Collaborative for Health and Environment – Washington
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Economic Costs of Diseases and Disabilities Attributable to Environmental Contaminants in Washington State

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Economic Costs of Diseases and Disabilities Attributable to

Environmental Contaminants in Washington State

Abstract:

This study estimates the economic costs associated with several diseases and disabilities attributable to environmental contaminants in Washington State, including asthma, cardiovascular disease, cancer, lead exposure, birth defects, and neurobehavioral effects. The estimates are based on 'cost of illness' estimates that include direct health care costs and indirect costs, such as those associated with morbidity and premature mortality. The estimates are also based on an 'environmentally attributable fraction' model that estimates the proportions of each disease or disability that can conservatively be attributed to exposure to environmental contaminants.

This study concludes that the 'best estimate' of the annual cost of childhood diseases and disabilities attributable to environmental contaminants (asthma, cancer, lead exposure, birth defects, and neurobehavioral effects) in Washington State is $1.875 billion in 2004$ (comprising $310.6 million in direct health care costs and $1,565 million in indirect costs), with a range of $1.6 - $2.2 billion a year, depending on the methods and assumptions used.

It also concludes that the 'best estimate' of the annual cost of adult and childhood diseases and disabilities attributable to environmental contaminants (asthma, cardiovascular disease, cancer, lead exposure, birth defects, and neurobehavioral effects) in Washington State is $2.734 billion (comprising $782.1 million in direct health care costs and $1,953 million in indirect costs), with a range of $2.8 - $3.5 billion a year, depending on the methods and assumptions used.

These cost estimates are consistent with the results of other similar studies. It should be noted that like the previous studies, a significant proportion of the estimated costs can be attributed to lead exposure.

To put these costs in context, the estimate for childhood diseases and disabilities is equivalent to 0.7% of the total Washington Gross State Product and the estimate for adult and childhood diseases and disabilities is equivalent to about 1%. Looking at direct health care costs, the estimated cost of childhood diseases and disabilities attributable to environmental contaminants is approximately 1.9% of the total Washington State health expenditures and the direct costs for child and adult diseases and disabilities are approximately 4.9%. These costs could be prevented if exposures to environmental contaminants were reduced or eliminated.

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Economic Costs of Diseases and Disabilities Attributable to Environmental Contaminants in Washington State

1. Introduction

In recent years, health economists have made significant advances in calculating the costs of diseases and disabilities and there are now generally-accepted 'cost of illness' estimates for all common diseases and disabilities in the US, including cardiovascular disease, cancer, diabetes and asthma (see for example, National Heart, Lung and Blood Institute, 2003; Environmental Protection Agency, undated; National Institutes of Health, 2000; American Diabetes Association, 2003). 'Cost of illness' estimates usually comprise direct health care costs, including hospital and nursing home care, prescription drugs, home care, and physician and other services, and indirect costs associated with lost productivity due to morbidity and premature mortality. Although monetary valuations of illness do not address the psychological and emotional costs to patients, or to their families, friends and communities, they are important because economic considerations have come to dominate public policy decision-making in the US.

This preliminary study estimates the economic costs associated with several diseases and disabilities attributable to environmental contaminants in Washington State. It is intended to provide information to State environmental health policy-makers and other interested parties, and to complement estimates of the costs of environmental protection measures.

The main purpose of this study is to highlight that the health and related costs of the continued use of toxic chemicals are rarely considered in cost benefit analyses, that these costs are likely to be very significant, and that they are born by us, as a society. While we will probably never know the costs precisely, the estimates in this study are based on conservative assumptions used by others and they should provide reasonable lower-end approximations of costs.

Previous Studies
The methods and assumptions used in this study are based on many earlier studies, especially Landrigan et al. (2002) and Massey and Ackerman (2003). Landrigan et al. (2002) estimated the national costs of four types of childhood diseases and disabilities attributable to environmental contaminants, including lead poisoning, asthma, cancer, and developmental disabilities. To calculate the health and related costs of these conditions, they used an 'environmentally attributable fraction' (EAF) model that estimated the proportion of each condition that can reasonably be attributed to exposure to environmental contaminants. Using this approach, Landrigan et al. estimated the total national costs of the environmentally-attributable fraction of these four conditions at approximately $55 billion a year in 1997$.

The second study (Massey and Ackerman, 2003) also used an EAF model to estimate the costs associated with childhood cancer, asthma, neurobehavioral disorders, lead poisoning and birth defects in Massachusetts. The two studies used similar methodologies, although they differed in several respects including the sources of health information and the economic assumptions used.

The other principal model that has been used to estimate how much disease and disability can be attributable to environmental factors is based on lost 'disability-adjusted life years' (DALYs). This approach considers the years of disability-free life lost as a result of environmentally-attributable illness (see for example, Smith et al., 1999), however, it has not been used to estimate the economic costs associated with diseases and disabilities.

Several other studies have considered the health costs of environmental contaminants including the costs of child lead poisoning (Stefanak et al., 2005; Korfmacher, 2003), and the costs of methyl mercury from US power plants (Trasande et al., 2005).

This Study

This study uses an EAF model to estimate the costs of several diseases and disabilities in Washington State attributable to environmental contaminants. The diseases and disabilities considered include: asthma (childhood and adult/childhood), cardiovascular disease, cancer (childhood and adult/childhood), lead exposure, birth defects, and neurobehavioral defects. It builds on an earlier study on the 'completeness' of the scientific information on health and environmental contaminants in Washington State that concluded that there is a lack of information on the economic costs of health effects that can be linked to environmental exposures (Davies et al., 2005).

This study is based on the following general assumptions and limitations:

- There is growing scientific evidence that exposure to environmental contaminants plays a role in many diseases and disabilities, but the precise proportions attributable to environmental contaminants will probably never be known. To take account of this uncertainty, the 'environmentally attributable fractions' used in this study are conservative and are expressed as ranges, or 'environmentally attributable fraction ranges' (EAFR)[1]. In addition, the costs have been estimated using a 'best estimate' of the proportion of disease and disability attributable to environmental contaminants. The rationale for the EAFR and the 'best estimate' for each disease and disability is discussed in the relevant section below.

- Most of the cost estimates for Washington State are derived from national cost estimates. However, the costs in Washington may be higher or lower than national ones.

- Where national cost estimates have been used, they have been converted to provide State estimates based on population data taken from the US Census. According the 2000 Census, the total population of the US was 281,421, 906 and the population of

[1] The only exception to this is lead, where an EAFR of 100% is assumed.

Washington State was 5,894,121 (US Census Bureau, undated). Thus, the population of Washington State is approximately 2.09% of the national total. This proportion has been used to generate cost estimates in Washington State. However, this assumption does not take account of the possibility that the rates of disease and disability in Washington State may be different from national rates.

- The Department of Labor's Consumer Price Index Inflation Calculator (available at: http://www.bls.gov/cpi/home.htm) has been used to show all cost estimates in 2004$. This Inflation Calculator is a generic national inflation calculator, and it does not take account of the fact that the health and related costs estimated in this study may have risen at a different rate than the national inflation rate. Similarly, it does not take account of the fact that inflation in Washington State may have risen at a different rate than the national rate.

- Cost estimates have been rounded to one decimal place.

The detailed methods and assumptions used to develop the cost estimates for each disease or disability are described in the relevant section below. For cardiovascular disease, birth defects, and neurobehavioral disorders, two or more cost estimates have been developed, based on different methods and assumptions.

2. Costs of Childhood Asthma

Childhood asthma has been associated with a variety of indoor and outdoor environmental factors including: particulate matter; ozone; nitrogen and sulfur oxides; dust mites, cockroach, dog and cat allergens, and second hand smoke (see for example, Etzel, 2003; Institute of Medicine, 2000). Both Landrigan et al. (2002) and Massey and Ackerman (2003) estimated the costs of childhood asthma attributable to environmental contaminants.

Landrigan et al. and Massey and Ackerman's Methods
Landrigan et al. based their estimated costs of childhood asthma on the methods used by Chestnut et al. (2000) and Weiss et al. (2000) and they estimated the total annual costs of childhood asthma as $6.6 billion in 1997$, comprising $4.6 billion in direct health care costs and $2.0 billion in indirect costs, including lost school days and lost productivity due to premature death. This is equivalent to $7.8 billion in 2004$.

The direct health care costs included hospital care (in patient, emergency, and out patient) and physician services (in patient, out patient, medications). The indirect costs included school days lost and costs associated with premature death, such as lost productvity.

Massey and Ackerman (2003) used three methods to calculate the costs of childhood asthma in Massachusetts. They used one method based on the costs of acute asthma hospitalisation, one based on the costs of asthma in the EPA's 'Cost of Illness Handbook' (Environmental Protection Agency, undated) that estimates health care costs only, and Landrigan et al.'s method that takes account of direct health care costs and indirect costs associated with lost productivity.

This study uses Landrigan et al.'s method because it is the only one that includes indirect costs, and these are very significant for childhood 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 proportion of childhood asthma attributable to environmental contaminants. The panel estimated that 10-35% of acute exacerbations of childhood asthma are related to outdoor, non-biologic pollutants from sources amenable to abatement, 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. In addition, Landrigan et al. used a 'best estimate' of 30%. These proportions are used in the present study.

Costs in Washington State

Approximately 8% of all children (0-17 years) in Washington State have asthma (Washington State Department of Health and the Washington Asthma Initiative, 2005).

The estimates of the costs of childhood asthma attributable to environmental contaminants in Washington State are based on the following assumptions:

- Washington State comprises 2.09% of the US population;
- A 'best estimate' of 30% and an EAFR of 10 – 35%; and
- The cost estimates used by Landrigan et al. updated to $7.8 billion in 2004$.

Using these assumptions, the 'best estimate' of the annual costs of childhood asthma attributable to environmental contaminants in Washington State is $48.9 million in 2004$ (comprising $34.1 million in direct health care costs and $14.8 million in indirect costs), with a range of $16.3 – 57.1 million.

3. Costs of Adult and Childhood Asthma

A recent report on the 'Burden of Asthma in Washington State 2005' (Washington State Department of Health and the Washington Asthma Initiative, 2005) estimated the total annual costs of asthma in Washington State as $406 million in 2002$, comprising $240 million in direct health care costs (hospital care, physician services and prescriptions), and $166.1 million in indirect costs including school days lost, lost productivity, housekeeping and premature mortality. This is equivalent to $426.3 million in 2004$.

The estimates of the costs of adult and child asthma in Washington State attributable to environmental contaminants are based on the following assumptions:

- The Department of Health / Washington Asthma Initiative estimate updated to $426.3 million in 2004$; and

- A ‘best estimate’ of 30% and an EAFR of 10-35%[2].

Using these assumptions, the ‘best estimate’ of the annual costs of adult and childhood asthma attributable to environmental contaminants in Washington State is $127.8 million in 2004$ (comprising $75.5 million in direct health care costs and $52.3 million in indirect costs), with a range of $42.6 - $149.2 million.

4. Costs of Cardiovascular Disease

There is now strong evidence that particulate matter is a risk factor for cardiovascular disease. In a recent review of the scientific literature, the American Heart Association concluded that short- and long-term exposure to ambient particulate matter is a risk factor for cardiovascular disease (Brook et al., 2004) and a study of the effects of fine air particulate matter (PM) with a diameter of less than 2.5 µm stated that “long-term exposure to combustion-related fine particulate air pollution is an important environmental risk factor for cardiopulmonary and lung cancer mortality” (Pope et al., 2002).

National Cost Estimates

There are two estimates of the national costs of cardiovascular disease.

The Centers for Disease Control and Prevention (CDC) estimated that in 2003 the national costs of cardiovascular disease were $351 billion comprising $209 billion for direct health care expenditures and $142 billion in indirect costs associated with lost productivity from death and disability (Centers for Disease Control and Prevention, 2004). This is equivalent to $360 billion in 2004$.

Also in 2003, the National Heart, Lung and Blood Institute (NHLBI) estimated that the national costs of cardiovascular disease in 2004 would be $368.4 billion, including $226.7 million for direct health care costs (personal health care expenditures for hospital and nursing home care, drugs, home care and physician and other professional services), $33.6 billion for indirect morbidity costs and $108.1 billion for indirect mortality costs associated with premature death (National Heart, Lung and Blood Institute, 2003). This is equivalent to $378.21 billion in 2004$.

Environmentally-Attributable Factor Range (EAFR) and ‘Best Estimate’

There are no estimates of the proportion of cardiovascular disease that can be attributed to air pollution, however, Pope et al. (2002) found that for every 10 $\mu g/m^3$ of fine particulates, cardiopulmonary deaths rose by 6%. An earlier report published in 1996 (Sheiman Shprentz, 1996) used similar mortality risk factors for cardiopulmonary diseases and the assumption that the ratio of $PM_{2.5}/PM_{10}$ is an average of 60% in urban areas of the US (Dockery and Pope, 1994) to generate point and range estimates of the annual adult cardiopulmonary deaths attributable to air pollution in 239 American cities.

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[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, but they are likely to be approximately the same as those for childhood asthma.

The data in Sheiman Shprentz (1996) addressed nine Metropolitan Statistical Areas in Washington State, including Bellingham, Bremerton, Olympia, Portland OR-WA, Richland-Kennewick-Pasco, Seattle-Everett, Spokane, Tacoma, and Yakima. The study showed that in 1989 there was a total of 18,067 cardiopulmonary deaths in these cities and that a total of 1,424 of these were likely to be due to particulate air pollution. This is equivalent to 7.8% of the cardiopulmonary mortality in these cities. Thus, being conservative, this study assumes an EAFR for cardiovascular morbidity and mortality of between 5-10% in Washington State, with a 'best estimate' of 7.5%.

Costs in Washington State

<u>Estimate 1 (based on CDC's cost estimate):</u>

These estimates are based on the following assumptions:

- The CDC's estimate updated to $360 billion in 2004$;
- A 'best estimate' of 7.5% and an EAFR of 5-10% for cardiovascular disease in Washington State; and
- The costs in Washington State are likely to be about 2.09% of the national costs (based on population).

Using these assumptions, the 'best estimate' of the annual costs of cardiovascular disease in Washington State that can be attributed to air particulates is $564.3 million in 2004$ (comprising $335.8 in direct health care costs and $228.5 in indirect costs), with a range of $376.2 – 752.4 million.

<u>Estimate 2 (based on the NHLBI cost estimate):</u>

These estimates are based on the following assumptions:

- The NHLBI estimate updated to $378.21 billion in 2004$;
- A 'best estimate' of 30% and an EAFR of 5-10%; and
- The costs in Washington State are likely to be about 2.09% of the national costs (based on population).

Using these assumptions, the 'best estimate' of the annual costs of cardiovascular disease in Washington State that can be attributed to air particulates is $592.8 million in 2004$ (comprising $364.8 million in direct health care costs, $54.1 in indirect morbidity costs, and $173.9 million in indirect mortality costs), with a range of $395.2 - 790.4 million.

These two estimates are remarkably similar.

5. Costs of Childhood Cancer

The two most common forms of childhood cancer are brain cancer and leukemia and there is “strong” scientific evidence that both of these types of cancer are associated with environmental contaminants (Janssen et al., undated). To estimate the costs of childhood cancer in Washington State Landrigan et al.’s method and assumptions have been used.

Landrigan et al.’s Method

Landrigan et al. (2002) estimated the national average cost per child was approximately $623,000 in 1998$. This estimate is comprised of the following costs:

<u>Direct Health Care Costs</u>	
Physician fees	$ 35,900
In patient services	$189,600
Out patient services	$ 20,400
Laboratory services	$263,200

Total Direct Health Care Costs	$509,000
<u>Indirect Costs:</u>	
Lost parental wages[3]	$ 13,500
Lost future income due to loss of IQ[4]	$ 60,500
Costs of treating a second primary cancer[5]	$ 40,000

Total Indirect Costs	$114,000
Total Cost per Child	$623,000

Landrigan et al. then multiplied this cost by the estimated number of new childhood cancer cases in the US each year (7,722) to yield an estimate of $4.8 billion. They then estimated the costs of premature death due to primary and secondary cancer as $1.8 billion, to give a total estimated annual cost of childhood cancer of $6.6 billion in 1997$.

The total cost per child is equivalent to $723,817 in 2004$, the costs of premature death are equivalent to $2.1 billion in 2004$, and the total estimated annual cost of childhood cancer nationally is equivalent $7.8 billion in 2004$.

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[3] Loss of parental income estimated assuming 5 lost wage days per 7 child hospital days.

[4] Loss of IQ 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 (references provided in Landrigan et al., 2002).

[5] Subsequent primary cancers are more common in children that have had one primary cancer. The costs of treating subsequent primary cancers was 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.).

Environmentally Attributable Fraction Range (EAFR) and 'Best Estimate'
To estimate the EAFR for childhood cancer, Landrigan et al., convened an expert panel. Based on the available scientific evidence, the panel concluded that the EAFR for childhood cancer is at least 5-10% and less than 80-90%. Given this uncertainty, Landrigan et al. based their cost estimates on an EAFR of 2-10%, with a 'best estimate of 5%. Massey and Ackerman based their cost estimates on an EAFR of 5-90%. To be conservative, this study uses a 'best estimate of 5% and an EAFR of 2-10%.

Costs in Washington State
Data from the Washington State Cancer Registry (undated) show that in 2001 (the most recent year for which data are available) 308 children aged 0-19 years were diagnosed with cancer.

These estimates are based on the following assumptions:

- A 'best estimate' of 5% and an EAFR of 2-10%;
- A total cost per child of $723,817 in 2004$; and
- 308 children diagnosed with cancer annually in Washington State.

Based on these assumptions, the 'best estimate' of the annual costs of childhood cancer attributable to environmental contaminants is $11.2 million in 2004$ (comprising $9.1 million in direct health care costs and $2.0 million in indirect costs), with a range of $4.5 - $22.3 million, excluding the costs of premature death.

Including the pro-rated costs of premature death of $2.1 billion from 7,722 nationally to the 308 children diagnosed in Washington State results in a 'best estimate' of the annual costs of childhood cancer attributable to environmental contaminants in Washington State, including costs of premature death, of $15.4 million in 2004$ (comprising $9.1 million in direct health care costs, $2.0 million in indirect costs, and $4.2 million premature mortality costs), with a range of $6.2 - $30.7 million.

6. Costs of Adult and Childhood Cancer

There is "strong" or "good" evidence that many cancers are associated with environmental exposures, including bladder cancer, bone cancer, brain cancer, breast cancer, cervical cancer, esophageal cancer, laryngeal cancer, leukemia, liver cancer and angiosarcoma, lung cancer, multiple myeloma, lymphoma (Hodgkins and non-Hodgkins), oral cancer, pancreatic cancer, renal (kidney) cancer, salivery gland cancer, skin cancer (melanoma and non-melanoma), scrotal cancer, and thyroid cancer (Janssen et al., undated).

The National Heart, Lung and Blood Institute has estimated the national costs of cancer in the US.

NHLBI Cost Estimate

The NHLBI estimated the direct and indirect costs of cancer in the US in 2003$ (National Heart, Lung and Blood Institute, 2003; American Cancer Society, 2005). According to this study, the costs for 2004 were expected to total $189.8 billion comprising:

- $69.4 billion in direct health care costs including personal health care expenditures for hospital and nursing home care, drugs, home care and physician and other professional services;

- $16.9 billion in indirect morbidity costs including lost productivity; and

- $103.5 billion in premature mortality costs including lost productivity.

This total of $189.8 billion in 2003$ is equivalent to $194.9 billion in 2004$.

Environmentally-Attributable Factor Range (EAFR) and 'Best Estimate'

It has been estimated that perhaps 75-80% of all cancer in the US is due, at least partly, to broadly defined 'environmental factors' including tobacco, diet, medicines, infectious agents, radiation, occupational exposure and environmental contaminants (see for example, Davis and Muir, 1995). Doll and Peto (1981) and Doll (1998) have provided estimates of the relative contributions of these different 'environmental factors'. These studies estimate that exposure to environmental contaminants in air, water and food are responsible for about 1-5% of all cancer deaths. There are no estimates of the proportion of cancer morbidity that can be attributed to environmental contaminants, but it is likely to be significantly higher than 1-5%.

Based on these estimates, this study uses a conservative 'best estimate' of 5% and an EAFR for combined cancer morbidity and mortality of 2-10%.

Costs in Washington State

These estimates are based on the following assumptions:

- The NHLBI estimate updated to $194.9 billion in 2004$;
- A 'best estimate' of 5% and an EAF of 2-10%; and
- The costs in Washington State are 2.09% of the national costs (based on population).

Using these assumptions, the 'best estimate' of the annual costs of cancer in Washington State attributable to environmental contaminants is $203.5 million in 2004$ (comprising $74.4 million in direct health care costs, $18.1 million in indirect morbidity costs, and $111 million in indirect premature mortality costs), with a range of $81.4 – 407.2 million.

7. Costs of Childhood Lead Exposure

Exposure to lead during the early years of life can damage the developing brain and nervous system, causing learning disabilities, behavioral problems, and, at very high levels, seizures, coma, and even death. Recent research indicates that there is no threshold below which there is no risk of adverse effects.

This estimate of the cost of childhood lead exposure in Washington State is based on the method and assumptions used by Landrigan et al. (2002).

Landrigan et al.'s Method

Landrigan et al. (2002) based their estimate of the national costs of lead poisoning on the numbers of 5 year old boys and girls in the US population in 1997, the national mean blood lead level for 5 year old children (Centers for Disease Control and Prevention, 1997), information on the relationship between blood lead levels and loss of IQ (Schwartz et al., 1985), data on the relationship between the loss of IQ and expected lifetime earnings (Salkever, 1995), and the expected lifetime income of 5 year old boys and girls (Bureau of Labor Statistics, 1999).

Landrigan et al. used the mean blood lead level for 5 year old children in the US in 1991-1994 of 2.7 µg/dl (Centers for Disease Control and Prevention, 1997). It should be noted that surveillance information published after Landrigan et al.'s study indicated that the mean blood lead level decreased to 2.0 µg/dl for 1996-1999 (Centers for Disease Control and Prevention, 2000).

In 1985, the Environmental Protection Agency stated that 1 µg/dl of blood lead is associated with a reduction of 0.675 IQ points (Schwartz et al., 1985). However, research published after Landrigan et al.'s study showed that the IQ loss per µg/dl was higher than this. Specifically, Canfield et al. (2003) found a loss of 0.46 IQ points per µg/dl.

To relate IQ loss with lifetime earnings, Landrigan et al. used Salkever's finding that the loss of one IQ point is associated with an overall reduction in lifetime earnings of 2.39% (Salkever, 1995).

The Bureau of Labor Statistics has determined that the expected lifetime income for 5 year old boys as $881,027 and for 5 year old girls as $519,631 in 1997$ (Bureau of Labor Statistics, 1999). These estimates are equivalent to $1,036,890 and $612,010 in 2004$.

Landrigan et al. assume an EAF of 100% for lead exposure.

It should be noted that Landrigan et al.'s method is based on lost income and does not take account of direct health care costs for screening, treatment, etc. or other indirect costs, such as special education and juvenile justice services.

Costs in Washington State

In 2003 (the most recent year for which data are available), there were 41,476 5-year old boys and 39,422 5-year old girls in Washington State (Washington State Office of Financial Management, undated). The numbers do not fluctuate significantly from year to year, so this study assumes that there were approximately 41,500 5-year old boys and 39,500 5-year old girls in Washington State in 2004.

The mean blood lead level for 5-year olds in Washington State is assumed to be the same as the national mean for 1996-99 i.e., 2.0 µg/dl[6]. Assuming an IQ loss of 0.46 points per µg/dl, it can be estimated that there is a reduction of 0.92 IQ points per child due to lead exposure. Using Salkever's calculation that the loss of one IQ point is associated with an overall reduction in lifetime earnings of 2.39%, it can be estimated that a reduction of 0.92 IQ points is associated with a 2.20% overall reduction in lifetime earnings.

Assuming an expected lifetime income of $1,036,890 for 5-year old boys and $612,010 for 5-year old girls (in 2004$) in Washington State, it can estimated that the total loss in lifetime income for 5-year old boys is $946.7 million and for 5-year old girls is $531.8 million, giving a total of $1.5 billion in 2004$. Thus, using this method the total cost of lead exposure to Washington State can be estimated as $1.5 billion for 5-year old children in 2004$ (see table below).

Estimated Total Lost Expected Lifetime Income for 5-Year Old Children in Washington State, Due to Lead Exposure

	Estimated # of 5-Year Olds in WA (2004)	**Total Expected Income (2004$ bn)**	**Total Lost Expected Lifetime Income (2004$ bn)**
Boys	41,500	43.03	0.946
Girls	39,500	24.17	0.532
Total	**81,000**	**67.2**	**1.478**

[6] There is no information on the actual mean blood lead level of 5 years olds in Washington State, although studies on the prevalence of "elevated" blood lead levels are available (Washington State Department of Health, 2000).

8. Costs of Birth Defects

Major birth defects are the leading cause of infant mortality in the US but the causes of most are unknown. About 3.5%% of all babies born in the US have structural birth defects, but this is likely to be an underestimate as it does not include defects diagnosed later in life, most notably many functional birth defects.

This study estimates the costs of structural birth defects attributable to environmental contaminants in two ways. The first estimate is based on the total costs of a list of twelve birth defects developed by the Trust for America's Health, and the second one is based on a CDC publication on the national costs of a list of eighteen defects.

The Trust for America's Estimate
The Trust for America's Health estimated that in 2001 the lifetime costs associated with twelve selected birth defects[7] in a single year's birth cohort in Washington State was $158 million (Trust for America's Health, undated). This was based on an earlier 1997 study that estimated the costs of these birth defects on a state-by-basis basis (Harris and Levy, 1997). Harris and Levy do not separate out the direct health care costs and the indirect costs, although their estimates include costs of medical treatment, developmental services, special education and lost productivity as a result of the affected children's death or disability. They did not include lost wages of family members caring for children with birth defects, psychosocial costs, or the effects of inflation on health care costs.

The Trust for America's Health estimate of $158 million in 2001 is equivalent to $168.5 million in 2004$.

CDC Publication
In 1995, Waitzman et al. (1995) estimated the national economic costs of the eighteen defects[8] in 1992$ as $8 billion for a single year's birth cohort, comprising $2.1 billion in direct health care costs and $5.9 billion in indirect costs such as developmental services, special education, and lost productivity. This is equivalent to $10.8 billion in 2004$.

Environmentally-Attributable Fraction Range (EAFR) and 'Best Estimate'
Approximately 5-10% of all birth defects may be associated with environmental and occupational exposures to chemical contaminants during pregnancy (Smith et al., 1999). Assuming that half of this 5-10% are attributable to environmental exposures, one could assume a 'best estimate' of 2.5% and an EAFR of 2.5 – 5%.

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[7] 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.
[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, lower limb reduction, upper limb reduction, omphalocele, gastroschisis, Down syndrome, and other diaphragmatic hernia.

Costs in Washington State

Cost Estimate 1 (based on the Trust for America's Health estimate):

These estimates are based on the following assumptions:

- The Trust for America's Health's estimate updated to $168.5 million in 2004$; and
- A 'best estimate' of 2.5% and an EAFR of 2.5 – 5%.

Using these assumptions, the 'best estimate' of the cost of birth defects attributable to environmental contaminants in Washington State for a single year's birth cohort is $4.2 million in 2004$ with a range of $4.2 - 8.4 million[9].

This cost is likely to underestimate the actual costs because many of the birth defects that have been associated with exposure to environmental contaminants, such as neural tube/CNS defects and genito-urinary defects, are not included in Harris and Levy's list of twelve. Moreover, their list is limited to structural defects and does not include any metabolic or functional defects that have been associated with exposure to environmental contaminants. It is also true that at least one of the twelve birth defects, Down syndrome, is genetic in origin and not thought to be linked with environmental exposures.

Cost Estimate 2 (based on the CDC publication):

These estimates are based on the following assumptions:

- There are 2.03% of the number of birth defects in Washington State as nationally[10];
- Waitzman et al.'s estimate updated to $10.8 billion in 2004$; and
- A 'best estimate' of 2.5% and an EAFR of 2.5-5%.

Using these assumptions, the 'best estimate' of the costs of birth defects in Washington State attributable to environmental contaminants is $5.5 million in 2004$ (comprising $1.5 million in direct health care costs and $4.0 million in indirect costs), with a range of $5.5 -10.9 million.

The two cost estimates for birth defects are reasonably similar.

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9 Direct and indirect costs cannot be broken out, as these are not provided in the original Harris and Levy paper.

10 This assumption is based on the following: Between 1995-2000 there were approximately 4 million live births in the US a year (Centers for Disease Control and Prevention, undated). In Washington State there are about 81,000 live births a year (Washington State Office of Financial Management, undated). This is equivalent to approximately 2.03% of the national total.

9. Costs of Neurobehavioral Disorders

Neurobehavioral disorders, including ADD/ADHD, autism and diminished IQ, affect an estimated 3-8% of US children (Buxbaum et al., 2000; Kiely, 1987). Although there are no estimates of the proportion of children in Washington State with neurobehavioral disorders, it is probably about the same as this national range. As there are approximately 81,000 live births in Washington State every year, this is equivalent to about 2,400 – 6,500 children a year.

This study contains three estimates of the costs of childhood neurobehavioral disorders. The first one is based on the methods and assumptions used by Landrigan et al. (2002). The second one is based on the method and assumptions used by Massey and Ackerman (2003), and the third one is based on an estimate of the costs of nervous system diseases generated by the NHLBI. All three estimates are based on the same EAFR and 'best estimate'.

Landrigan et al.'s Method

Landrigan et al. (2002) estimated the costs of three neurobehavioral disorders only: mental retardation, autism, and cerebral palsy. They based their estimate on the proportions of children born each year in the US that suffer from these three disorders and US Census data. They used cost estimates developed by Honeycutt et al., (2000) which avoid double counting children with more than one of these disorders. Because some neurobehavioral dysfunction is caused by lead poisoning, Landrigan et al. also estimated the fraction of cases attributable to lead exposure and reduced their estimates of disease burden and costs accordingly.

Landrigan et al.'s estimates do not separate direct and indirect costs, but they include physician visits, prescription drugs, hospitalization, assistive devices, therapy and rehabilitation, long-term care, home and auto modifications, special education, home care, and productivity losses.

Landrigan et al. estimated the costs of neurobehavioral disorders as $72.4 billion for mental retardation, $5.0 billion for autism, and $14.6 billion for cerebral palsy, for a total of $92.0 billion in 1997$. This is equivalent to $108.3 billion in 2004$.

Massey and Ackerman's Method

Massey and Ackerman (2003) used a different method based on the number of children in special education in Massachusetts as an approximation for the number of children with neurobehavioral disorders, and the cost of special education per child which they calculated at $5,143 per child in 1999$. This is equivalent to $5,831 in 2004$.

They recognize, however, that the costs of special education are only one small part of the total costs of neurobehavioral disorders that does not include direct health costs (such as physician visits, prescription drugs, therapy and other professional health services), many indirect costs (such as home and auto modifications and long-term care), or lost productivity. Therefore, they also provide a second estimate based on Landrigan et al.'s method and assumptions. Their second estimate takes account of these additional costs and addresses the same three neurobehavioral disorders studied by Landrigan et al.

NHLBI Cost Estimate
The NHLBI has estimated the total costs of diseases of the nervous system as $146.2 billion in 2004$ (National Heart, Lung and Blood Institute, 2003), comprising $127.2 billion for direct health care costs (personal health care expenditures for hospital and nursing home care, drugs, home care, and physician and other professional services), $7.7 billion for indirect morbidity costs including lost productivity, and $11.3 billion for indirect mortality costs including lost productivity.

Environmentally-Attributable Factor Range (EAFR) and 'Best Estimate'
In 2000, an expert committee convened by the US National Academy of Sciences estimated 3% of all neurobehavioral disorders in children are directly caused by exposure to environmental contaminants and that another 25% are caused by interactions between environmental factors, defined broadly, and genetic susceptibility (National Academy of Sciences Committee on Developmental Toxicology, 2000). Thus, the expert committee found that a total of 28% of neurobehavioral disorders could be attributed directly or indirectly to environmental contaminants, not including alcohol, tobacco or drugs of abuse.

Based on his 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, this study uses a 'best estimate' of 10% and an EAFR of 5-20%.

Costs in Washington State
As noted above, this study provides three estimates of the costs of neurobehavioral disorders in Washington State, based on these three methods.

<u>Estimate 1 (based on Landrigan et al.):</u>
This estimate is based on the following assumptions:

- Washington State comprises 2.09% of the US population;
- A 'best estimate' of 10% and an EAFR of 5-20%; and
- Landrigan et al's cost estimate updated to $108.3 billion in 2004$.

Based on these assumptions, the 'best estimate' of the annual costs of neurobehavioral disorders (mental retardation, autism, and cerebral palsy) attributable to environmental contaminants in Washington State is $226.4 million in 2004$, with a range of $113.2 – 452.7 million[11].

<u>Estimate 2 (based on Massey and Ackerman):</u>
This estimate is based on the following assumptions:

- The number of children in Washington State (124,067 ages 3-21 years) receiving special education in 2004 (Office of the Superintendent of Public Instruction, undated); and
- A 'best estimate' of 10% and an EAFR of 5-20%; and

[11] Direct and indirect costs are not separated out, as Landrigan et al.'s original estimates did not do this.

- The estimate for special education updated to $5,831 in 2004$[12].

Based on these assumptions, the 'best estimate' of the annual costs of neurobehavioral disorders attributable to environmental contaminants in Washington State is $72.4 million in 2004$, with a range of $36.2 – 144.7 million.

<u>Estimate 3 (based on the NHLBI):</u>
This estimate is based on the following assumptions:

- Washington State comprises 2.09% of the US population;
- A 'best estimate' of 10% and an EAFR of 5-20%;
- The NHLBI estimate of $146.2 billion in 2004$.

Based on these assumptions, the 'best estimate' of the annual costs of nervous system diseases attributable to environmental contaminants in Washington State is $305.6 million in 2004$ (comprising $265.9 million in direct health care cists, $16.2 million in indirect morbidity costs, and $23.5 million in indirect mortality costs), with a range of $152.8 - $611.1 million.

Not surprisingly the second estimate, comprising only the costs of special education, is the lowest and the third estimate, based on all nervous system diseases, is the highest.

10. Conclusions

The estimates presented in this study are summarized in the table below:

Summary of Economic Costs of Diseases and Disabilities Attributed to Environmental Contaminants in Washington State

Disease/Disability	'Best Estimate' (2004$ million)	Direct Costs (2004$ million)	Indirect Costs (2004$ million)	Range (2004$ million)	Based On
Childhood Asthma	$48.9	$34.1	$14.8	$16.3 – 57.1	Landrigan et al.
Adult and Childhood Asthma	$127.8	$75.5	$52.3	$42.6 – 149.2	WA Dept. of Health/WA Asthma Initiative cost estimate
Cardiovascular Disease	$564.3	$335.8	$228.5	$376.2 - $752.4	CDC national cost estimate
	$592.8	$364.8	$54.1+$173.9	$395.2 – 790.4	NHLBI national cost estimate

[12] This method assumes that the cost of special education in Washington State is the same as in Massachusetts.

Disease / Disability	'Best Estimate' (2004$ million)	Direct Costs (2004$ million)	Indirect Costs (2004$ million)	Range (2004$ million)	Based On
Childhood Cancer	$11.2	$9.1	$2.0	$4.5-22.3	Landrigan et al. excl premature death
	$15.4	$9.1	$2.0+$4.2	$6.2 – 30.7	Landrigan et al. incl premature death
Adult and Childhood Cancer	$203.5	$74.4	$18.1+$111	$81.4 – 407.2	NHLBI national cost estimate
Lead Exposure	$1,500		$1,500	-	Landrigan et al.
Birth Defects	$4.2	-	-	$4.2 - 8.4	Trust for America's Health national cost estimate of 12 defects
	$5.5	$1.5	$4.0	$5.5 – 10.9	Waitzman et al.'s national cost estimate of 18 defects
Neurobehavioral Disorders	$226.4	-	-	$113.2 – 452.7	Landrigan et al.
	$72.4	-	-	$36.2 – 144.7	Massey and Ackerman
	$305.6	$265.9	$16.2+23.5	$152.8 – 611.1	NHLBI cost estimates
Total Childhood	**$1,875**	**$310.6**	**$1,565**	**$1,600-2,200**	
Total Adult & Child	**$2,734**	**$782.1**	**$1,953**	**$2,800-3,500**	

This study concludes that the 'best estimate' of the annual cost of childhood diseases and disabilities attributable to environmental contaminants (asthma, cancer, lead exposure, birth defects, and neurobehavioral effects) in Washington State is $1.875 billion in 2004$ (comprising $310.6 million in direct health care costs and $1,565 million in indirect costs), with a range of $1.6 - $2.2 billion a year, depending on the methods and assumptions used.

It also concludes that the 'best estimate' of the annual cost of adult and childhood diseases and disabilities attributable to environmental contaminants (asthma, cardiovascular disease, cancer, lead exposure, birth defects, and neurobehavioral effects) in Washington State is $2.734 billion (comprising $782.1 million in direct health care costs and $1,953 million in indirect costs), with a range of $2.8 - $3.5 billion a year, depending on the methods and assumptions used.

These cost estimates are consistent with the results of other similar studies. It should be noted that like the previous studies, a significant proportion of the estimated costs can be attributed to lead exposure.

To put these costs in context, total health care expenditure in Washington State in 1990 was $11.1 billion (Centers for Medicare and Medicaid Services, undated). This is equivalent to $16.0 billion in 2004$. Also, in 2004 the Washington State Gross Domestic Product was $260 billion (Bureau of Economic Analysis, undated).

Thus, the ‘best estimate’ of the annual cost of childhood diseases and disabilities attributable to environmental contaminants is approximately 0.7% of the total Washington Gross State Product and the ‘best estimate’ of the annual cost of child and adult diseases and disabilities attributable to environmental contaminants is about 1%.

The direct health care costs for childhood diseases and disabilities attributable to environmental contaminants is 1.9% of the total Washington State health expenditures and the direct costs for child and adult diseases and disabilities attributable to environmental contaminants is 4.9% of the total Washington State health expenditures

Thus, this study finds that there are likely to be very significant direct health care costs and the indirect costs associated with diseases and disabilities attributable to environmental contaminants in Washington State. Many of these costs could be prevented if exposures to environmental contaminants were reduced or eliminated. For example, over the long term Washington State’s Chemical Action Plan for Mercury (Washington State Departments of Ecology and Health, 2003) is likely to improve neurobehavioral outcomes in children by reducing exposures to this toxic substance. Similarly, the Washington State Asthma Plan (American Lung Association Washington, 2004) is likely to reduce the incidence of asthma. By replacing toxic chemicals with safer alternatives and using cleaner production practices, the burden of disease and disability in Washington State could be reduced, health and related costs could be decreased and the economy could be improved through increased productivity.

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