of the national total.

Definition of environmental factors: For the purposes of this study, environmental factors are defined as air, water and soil pollutants, both naturally occurring and anthropogenic. Examples include metals such as lead and mercury; chemicals such as benzene, acrolein, and dioxins; pesticides used both agriculturally and in residences; particulate matter (PM) from the combustion of fossil fuels; and other toxic substances to which people may be exposed. This definition is used because the exposures included within it are potentially preventable through application of pollution prevention and public health approaches. This definition of environmental factors does not include diet, smoking, alcohol consumption, sexual behavior, infectious disease, accidents or injuries.

National cost estimates: Where national cost estimates have been used, they have been converted to state estimates based on population data taken from the U.S. Census Bureau. According to the 2000 Census, the total U.S. population was 281,421,906 and the population of Oregon was 3,421,399 (U.S. Census Bureau, 2006). Based on these data, the population of Oregon is approximately 1.22% of the national total.

Disease incidence/prevalence and cost data: We utilized actual Oregon 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 Oregon proportion of the U.S. population. This assumption does not take account of the possibility that the rates of disease and disability in Oregon may be different from national ones.

Data sources for each disease or disability are:

Asthma: Estimated total national costs, national cost-per-case data, Oregon-specific asthma prevalence for children, and Oregon-specific population <18 years of age.

Cardiovascular Disease: Estimated total national costs and Oregon-specific environmentally attributable fraction based on Oregon-specific air particulate measurements.

Cancer: National cost-per-case data, Oregon-specific cancer incidence, and estimated total national costs.

Lead Poisoning: National data on loss of lifetime earnings, national prevalence of lead poisoning, and Oregon-specific birth rates.

Birth Defects: National incidence and cost information, and Oregon-specific birth rates.

Neurobehavorial: National cost data, Oregon-specific costs for special education, and Oregon-specific data for the number of children enrolled in K-12 public schools.

Costs included: This study includes costs relating to both direct and indirect health care costs. Direct health care costs include inpatient, outpatient, and emergency room care, physician services, and medications. Indirect health care costs include lost work and school days, lost productivity due to premature death, loss of parental wages, and loss of future income due to loss of IQ. Not all of these costs were used in all estimates and for some disease categories additional costs were considered. The specific costs for each disease category are discussed in each relevant section.

Costs not included: This study does not include costs relating to legal and social services, childcare costs and lost productivity due to family illness and care. The lead exposure estimate does not take into account direct health care costs for screening and treatment, or indirect costs such as special education and juvenile justice services. We do not include the costs of a number of adverse social outcomes associated with lower IQs such as poverty, receiving welfare, dropping out of high school, low-weight birth complications, and involvement in the criminal justice system (Muir & Zegarac, 2001). These costs were excluded because of the limited amount of reliable or disease specific estimates associated with these costs.

Inflation factor: This study utilizes the Department of Labor's Consumer Price Index Inflation Calculator to calculate cost estimates in 2007 dollars. The inflation factor can be found at: http://www.bls.gov/cpi/home.htm. This Inflation Calculator is a generic national inflation calculator, and it does not take account of the fact that the estimated costs in this study may have risen at a different rate than the national inflation rate. Additionally, it does not take into account that inflation in Oregon may have risen at a different rate than the national rate.

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

Asthma

Asthma is a chronic inflammatory disease of the airways. Asthma has been associated with a number of environmental pollutants including ozone, nitrogen and sulfur oxides, dust mites, second hand smoke, asbestos, and particulate matter (Etzel, 2003; Institute of Medicine, 2000). Although there are genetic factors which predispose people to the development of asthma, exposure to certain environmental factors may contribute significantly to the risk of developing the disease. Once somebody has asthma, exposure to certain environmental factors can increase the likelihood of suffering from attacks. Air pollutants in both indoor and outdoor environments are known contributors to asthma attacks (U.S. EPA, 2007).

Over the past decade, the prevalence of asthma in both children and adults has increased in the United States. Asthma prevalence in Oregon continues to rise and is considerably higher than the U.S. average of 7.2% (Moorman et al., 2007). Current asthma prevalence in 2005 was 9.9% in Oregon adults aged 18 or older and 8.4% in Oregon children less than 18 years of age (Oregon Department of Human Services [Oregon DHS], 2007). Accordingly, approximately 345,000 Oregonians currently have asthma, including almost 274,000 Oregon adults and nearly 73,000 Oregon children.

Following the methodology of Landrigan et al. and Massey & Ackerman, we estimate the environmentally attributable costs of adult and childhood asthma in Oregon.

Asthma prevalence in Oregon continues to rise and is considerably higher than the U.S. average of 7.2%.

Costs of Childhood Asthma

For asthma, Landrigan et al. did not derive their estimate of national asthma costs on a cost-per-case basis as they did with other diseases. Instead, they based their estimated costs of childhood asthma on an existing estimate of total national costs from the methods used by Chestnut, Mills, & Agras (2000) and Weiss, Gergen, & Hodgson (2000). Using these studies, Landrigan et al. estimated the total annual costs of childhood asthma to be $6.6 billion in 1997 dollars, comprising $4.6 billion in direct health care costs and $2.0 billion in indirect costs. Direct health care costs include inpatient, outpatient, and emergency room care, physician services, and medications. Indirect health care costs include lost school days and lost productivity due to premature death.

Massey and Ackerman (2003) use three methods to calculate the costs of childhood asthma in Massachusetts. One method is based on the costs of acute asthma hospitalization. A second method uses the costs of asthma in the United States Environmental Protection Agency's Cost of Illness Handbook (U.S. EPA COI; p. IV.2-3) which estimates health care costs only. The third method, that of Landrigan et al., takes account of direct health care costs and indirect costs associated with lost productivity.

This study uses both Landrigan et al.'s method and Massey and Ackerman's EPA-based estimate to calculate the costs of childhood asthma in Oregon.

Asthma

Environmentally Attributable Factor Range (EAFR) and Best Estimate:
Landrigan et al. convened a panel of experts in environmental and pulmonary medicine to estimate the portion of childhood asthma attributable to environmental contaminants. The expert panel estimated that 10-35% of acute exacerbations of childhood asthma are related to outdoor, non-biologic pollutants from sources such as vehicle exhaust and emissions from stationary sources. Asthma exacerbation due to household allergens, molds, second-hand smoke, infections or climatic conditions were not included in the EAFR. Both Landrigan et al. and Massey and Ackerman used an EAFR of 10-35% for childhood asthma. Landrigan et al. used a best estimate of 30%.

Cost and Prevalence:
Following are two methods for calculating childhood asthma costs in Oregon. The first is based on the methods of Landrigan et al., and the second utilizes the methods of Massey and Ackerman.

i) Landrigan et al. method

This estimate of the costs of childhood asthma attributable to environmental contaminants in Oregon is based on the following assumptions:

- Oregon comprises 1.22% of the U.S. population;
- Estimate of total annual U.S. national costs of childhood asthma used by Landrigan et al. of $6.6 billion in 1997 dollars updated to $8.6 billion in 2007 dollars;
- Direct health care costs constitute 69.7% of total costs;
- Indirect health care costs constitute 30.3% of total costs; and
- An EAF of 30% and a range of 10-35%.

*Annual costs of asthma in Oregon = $8.6 billion * 1.22% = $104.9 million in 2007 dollars.*

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

- EAF 0.10 = $10,492,000
- EAF 0.30 = $31,476,000
- EAF 0.35 = $36,722,000

Using these assumptions, the best estimate of the annual cost of childhood asthma attributable to environmental contaminants in Oregon is $31.5 million in 2007 dollars (comprising an estimated $22 million in direct health care costs and $9.5 million in indirect costs), with a range of $10.5-36.7 million.

ii) Massey and Ackerman method

Another method for calculating the cost of childhood asthma is to use the approach of Massey & Ackerman. In their Massachusetts study, Massey and Ackerman used the U.S. EPA Cost of Illness Handbook figures for annual costs per case, updated from 1999 dollars to 2002 dollars. Then they used Massachusetts' prevalence data and the EAFs to calculate the annual cost of environmentally attributable fraction:

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

This estimate of the costs of childhood asthma attributable to environmental contaminants in Oregon is based on the following assumptions:

- 8.4% of all children (<18 years) in Oregon have asthma;
- 846,256 children (<18 years) in Oregon based on U.S. Census projections (U.S. Census);
- 71,085 children with asthma in Oregon;
- Annual costs = $1,116 per case; and
- A best estimate of 30% and an EAFR of 10-35%.

We then apply the annual cost-per-case data and figures from the U.S. EPA Cost of Illness Handbook (updated from 1999 dollars to 2007 dollars):

Annual cost-per-case for ages 4 to 5 years = $761.16 in 1999 dollars = $960.25 in 2007 dollars

Annual cost-per-case for ages 6 to 17 years = $904.90 in 1999 dollars = $1,141.59 in 2007 dollars

Since EPA's estimates were separated into costs for ages 4 to 5 years and costs for ages 6 to 17 years, and the Oregon DHS current asthma prevalence is for all children less than 18 years, we averaged the costs out over the whole time period:

*[($960.25 *2 years) + ($1,141.59 *12 years)]/(14 years) = $1,115.68 per case for ages 4 to 17 years.*

We apply this as the estimated costs-per-case for all cases less than 18 years:

(71,085 cases)($1,116 per case) = $79,330,860 total cost for all Oregon childhood asthma cases.*

Using the EAFs of 0.10, 0.30 and 0.35 gives the following results:

- EAF 0.10 = $7,933,086
- EAF 0.30 = $23,799,258
- EAF 0.35 = $27,765,801

Using these assumptions, the best estimate of the annual costs of childhood asthma attributable to environmental contaminants in Oregon is $23.8 million in 2007 dollars with a range of $7.9-27.8 million.

Averaging the best estimates, the environmentally attributable costs of childhood asthma in Oregon are estimated at $27.65 million per year, with a range of $7.9 to $36.7 million.

Costs of Adult and Childhood Asthma

A 1997 report by Smith, Malone, Lawson, Okamoto, Battista, & Saunders estimated that the national cost and resource utilization by adult and child asthma sufferers totaled $5.8 billion per year in 1994 dollars. The estimated direct costs were $5.1 billion (1994 dollars) which included costs related to prescription medications, office visits, outpatient hospital visits, emergency room visits, and hospital stays. The estimated indirect costs were $673 million (1994 dollars) which included costs associated with lost work productivity.

This cost estimate for adult and childhood asthma in Oregon attributable to environmental contaminants is based on the following assumptions:

- $5.8 billion in asthma related health care costs in 1994 dollars updated to $8.2 billion in 2007 dollars;
- Direct health care costs of $5.1 billion in 1994 dollars updated to $7.2 billion in 2007 dollars;
- Indirect health care costs of $673 million in 1994 dollars updated to $954.5 million in 2007 dollars; and
- Costs in Oregon are 1.22% of the national costs (based on population).
- An EAF of 30% and a range of 10-35%,[2]

[2] These proportions are based on the proportions used for childhood asthma. There are no estimates of the exact proportions of adult and child asthma attributable to environmental contaminants.

Using these assumptions, the annual costs of adult and childhood asthma in Oregon are $100.0 million in 2007 dollars. This estimate is comprised of $87.8 million in direct costs and $11.6 million in indirect costs.[3]

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

- EAF 0.10 = $10,000,000
- EAF 0.30 = $30,000,000
- EAF 0.35 = $35,000,000

Using these assumptions, the best estimate of the annual costs of adult and childhood asthma attributable to environmental contaminants in Oregon is $30.0 million in 2007 dollars (comprising an estimated $26.3 million in direct health care costs and $3.5 million in indirect costs), with a range of $10.0 -35.0 million.

The environmentally attributable costs of adult and childhood asthma in Oregon are estimated at $30.0 million per year, with a range of $10.0 to $35.0 million.

[3] The sum of these estimates does not total $100.0 million due to rounding.

Direct, Indirect and Intangible Costs

There are three types of costs that can be measured when determining the total costs associated with a particular disease or disability:

Direct Costs are the value of resources used in the treatment, care, and rehabilitation of person with the disease or disability. Examples of direct costs include expenditures for hospitalization, outpatient clinical care, nursing home care, and home health care; services of primary physicians and specialists, dentists, and other health practitioners; medications; and rehabilitation counseling and other rehabilitation cost such as for prostheses, appliances, eyeglasses, hearing aids, and other devices to overcome impairments resulting from illness or disability.

Indirect Costs represent the value of economic resources lost because of disease-related disability or premature mortality. Examples of indirect costs include loss of opportunity for promotion or education, lost parental wages, loss of future income due to loss of IQ, and loss of future earnings due to premature death.

Intangible Costs are the costs associated with emotional anxiety and fear, with physical pain and suffering, and with deterioration in other dimensions of health-related quality of life including emotional and psychological impacts on families, friends, and co-workers.

In this study we used both direct and indirect costs in our calculations. We did not include the intangible costs associated with particular diseases or disabilities.

Cardiovascular Disease

In May 2004, the American Heart Association acknowledged that chronic exposure to air pollution contributes to the development of cardiovascular diseases (heart disease and stroke) (Brook et al., 2004). Epidemiological studies conducted in the past ten years have shown a consistent, increased risk for cardiovascular events, including cardiac and stroke deaths, related to short- and long-term exposure to present-day concentrations of pollution, especially particulate matter (Brook et al., 2004). Microscopic fine air particulate matter, or PM2.5, has been shown as an important risk factor for mortality from lung cancer and cardiopulmonary disease (Pope et al., 2002). Particulate matter is a byproduct of burning fossil fuels, in particular the burning of diesel gasoline. Many sources of PM2.5 can be reduced through pollution controls, such as the retrofitting of diesel engines or by increasing air quality standards for machines that produce PM2.5.

Cost Estimates: Using cost estimates based on data from the American Heart Association (2007), we calculated an estimate of the environmentally attributable costs of cardiovascular disease in Oregon.

According to the 2006 Oregon Heart Disease and Stroke Report, cardiovascular disease is the leading cause of death in Oregon and accounted for 34% of all deaths in 2003 (Dahlin, Leman & Ngo, 2006). The most common causes of cardiovascular disease mortality are heart attack and stroke. In addition to the more than 10,000 deaths caused annually by all forms of cardiovascular disease, thousands of Oregonians are hospitalized each year from cardiovascular disease related events. According to the State Hospital Discharge Index, there were 32,000 hospitalizations of Oregonians for heart disease, stroke and related disease in 2004, resulting in $781 million in hospital costs (Dahlin et al., 2006). Hospitalization costs, however, reflect only a portion of the full financial burden of cardiovascular disease. Costs related to outpatient care, prescription medications, rehabilitation, long-term care, and loss of productivity are not included in the above totals and would greatly increase the estimates of the economic burden from cardiovascular disease in Oregon.

According to the 2006 Oregon Heart Disease and Stroke Report, cardiovascular disease is the leading cause of death in Oregon and accounted for 34% of all deaths in 2003.

The American Heart Association estimated that in 2007 the national costs of cardiovascular disease were $431.8 billion. This figure includes direct health care expenditures (the cost of physicians and other professionals, hospital and nursing home services, the cost of medications, home health care and other medical durables) and indirect costs (lost productivity resulting from morbidity and mortality). The direct health care costs constitute $283.2 billion while indirect costs constitute $148.6 billion of the total.

Environmentally Attributable Factor Range (EAFR) and Best Estimate: Pope et al. (2002) found that for every 10μg/m^3 increase of fine particulates, cardiopulmonary deaths rose by 6%. A 1996 report (Sheiman Shprentz, 1996) used similar mortality risk factors for cardiopulmonary diseases to generate point and range

Cardiovascular Disease

estimates of the annual adult cardiopulmonary deaths attributable to air pollution in 239 U.S. cities.

The data in Sheiman Shprentz (1996) addressed three Metropolitan Statistical Areas in Oregon, including Eugene-Springfield, Medford, and Portland. The study showed that in 1989 there were a total of 7151 cardiopulmonary deaths in these cities and that a total of 492 of these were likely due to particulate air pollution. This is equivalent to 6.8% of the cardiopulmonary mortality in these cities. Thus, being conservative, this study assumes an EAFR for cardiovascular mortality from particulate air pollution of between 4-9% in Oregon. We use a best estimate of 6.5%, the median of the EAFR. This EAF only considers air-pollution associated mortality. It is likely that cardiovascular disease also has associated morbidity from air pollution not accounted for in this estimate. Furthermore, a number of recent studies have shown that other environmental pollutants, such as mercury, can negatively impact cardiovascular health (Virtanen et al., 2005; Sorensen, Murata, Budtz-Jorgensen, Weine, and Grandjean 1999).

Costs in Oregon

This estimate of the costs of cardiovascular disease in Oregon attributable to environmental contaminants is based on the following assumptions:

- American Heart Association national estimate of $431.8 billion in 2007 dollars;
- Oregon constitutes 1.22% of the U.S. population;
- Direct health care costs constitute 65.6% of total costs;
- Indirect health care costs constitute 34.4% of total costs; and
- An EAF of 6.5% and a range of 4-9%.

*Annual costs of cardiovascular disease in Oregon = $431.8 billion * 1.22% = $5.27 billion in 2007 dollars.*

Applying the EAFs of 0.04, 0.065, and 0.09 yielded the following results:

- EAF 0.04 = $210,800,000
- EAF 0.065 = $342,550,000
- EAF 0.09 = $474,300,000

This cost estimate is very conservative since the EAF only considers the particulate air pollution related mortality of cardiovascular disease.

Using these assumptions, the best estimate of the annual costs of cardiovascular disease attributable to environmental contaminants in Oregon is $342.5 million in 2007 dollars (comprising an estimated $224.7 million in direct health care costs and $117.8 million in indirect costs), with a range of $210.8-474.3 million.

Cancer

Nearly one in two men and more than one in three women in the United States will be diagnosed with cancer at some point in his or her lifetime (Clapp, Howe, & Lefevre, 2005). In 2001, cancer accounted for 24% of all deaths in Oregon, making it the second leading cause of death in the state (Oregon DHS, 2004). The most commonly diagnosed cancers in Oregon include breast cancer, prostate cancer, and lung cancer. In 2002 Oregon had the second highest melanoma mortality rate in the nation and Oregon is consistently among the nation's top five states for incidence of breast cancer (Oregon Partnership for Cancer Control, 2005). Approximately three-quarters of the nation's cancer deaths are associated with environmental factors, broadly defined to include smoking, diet and infectious disease, as well as pollution, some chemicals and radiation (American Cancer Society, 2006). Our estimates, however, do not include the impact of smoking, diet, and infectious disease in the calculations.

Childhood Cancer

The most frequently occurring childhood cancers nationwide and in Oregon are leukemias, brain cancer, and other central nervous system cancers (American Cancer Society, 2007; Riddell & Pliska, 2007). There is evidence that all of these cancers are associated with environmental contaminants (Janssen, Solomon, & Schettler, 2004). Chemicals in outdoor air such as benzene and 1,3-butadiene have been associated with elevated rates of cancer in children (Steffen, Auclerc, & Auvrignon, 2004; Crosignani et al., 2004; Knox, 2005). Many studies have demonstrated that pesticide exposure is associated with an increased risk of childhood cancer, with several studies reporting significantly increased risk for leukemia and cancers of the brain among children exposed to pesticides in and around the home (Daniels, Olshan, & Savitz, 1997; Zahm & Ward, 1998; Menegaux et al., 2006; Ma et al., 2002). In 2004, there were 165 cancers diagnosed in Oregon children (0-20 years of age) (Riddell & Pliska, 2007). To estimate the costs of childhood cancer in Oregon, we followed the methods and assumptions of Landrigan et al.

Method of Landrigan et al.

Landrigan et al. derived an estimate of national costs from childhood cancer on a cost-per-case basis. They estimated that the national average cost per child was approximately $623,000 in 1997 dollars. This estimate includes direct health care costs (physician fees, inpatient services, outpatient services) of $509,000 and indirect costs (loss of parental wages,[4] loss of future income due to loss of IQ,[5] cost of treating a second primary cancer[6]) of $114,000.

Landrigan et al. then multiplied this cost by the annual incidence of 7,722 cases of cancer per year for children less than 15 years old to yield an estimate of $4.8 billion for annual costs of childhood cancer nationwide. They then added costs of mortality as a lump cost of $1.8 billion (the costs of premature loss of life due to primary and secondary cancer in the cohort of children), which is roughly $233,100 in additional costs per case in 1997 dollars. This leads to an estimated annual cost of childhood cancer of $6.6 billion in 1997 dollars.

[4] Loss of parental income estimated assuming five days of lost wages per seven child hospital days.

[5] Loss of IQ was estimated assuming that cranial irradiation used to treat brain cancer will reduce IQ an average of 2.8 points in each child treated, corresponding to a loss of lifetime earnings of $60,471 (Landrigan et al., 2002).

[6] Subsequent primary cancers are more common in children that have had one primary cancer. The costs of treating subsequent primary cancers were estimated using the same costs as the first primary cancer, adding in the present value of those future costs at 7.46% (as explained in Landrigan et al., 2002).

Nationally, the cost per child is equivalent to $815,830 in 2007 dollars, the costs of premature death are equivalent to $2.36 billion in 2007 dollars, and the total estimated annual cost of childhood cancer nationally is equivalent to $8.66 billion in 2007 dollars. This gives a cost per case estimate of $1.12 million in 2007 dollars when the costs of mortality are included.

Environmentally Attributable Fraction: To assess the environmentally attributable fraction of childhood cancer, Landrigan et al. convened a panel of experts in pediatric oncology, epidemiology, and environmental medicine. Based on the scientific evidence, the panel concluded that EAFs of 2, 5, and 10% most accurately reflected the data at the time. These numbers are conservative since there is a great deal of uncertainty regarding the environmental risk factors for cancer. In addition, these numbers do not account for childhood environmental exposures that lead to cancer development later in life. In this study, we will use an EAF of 5% as our best estimate and a range of 2-10%.

Costs in Oregon

This estimate of the costs of childhood cancer in Oregon attributable to environmental contaminants is based on the following assumptions:

- Oregon annual incidence is 165 childhood cancer diagnoses per year (0-20 years of age) (Riddell & Pliska, 2007);
- Total cost per case is $1.12 million per case per year in 2007 dollars; and
- An EAF of 5% and a range of 2-10%.

Annual costs of childhood cancer in Oregon = $184.8 million in 2007dollars.

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

- EAF 0.02 = $3.7 million
- EAF 0.05 = $9.2 million
- EAF 0.10 = $18.5 million

Using these assumptions, the best estimate of the annual costs of childhood cancer attributable to environmental contaminants in Oregon is $9.2 million per year, with a range of $3.7 to $18.5 million.

These costs underestimate the total yearly costs of cancer because the calculations only consider the costs of new cases. The costs for the ongoing management and treatment of all existing childhood cancer cases (prevalence) are not available for Oregon and therefore are not included.

Adult and Childhood Cancer

Following the methodology of Davis and Haugh (2005) and Landrigan et al. (2002), and using data from the National Heart Blood and Lung Institute (NHLBI), we estimate the environmentally attributable costs of adult and childhood cancer in Oregon.

Cost Estimates: The NHLBI estimated the direct and indirect cost of cancer in the U.S. in 2003 (NHLBI, 2004). According to this study, the costs for 2003 were expected to total $189.8 billion including $69.4 billion in direct health care costs (personal heath care expenditures for hospital and nursing home care, drugs, home care and physician and other professional services), $16.9 billion in indirect morbidity costs (lost productivity), and $103.5 billion in premature mortality costs.

This total of $189.9 billion in 2003 dollars is equivalent to $214.8 billion in 2007 dollars.

EAFR and Best Estimate: By some estimates, 75-80% of all cancer in the U.S. is in part due to broadly defined environmental factors including tobacco, diet, infectious agents, radiation, occupational exposure, and environmental contaminants (Davis & Muir, 1995). Two studies have estimated that exposure to environmental contaminants alone in air, water, and food are responsible for approximately 1-5% of all cancer mortality (Doll & Peto, 1981; Doll, 1998).

Following the methodology of Davies & Hauge (2005), this study uses a conservative best estimate of 5% and an EAFR for combined cancer morbidity and mortality of 2-10%.

Costs in Oregon
This estimate of the costs of cancer in Oregon attributable to environmental contaminants is based on the following assumptions:

- The NHLBI estimate is updated to $214.8 billion in 2007 dollars;
- The cancer costs in Oregon are 1.22% of the national costs (based on population); and
- An EAF of 5% and a range of 2-10%.

Based on these assumptions, the annual costs of cancer in Oregon is $2.62 billion in 2007 dollars.

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

- EAF 0.02 = $52,400,000
- EAF 0.05 = $131,000,000
- EAF 0.10 = $262,000,000

Using these assumptions, the best estimate of the annual costs of cancer attributable to environmental contaminants in Oregon is $131 million in 2007 dollars (comprising $47.9 million in direct health care costs, $11.6 million in indirect morbidity costs, and $71.4 million in indirect premature mortality costs[7]), with a range of $52.4-262.0 million.

The environmentally attributable costs of adult and childhood cancer in Oregon are estimated at $131 million per year, with a range of $52.4 to $262 million.

Lead Exposure

Lead exposure causes numerous health effects including lowered IQ, shortened attention span, decreased coordination, learning disabilities, and neurological development problems. These adverse affects can occur below the threshold of harm blood lead level of 10 micrograms/deciliter set by the Centers for Disease Control and Prevention (Canfield, Henderson, Cory-Slechta, Cox, Jusko & Lanphear, 2003). This is the number above which doctors and state agencies may step in to help identify lead sources to reduce blood lead levels in children.

Historically, lead has been found in a number of consumer products, such as paint, plumbing, and gasoline. This legacy lives on today in children's toys, ceramics, vinyl products, and certain jewelry. The government continues to devote significant resources annually to remediate the long term impacts and presence of lead.

Our estimate of the costs associated with the full range of behavioral and cognitive effects of lead poisoning in Oregon is based on the methodology used by Landrigan et al. To account for the lifetime costs associated with lower earning potential caused by lead poisoning, Landrigan et al. used data on the relationship between the loss of IQ due to lead-related decreases in IQ and expected lifetime earnings. This method assigns to a birth cohort an average amount of money they would be expected to earn in a lifetime. This method is based on lost income and does not take account of direct health care costs for screening and treatment, or indirect costs such as special education and juvenile justice services.

Following Landrigan, we assume an EAF of 100%, as all cases of lead poisoning are reasonably assumed to be of environmental origin.

[7] The sum of these estimates does not total to $131 million due to rounding.

Lead Exposure

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

(mean blood lead level of 1-5 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%)

We used the CDC's latest National Health and Nutrition Examination Survey (NHANES) data on average blood lead levels of 1.9 µg/dL for 1- to 5 year-olds (Schwemberger et al., 2005). There are no Oregon specific data on blood lead levels available.

Based on a study by Canfield et al. (2003), we assumed a blood lead level of 1µg/dL translates into a loss of 0.46 IQ points. This estimates that a blood lead level of 1.9 µg/dL results in a loss of 0.874 IQ points (1.9 * 0.46).

According to Landrigan et al.'s methodology, we assumed that a loss of one IQ point equals the loss of 2.39% of lifetime earnings; therefore a loss of 0.874 IQ points equals a loss of 2.09% lifetime earnings.

The Bureau of Labor Statistics has determined that the expected lifetime earnings for 5 year old boys as $881,027 and for 5 year old girls as $519,631 in 1997 dollars (Bureau of Labor Statistics, 1999). These estimates adjusted are equivalent to $1,153,717 for boys and $680,464 for girls in 2007 dollars.

Oregon's 2005 birth cohort consisted of 45,905 babies (Oregon DHS, 2005a). Since Oregon does not track sex ratios of live births, we calculated the sex ratio of the 2005 birth cohort using 2000 U.S. Census data showing that Oregon's population is 49.6% male and 50.4% female (U.S. Census Bureau, n.d.). Assuming that these same ratios are present at birth, the 2005 birth cohort consisted of 22,768 boys and 23,136 girls.

Our estimate of the annual lost lifetime earnings due to lead poisoning are based on the following assumptions:

- Current average blood lead level of 1-5 year olds in U.S. is the same as 1999-2002 data: 1.9mg/dL;
- Children in Oregon have average blood lead levels equivalent to national levels;
- Loss of 0.46 IQ points per 1 mg/dL blood lead;
- 2.39% loss of life time earning per IQ point;
- Lifetime earnings lost for boys $1,153,717 and for girls $680,464 (2007 dollars);
- Oregon's 2005 birth cohort: 45,905;
- Oregon sex ratios: 49.6% boys, 50.4% girls resulting in 22,768 boys and 23,136 girls in born in 2005; and
- EAF = 100%

Costs in Oregon
Lost lifetime earnings for Oregon boys/girls:
=Expected lifetime income for boys/girls * number of boys/girls in Oregon 2005 birth cohort * 2.09% lifetime loss * EAFR 1.0

*Lost lifetime earnings for Oregon boys: ($1,153,717) * (22,768) * (2.09%) * (EAF 1.0) = $549.0 million*

*Lost lifetime earnings for Oregon girls: ($680,464) * (23,136) * (2.09%) * (EAF 1.0) = $329.0 million*

Lost lifetime earnings for Oregon boys and girls together:

=$549.0 million + $329.0 million = $878.0 million.

Lost lifetime earnings due to lead exposure in Oregon are estimated at $878.0 million per year.

Birth Defects

According to the CDC, approximately 120,000 babies in the United States are born each year with birth defects—one out of every 33 (Centers for Disease Control and Prevention [CDC], 2007). A birth defect is an abnormality of structure, function, or metabolism (body chemistry) present at birth that results in physical or mental disabilities or death. Several thousand different birth defects have been identified. For the past 20 years, birth defects have been the leading cause of death in the first year of life (Martin, Kochanek, Strobino, Guyer, & MacDorman, 2003). Genetic and environmental factors, or a combination of these factors, can cause birth defects. However, the causes of about 70% of birth defects are unknown (CDC, 2007).

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. Several environmental contaminants cause birth defects when pregnant women are exposed to high concentrations, including mercury and polychlorinated biphenyls (PCBs); for example, fetal mercury poisoning can cause deafness and blindness, and fetal exposure to high levels of PCBs causes skin and nail abnormalities (Harada et al., 1999; Rogan, 1982). Epidemiological studies have demonstrated associations between birth defects and a number of prenatal exposures. Multiple studies have linked women's occupational exposure to organic solvents to increased risk of birth defects such as heart defects and cleft lip and palate (McMartin, Chu, Kopecky, Einarson, & Koren, 1998). Studies evaluating the role of pesticides have found an association between maternal and paternal exposure to pesticides and increased risk of offspring having birth defects (U.S. EPA, 2003). A 2002 study by Ritz et al. found links between certain heart-related birth defects and ambient air pollution.

Mercury and PCBs cause birth defects when pregnant women are exposed to high concentrations.

Cost Estimates: This study estimates the costs of structural birth defects (i.e., malformed limbs, heart problems, facial abnormalities) attributable to environmental contaminants in two ways. The first estimate is based on a CDC publication on the national costs of a list of eighteen defects, and the second estimate is based on the total costs of a list of twelve birth defects developed by the Trust for America's Health. Both estimates are based on the same EAFR and best estimate.

A 1995 CDC study estimated the annual cost of 18 birth defects[8] at $8 billion in 1992 dollars for a single year's birth cohort (Waitzman, Romano, Scheffler, & Harris, 1995). Direct health care costs were estimated to be $2.1 billion and indirect costs were estimated to be $5.9 billion. Indirect costs include developmental services, special education and lost future income and reduced earning potential due to the disorders. Inflated to 2007 dollars the total cost rises to $12.0 billion. In order to avoid double-counting costs for cerebral palsy, which is already included in "neurobehavioral disorders" (the next section of this report), the cost for cerebral palsy is omitted here. In addition, the costs for Down syndrome, a condition not attributable to environmental factors is deducted:

($12.0 billion) – ($6.3 billion)[9] = $5.7 billion

[8] The eighteen birth defects included: 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.

[9] Per Waitzman et al., 1995 costs for cerebral palsy were $2.4 billion and $1.8 billion for Down syndrome in 1992 dollars. Adjusted to 2007 dollars, these costs are $3.6 billion and $2.7 billion respectively, for a total of $6.3 billion.

Birth Defects

The Trust for America's Health estimated that in 2001 the lifetime costs associated with twelve selected birth defects[10] in a single year's birth cohort in Oregon was $84 million (Trust for America's Health, n.d.; Harris & Levy, 1997). This is equivalent to $99.7 million in 2007 dollars. While the direct and indirect costs are not given separately, this estimate includes costs of medical treatment, developmental services, special education and lost productivity resulting from the affected children's death or disability. This estimate does not included lost wages of family members caring for children with birth defects, psychosocial costs, or the effects of inflation on health care costs. Deducting the costs for Down syndrome, a condition not attributable to environmental factors, the Trust for America's Health's total cost figure for Oregon is:

($99.7 million) - (22.4 million)[11] = $77.3 million

Environmentally-Attributable Fraction Range (EAFR) and Best Estimate: A 1999 study estimated that 5-10% of all birth defects are associated with environmental and occupational exposures to chemicals during pregnancy (Smith, Corvalan, & Kjellstrom, 1999). A 2006 report from the World Health Organization estimated that 5% of all birth defects are attributable to environmental causes, with a range of 2-10% (Pruss-Ustun & Corvalan, 2006). Based on these two studies, we estimate an EAFR of 2-10% and use a conservative best estimate of 4% to calculate the cost of birth defects from environmental contaminants.

Costs in Oregon

Following are two methods for calculating environmentally attributable birth defect costs in Oregon. The first is based on cost data from the CDC, and the second utilizes cost data from the Trust for America's Health. Because Oregon-specific information on the incidence of birth defects is unavailable, we applied the Oregon proportion of annual U.S. births to the CDC's and Trust for America's Health annual cost estimates to arrive at an Oregon cost estimate. This is the same methodology used by Davies and Haugh (2005) in the Washington study and Schuler et al. (2006) in the Minnesota study.

i. CDC Study Estimate

These estimates of the yearly costs of birth defects in Oregon attributable to environmental contaminants are based on the following assumptions:

- There were 4,143,000 births in the U.S. in 2005 (Munson & Sutton, 2006);
- There were 45,905 births in Oregon in 2005, which is 1.1% of the national total;
- The rate of birth defects in Oregon is comparable to national rates;
- CDC's estimate of total annual costs for 16 of 18 birth defects in 2007 dollars: $5.7 billion; and
- An EAF of 4% and a range of 2-10%.

*The annual costs of birth defects in Oregon = ($5.7 billion) * (0.011) = $62.7 million.*

Applying the EAFs of 0.02, 0.04, and 0.1 yielded the following results:

- EAF 0.02 = $1,254,000
- EAF 0.04 = $2,508,000
- EAF 0.10 = $6,270,000

Under these assumptions, the best estimate of the cost of birth defects in Oregon attributable to environmental contaminants is $2.5 million in 2007 dollars with a range of $1.3 to $6.3 million.

[10] The twelve birth defects included: spina bifida, truncus arteriosus, transposition of the great vessels, teratology of Fallot, cleft lip or palate, esophageal atresia/tracheo-esophageal fistula, colon, rectal or atresia, reduction defect-upper limbs, reduction defect-lower limbs, gastroschisis, diaphragmatic hernia, and Down syndrome.

[11] Per Waitzman et al., 1995 costs for Down syndrome were $1.8 billion in 1992$. This is approximately 22.5% of the total birth defect associated costs for 1992. Assuming Down syndrome comprises 22.5 % of birth defect associated costs in 2007 gives an estimated $22.4 million of Down syndrome costs in Oregon.

ii. Trust For America's Health Estimate

These estimates of the yearly costs of birth defects in Oregon attributable to environmental contaminants are based on the following assumptions:

- The Trust for America's Health's estimate in Oregon for 11 of 12 birth defects in 2007 dollars: $77.3 million; and
- An EAF of 4% and range of 2-10%.

Applying the EAFs of 0.02, 0.04, and 0.1 yielded the following results:

- EAF 0.02 = $1,546,000
- EAF 0.04 = $3,092,000
- EAF 0.10 = $7,730,000

Under these assumptions, the best estimate of the cost of birth defects in Oregon attributable to environmental contaminants is $3.1 million in 2007 dollars with a range of $1.5 to $7.7 million.

These two estimates, which are fairly similar, are likely to underestimate the actual costs of environment-related birth defects. Many birth defects that have been linked with exposure to environmental contaminants, such as genitourinary defects, are not included in either one of these two cost estimates.

Averaging the best estimates, the environmentally attributable costs of birth defects in Oregon are estimated at $2.8 million per year, with a range of $1.3 to $7.7 million.

Neurobehavioral Disorders

Neurobehavioral disorders, which include attention deficit hyperactivity disorder (ADHD), autism, and a variety of learning disabilities, affect 3-8% of U.S. children (Buxbaum, Boyle, Yeargin-Allsopp, Murphy, & Roberts, 2000; Kiely, 1987). Exposure to metals such as lead, mercury, and cadmium, as well as certain pesticides and organic solvents during pregnancy and childhood can impact normal brain development and function (Gilbert & Grant-Webster, 1995; Schettler, et al. 2000).

Cost Estimates: Neurobehavioral disorders lead to costs for both medical treatment and special education. Following the methodology of Landrigan et al., we calculate an estimate of the costs of neurobehavioral disorders in Oregon.

Excluding costs specific to lead exposures, Landrigan et al. estimated the costs for three neurobehavioral disorders—mental retardation, autism, and cerebral palsy. Their estimate uses yearly incidence data from the CDC (Buxbaum et al., 2000) and lifetime cost-per-case estimates based on cost estimates developed by Honeycutt, Dunlap, Chen and al Homsi (2000). This lifetime cost estimate of $92.0 billion in 1997 dollars incorporates both direct and indirect costs including hospitalizations, physician visits, prescription drugs, therapy and rehabilitation, home care, home and automobile modifications, special education services, and productivity losses due to morbidity. The cost estimate does not include costs for social services and criminal justice, or lost wages and diminished productivity of parents who reduce work hours to care for their child.

Because we later added in Oregon-specific costs for special education, we recalculated annualized national lifetime cost figures for cerebral palsy, mental retardation, and autism, omitting special education costs from the Landrigan et al. equation. We used the 2000 annual per student costs for special education as reported in a study commissioned by the Oregon School Boards Association (Econorthwest, 2002). This per student cost of $671 in 2000 dollars is for all K-12 students enrolled in Oregon public schools, not just students in special education programs. These costs cover classroom instruction and other special education services beyond the basic per pupil instructional costs.

The per student cost was multiplied by the total number of students enrolled in Oregon K-12 public schools during the 2006-2007 school year to determine the total special education expenditures (Oregon Department of Education, 2007a). This Oregon-specific cost estimate includes costs for the three disorders considered in the Landrigan et al. study, as well as other qualifying neurobehavioral and physical disorders.[12] Following Massey and Ackerman (2003), 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 potential over count.

Environmentally-Attributable Factor Range (EAFR) and Best Estimate: In 2000, the National Academy of Sciences estimated that 3% of all neurobehavioral disorders in children are caused by direct exposure to environmental contaminants. Additionally, this group of experts concluded that another 25% of neurobehavioral disorders are caused by interactions between broadly defined environmental factors and an individual's genetic susceptibility (National Academy of Sciences Committee on Developmental Toxicology, 2000).

[12] Every child in Oregon identified as special education has at least one of the disabilities defined in the Individuals with Disabilities Education Act (IDEA), which are: autism, deaf/blindness, emotional disturbance, hearing impairment/deaf, mental retardation, other health impairment, orthopedic impairment, specific learning disability, speech/language impairment, traumatic brain injury, visual impairment, or developmental delay (Oregon Department of Education, 2007b).

Based on this information, Landrigan et al. (2002) used an EAFR of 5-20%. Similarly, Massey and Ackerman (2003) used EAFs of 5%, 10%, and 20%. Following these examples, we use a best estimate of 10% and an EAFR of 5-20%.

Costs in Oregon

We estimated the costs of the environmentally attributable portion of neurobehavioral disorders in Oregon by combining lifetime cost estimates determined by Landrigan et al. with Oregon-specific special education costs. Our estimate of the costs of neurobehavioral disorders in Oregon attributable to environmental contaminants is based on the following assumptions:

- There were 562,828 K-12 Oregon public school children in the 2006-2007 school year;
- Oregon per student expenditures on special education were $671.00 in 2000 dollars; this is equivalent to $819.00 in 2007 dollars;
- Total national neurobehavioral costs of $120.5 billion in 2007 dollars;
- Landrigan's estimate of total national neurobehavioral costs minus costs for special education = $88.5 billion in 1997 dollars or $115.9 billion in 2007 dollars;
- Oregon constitutes 1.22% of the U.S. population; and
- An EAF of 10% and a range of 5-20%.

Oregon annualized lifetime costs, minus special education:

*[(Landrigan national estimate in 2007 dollars, minus special education) * (Oregon proportion of U.S. population)] = ($115.9 billion) * (0.0122) = $1.41 billion*

Best estimate of 10% = $141.0 million

Range 5% to 20% = $70.5 million to $282.0 million

Oregon annual special education costs:

*Actual Oregon special education expenditures for state FY 2006-2007 = ($819) * (562,828) = $460,956,132*

Best estimate of 10% = $46.1 million

Range 5% to 20% = $23.0 – $92.2 million

Estimate of Oregon's total annual costs of neurobehavioral disorders attributable to environmental causes:

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

($141 million) + ($46.1 million) = $187.1 million (range $93.5-374.2 million)

- EAF 0.05 = $93.5 million
- EAF 0.10 = $187.1 million
- EAF 0.20 = $374.2 million

The costs of environmentally attributable neurobehavioral disorders in Oregon are estimated at $187.1 million per year, with a range of $93.5 to $374.2 million.

Summary of Findings

The best estimate of total costs of environmentally attributable adult and childhood diseases and disabilities in the state of Oregon is $1.57 billion per year, with a range of $1.25 to $2.00 million. The best estimate of total costs of environmentally attributable disease in the state of Oregon for children alone is $1.10 billion, with a range of $984.40 million to $1.29 billion. The estimates are summarized in Table 1.

Cost estimates per year for specific diseases are:

- Adult + Childhood asthma: $30.0 million
- Childhood asthma: $27.7 million
- Adult cardiovascular disease: $342.5 million
- Adult + Childhood cancer: $131.0 million
- Childhood cancer: $9.2 million
- Childhood lead exposure: $878.0 million
- Birth defects: $2.8 million
- Neurobehavioral disorders: $187.1 million

To put these costs in context, the estimated costs for childhood diseases and disabilities is equivalent to 0.83% of the 2005 total Oregon Gross State Product (U.S. Bureau of Economic Analysis, 2006). The estimated costs for adult and childhood disease combined are equivalent to 1.18% of the Oregon Gross State Product.

Most policy, and in particular environmental health policy, fails to fully consider the environmentally attributable economic costs of diseases and disabilities. By implementing policies that help identify and eliminate exposure to environmentally attributable factors, Oregon can reduce a substantial economic burden on the state, while also safeguarding the public's health.

Study Limitations

Several limitations are inherent in this report. Perhaps the most important is the lack of data for certain measurements, including the lack of a lead poisoning registry in Oregon to keep track of lead poisoning cases. Other limitations include extrapolating disease incidence in Oregon based on a proportion of Oregon's population compared to the national population.

To account for some of these limitations, ranges of costs based on ranges of environmentally attributable factors for each disease have been calculated. An additional limitation to consider is that there are many intangible costs that come from the impacts of environmentally attributable disease and disability. These include family and social hardship and lost quality of life. Including these associated costs would result in a significantly larger economic burden from environmentally attributable disease.

Discussion and Recommendations

This study quantifies some of the economic impacts of childhood and adult diseases and disabilities linked to exposure to environmental pollution. Based on conservative assumptions, our calculations demonstrate that the health and related costs of environmentally attributable diseases and disabilities are imposing a significant cost to Oregon's economy. A number of other studies have estimated the cost of environmental diseases for individual states and have also found tremendous economic impacts. Both a Massachusetts study and a Minnesota study estimated a cost of $1.6 billion per year per state for childhood diseases (Massey & Ackerman, 2003; Schuler et al., 2006). A study of costs for Washington State, which also included adults, estimated $2.7 billion per year, and a similar study in Montana estimated $404.6 million per year for adult and childhood environmental diseases (Davies & Hauge, 2005; Seninger, 2005).

Protecting environmental public health saves money and lives.

Typically, public policy decisions only consider the upfront costs of environmental health protection measures and rarely take into account the health impact and associated costs of not taking action to implement needed pollution controls. Incorporating the health and related costs of environmental contaminants into policy decisions would provide a more complete, balanced, and accurate understanding and would strengthen decision-making processes.

Knowing that many of the environmental contributors to disease are often preventable, policy makers are encouraged to make environmental public health a top priority. Protecting environmental public health saves money and lives. The following are suggested policy directions designed to reduce or eliminate some of the key environmental contributors to disease and disability in Oregon.

Promote lead-abatement programs. People are exposed to lead primarily by ingesting it from peeling paint or paint dust. Homes painted before 1978 are likely to be painted with lead-based paint. Home renovations and remodeling contribute to nearly half of the childhood lead poisonings in Oregon, and approximately 2% of Oregon children under six have elevated blood lead levels (Oregon DHS, n.d.) Lead is also released from some industrial processes and the burning of fossil fuels. The following policies would reduce lead poisoning in Oregon:

- Provide effective incentives for property owners and renters to eliminate lead paint.
- Ensure that all children on Medicaid are tested for lead poisoning.
- Test schools and child care facilities for potential lead hazards, including paint and drinking water.
- Ensure that lead-containing products such as batteries and computer monitors are properly recycled.

Reduce pesticide exposure. Mainstream scientific research increasingly shows that a number pesticides and classes of pesticides negatively impact human health (Ma et al., 2002; Sanborn, 2004; Zahm & Ward, 1998). There is emerging evidence that chronic low-level exposure to certain pesticides, including organophosphate pesticides, may adversely effect both psycho-motor and mental development in more highly exposed children (Rauh et al., 2006; Eskenazi et al., 2007). Additionally, a number of research studies have demonstrated a link between chronic exposure to organophosphate pesticides and the incidence of pediatric asthma, cancer, and birth defects (Hoppin et al, 2006; Salam, Li, Langholz, & Gilliland, 2004; Abdollahi et al., 2004; Zahm & Ward, 1998; Nasterlack, 2006; Garcia, 1998; Shaw et al., 1999). Oregonians are potentially exposed to pesticides through fruit and vegetable consumption, contacting pesticide-contaminated surfaces, breathing air near pesticide applications (both indoors and outdoors), and drinking pesticide-contaminated water. Pesticides are found in our lawns, gardens, parks, workplaces, schools, homes, in the food we eat, the water we drink, and the air we breathe. **To reduce pesticide exposures in Oregon, a number of policies should be considered:**

- Support and implement Integrated Pest Management at all Oregon schools, childcare facilities, and public parks. Safer pest management strategies, such as Integrated Pest Management (IPM), prioritize alternatives to chemical-intensive practices. IPM is a systems approach to pest management based on an understanding of pest ecology. It begins with steps to accurately diagnose the nature and source of pest problems, and then relies on a range of preventive tactics and biological controls to keep pest populations within acceptable limits. Reduced-risk pesticides are used as a last resort if other tactics have not been effective, with care to minimize risks.
- Support the continuation of Oregon's Pesticide Use Reporting System (PURS). PURS provides

information on all pesticide use in the state. It requires businesses to report annual pesticide use while personal home use is evaluated through surveys. The goal of the program is to collect information that will lead to a better understanding of pesticide use in Oregon and its effect on public and environmental health. The statute authorizing PURS is set to expire December 2009.

- Fund research and education about effective, lower risk alternatives to those pesticides that pose the most significant health risks. The Oregon State University system does not currently have sufficient resources to research effective alternatives to the highest risk pesticides, or to provide broad education and outreach about alternatives. Increased funding for research and education about safer alternatives for pest and weed control in urban and rural areas is critical to reducing Oregonians pesticide exposure risks.

- Support and fund pesticide stewardship programs. In 1999 Oregon DEQ implemented a Pesticide Stewardship Partnership (PSP) to identify problems and improve water quality associated with pesticide use. The PSP approach encourages and supports voluntary changes that can result in measurable environmental improvements. In the past four years, pilot projects in the Columbia Gorge have shown substantial improvements in water quality associated with measurable changes in pesticide management (Oregon Department of Environmental Quality, 2007). Continued funding of this innovative, collaborative program can provide an effective alternative to traditional regulatory approaches.

Fund research on and data collection of environmental health threats. More research is needed to link information on environmental contaminants with specific health outcomes. Currently, Oregon has a few model programs that are beginning to deepen our understanding of environmental health threats. In some areas though, such as birth defects tracking, there is a noticeable lack of information.

Oregonians do not have the complete picture of rates of birth defects because Oregon has not established a birth defects monitoring program. Birth defects monitoring programs would provide communities and public health researchers with information to help prevent future birth defects. A state wide birth defects registry could be integrated into the current environmental public health tracking system, improving the system's efforts to track chronic and infectious diseases and conditions. A birth defects registry is a vital tool to help protect communities from chronic illnesses.

In 1995, Oregon established the Oregon State Cancer Registry (OSCaR), which collects information on all cancers diagnosed in Oregon. The annual reports on cancer in Oregon provide helpful information on cancer rates, but there are currently no data in these reports linking environmental exposures (excluding smoking) to specific cancer incidences.

Oregon is one of sixteen states nationwide participating in the CDC's National Environmental Public Health Tracking Program. The aim of the Oregon Environmental Pubic Health Tracking Program is to collect data on asthma and myocardial infarction hospitalizations, ozone and particulate matter levels, drinking water contaminants, childhood blood lead levels, vital statistics, birth defects and cancers. Once data have been collected, the program will develop, implement and assess an outreach plan and risk communication strategy.

Integrating exposure data with more complete information on rates of diseases caused or aggravated by pollutants would enable Oregon to focus its regulatory programs and disease prevention efforts on actual risks to public health.

Our chemical regulatory system must be healthy for all Oregonians and the environment.

For these programs to be effective in reducing environmentally attributable disease, Oregon needs to provide long term funding and develop a cohesive strategy to provide health officials, communities, and policy makers information on where and when diseases such as cancer and asthma occur, in addition to providing information on potential links to environmental factors.

Reduce exposure to diesel and gasoline exhaust. Pollution from road traffic and construction equipment are serious health hazards. In 2004, 34% of Oregon adults with current asthma reported that outdoor air pollution like smog and automobile exhaust had affected their health in the past 12 months (Oregon Department of Human Services, 2005b). Epidemiological studies have linked exacerbations of asthma with outdoor air pollution levels below current air quality standards (Peden, 2005). Diesel exhaust and many of its components are considered probable human carcinogens (U.S. EPA, 2002). In addition, diesel exhaust is associated with a wide range of health effects beyond cancer and asthma, including neurological effects, a weakened immune system, and cardiovascular disease (U.S. EPA, 2002). To reduce these poor health outcomes, exposure to both diesel and gasoline exhaust should be minimized through public education campaigns and better policies to protect the health of Oregonians.

Recent federal regulations are helping clean up both diesel fuel and diesel engines. However – because diesel engines last for over a million miles and are rebuilt multiple times – it will take approximately 30 years to realize the full benefits of the new EPA rules. For example, half of all bulldozers purchased new in 1995 – before any emission controls for particulate matter in these engines existed – will still be operating without pollution controls in 2024.

Therefore, we recommend the following:

- Increase funding to clean diesel initiatives, including funding for retrofits. Legislation passed during the 2007 Oregon legislative session will provide some state funding to help retrofit, rebuild, or replace older diesel engines. Unfortunately, this will only address a small fraction part of the problem. Further action and funding is necessary to reduce diesel emissions from construction and railway equipment, and to ensure that all vehicles are using the best available technology for emission control. In addition, we need to invest in mass transit and provide incentives to encourage Oregonians to take positive steps to reduce their vehicle emissions.

Reduce mercury exposure. Many adverse health effects are associated with the accumulation of mercury in the body. Methylmercury, the most common form of mercury to which people are exposed through consumption of contaminated fish, is a very potent neurotoxin that interferes with brain development. Children who are prenatally exposed to low concentrations of methylmercury are at increased risk of poor performance on neurobehavioral tests, including those measuring attention, fine motor function, language skills, and verbal memory (Grandjean et al., 1997; Kjellstrom, Kennedy, Wallis, & Mantell, 1986). A number of studies have linked exposure to methylmercury with impacts to the cardiovascular system (Virtanen et al., 2005; Sorensen et al., 1999). In Oregon there are currently fish consumption advisories for 12 bodies of water, including the entire main stem of the Willamette River, due to mercury contamination. **The following policies would reduce mercury exposures in Oregon:**

- Eliminate the use and sale of mercury-containing products. Oregon has begun to address the problem of mercury emissions through the Mercury Reduction Act of 2001, which has phased out use and sale of certain mercury-containing products such as fever thermometers, auto switches and novelty products. Although mercury-containing thermostats can still be sold under this legislation, they cannot be installed by contractors.

- Reduce mercury emissions from power plants. Oregon has adopted a Utility Mercury Rule that limits mercury emissions for new plants and mandates installation of mercury control technology for Oregon's only existing coal-fired power plant. The rule requires that the power plant achieve a 90% reduction in mercury emissions by 2012. If the 90% reduction is not technologically achievable, the coal-fired power plant must install continuous mercury monitoring equipment by 2008 and develop a mercury reduction plan. In the long-term, coal burning should be replaced with conservation and cleaner energy production.

- Reduce mercury emissions from manufacturing facilities. Oregon Department of Environmental Quality (DEQ), in partnership with the Ash Grove Cement plant and local community and environmental organizations, have completed a plan to reduce mercury emission through the installation of control equipment. The mercury reduction effort is a voluntary effort specific only to Ash Grove as it is the only cement manufacturing plant in Oregon. To avoid excessive mercury pollution, the state should require that all facility retrofits and every new facility constructed in Oregon use the best available technology.

- Health care facilities, including hospitals and dental offices, should phase out mercury-containing products in favor of safer alternatives. Policies are needed to encourage health care facilities to eliminate the use of mercury in health care practices to ensure that no mercury enters the environment from dental and medical offices.

- Expand and develop programs to safely collect and recycle mercury containing products. Government agencies need to expand and create programs to remove, collect, and safely store mercury from thermostats, thermometers, auto switches, and fluorescent tubes and compact fluorescent lightbulbs (CFLs). The rising popularity of energy-efficient CFLs makes necessary the quick implementation of an effective recycling program to avoid the accumulation of CFLs in our solid waste management systems.

- Develop scientifically based fish-consumption guidelines. The amount of fish eaten varies geographically and among different populations. Data demonstrate that some populations in Oregon consume more fish than the current EPA reference dose (U.S. Environmental Protection Agency, 2000). Oregon DEQ—in partnership with the EPA, the Confederated Tribes of the Umatilla Indian Reservation and other community members—is in the process of reviewing Oregon fish consumption rates to determine appropriate fish consumption guidelines. Oregon needs to adopt appropriate, regional guidelines for fish consumption that protect at risk populations from eating contaminated seafood and fish from local and commercial sources. Vigorous outreach programs must be implemented to ensure that Oregonians know about or can easily access these resources.

Comprehensive Chemical policy reform. Our current system of chemical regulation is outdated. Chemicals are not adequately tested as to their toxicity and our system legally allows people to be exposed to potentially dangerous toxic chemicals. Toxic chemicals are widely found in our environment, homes, workplaces, and bodies. Most people believe that the government ensures that chemicals – and the products that contain them – are safe. This is not true. Most chemicals are introduced into commerce without first testing whether they can harm human health. Neither our government nor industry are adequately protecting human health, in particular the health of our children who are at even greater risk of developmental and other disorders triggered by chemicals.

We must transform our chemical regulatory system into one that is healthy for all Oregonians and the environment. The European Union has initiated a system of chemical evaluation and regulation known as Registration, Evaluation, and Authorisation of Chemicals (REACH), which is designed to keep the most persistent, bioaccumulative, and toxic (PBT) chemicals out of the environment and our bodies. **Such a system is needed in the U.S. Specifically, we call for the following policies to be implemented:**

- *Require that complete information be provided on chemical ingredients and their toxicity.* The burden to prove that chemicals are safe before they are allowed on the market should fall to producers and manufacturers. Chemical safety data should be made available to the public and regulators. These data must take into account impacts on vulnerable populations. Due to the enormity of this information management task, Oregon should support the development of an interstate clearinghouse for chemical ingredients.
- *Categorize chemicals into levels of concern.* The public, businesses, workers, and consumers should have tools to help distinguish between chemicals. A chemical categorization system will identify safer chemicals, chemicals to avoid, and chemicals that lack adequate safety data.
- *Manage chemicals based on hazards and substitute those of highest concern with safer alternatives.* Oregon should develop and use criteria to identify chemicals of concern and have the authority to restrict certain chemical uses. State agencies should have the authority to identify, collect data on, and mandate the replacement of chemicals of highest concern.
- *Establish policies, practices, and incentives that move Oregon toward safer alternatives.*
  - Invest in and build in-state institutional alternatives research capacity.
  - Promote least-toxic and biobased procurement policies for state, local, and municipal governments and other large institutions such as hospitals, universities, and schools.
  - Ensure that all communities can participate in new green economy by creating incentives for investment in safer alternatives.
  - Create tax incentives for and provide technical assistance to firms working toward safer alternatives.
  - Increase and direct research and economic development dollars to promote safer alternatives, particularly in key sectors ripe for alternatives.
- *Provide adequate funding and enforcement.* Oregon must create the funding and enforcement mechanisms to successfully implement chemical policy reform. Despite the new policies and programs funded in 2007, Oregon DEQ and other state agencies are still severely underfunded. Resources for technical assistance and program implementation are essential to ensuring a successful transition by the business community to these new, safer chemical policy standards.
- *Ensure that workers and affected communities are protected.* Oregon should address concerns about any job losses that may result from a transition to safer chemicals. This means incorporating policies that support a just transition to cleaner, safer jobs, worksites, and communities. Oregon should ensure that communities facing environmental injustice are given particular priority for remediation.

The preventable costs of environmentally attributable diseases will continue to increase in the years ahead as our exposures to inadequately tested chemicals continues and grows. While we spend valuable resources to treat and compensate for environmentally attributable diseases, there are approaches available that would begin to eliminate and reduce many of these costs. It is imperative that we increase our investment in chemical policy reforms and safer alternative development to reduce and eliminate these unnecessary and costly exposures.

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APPENDIX

Table 1: Summary of Annual Economic Costs of Environmentally Attributable Disease and Disabilities in Oregon

Disease/Disability	Best Estimate (million)	Range (million)
Childhood Asthma[1]	$31.5	$10.5 - 36.7
	$23.8	$7.9 – 27.8
Adult and Childhood Asthma	$30.0	$10.0 – 35.0
Cardiovascular Disease	$342.5	$210.8 - 474.3
Childhood Cancer	$9.2	$3.7 – 18.5
Adult and Childhood Cancer	$131.0	$52.4 - 262.0
Lead Exposure	$878.0	-
Birth Defects[2]	$2.5	$1.3 – 6.3
	$3.1	$1.5 – 7.7
Neurobehavioral Disorders	$187.1	$93.5 – 374.2
Total Childhood[3]	$1104.8[4]	$984.4 - 1,288.1
Total Adult & Child[5]	$1571.4[4]	$1,246.0 – 2,004.2

1. Two different methods were used to estimate the cost of childhood asthma.
2. Two different methods were used to estimate the cost of birth defects.
3. This total includes: childhood asthma, childhood cancer, lead exposure, birth defects, and neurobehavioral disorders.
4. When there was more than one estimate for a given category, the average of the estimates were used to calculate the total.
5. This total includes: adult and childhood asthma, cardiovascular disease, adult and childhood cancer, lead exposure, birth defects, and neurobehavioral disorders.

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