Costs of Environmental Health Conditions in California Children

California Environmental Health Tracking Program

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Executive Summary

Most Californians are living longer and more productive lives than ever. Improved environmental conditions, such as the provision of clean water and air, improvements in sanitation, and safe housing, have contributed greatly to healthier lives. However, many thousands of California's children still suffer from preventable environmental health conditions, most notably children living in low-income communities and communities of color. In addition to significant suffering, stress, and financial strain felt by affected families, these conditions have a considerable economic impact on California. To date, there have been little data to measure these impacts.

This report provides data on the health burden of selected environmentally-related conditions among children, describes the costs associated with these conditions, and attempts to identify what proportion of disease burden is potentially preventable through public health interventions. It shows that reducing preventable exposures to environmental hazards could save over $254 million annually in costs related to childhood conditions and save $13 billion over the lifetime of all children born in a single year in California. Reducing environmental hazards could alleviate asthma symptoms requiring medical attention in 280,000 children, prevent 120 cases of cancer, and avert the development of over 1,800 neurobehavioral disorders each year. Conditions related to lead exposures result in the greatest cost. The prevention of lead exposures could save $8–11 billion in lifetime costs for all children born in a single year in California, as well as prevent a lifetime of healthcare treatment and educational challenges for affected children.

Data on the human and economic burden of disease can inform better decision-making; currently, such information is not always available or taken into account when considering the cost of environmental remediation. Past studies have estimated that, nationally, health conditions related to environmental exposures have lifetime costs of over $76 billion. However, few state-level estimates have been produced, and data on the costs of environmentally-related conditions in California are limited.

Better cost and disease prevalence data are needed to untangle the complex relationships between the environment and health, and to inform future research and promote strategies to reduce environmental exposures. Many suspected environmental hazards remain understudied, and new potential hazards emerge everyday. Data for many health outcomes and costs are not maintained in a central registry. Improved tracking of environmental hazards, illnesses, and disease costs would assist future research and decision-making activities.

The reduction of preventable environmental hazards in California could save...

- **$254 million annually**
- **$10–13 billion over the lifetime of all children born within a single year**

And each year prevent or alleviate...

- **Asthma in 280,000 children**
- **120 new cases of pediatric cancer**
- **The development of neurobehavioral disorders in 1,800 children**

The Environment and Health

The Impact of Public Health on Life Extension

Over the past century, life expectancy has increased by over 30 years. A child born in 2012 can expect, on average, to live to be 81 years old.[1] Since 1900, childhood mortality has declined by 95%. These achievements in life extension are largely the result of widespread immunizations, improved nutrition, and better environmental quality—such as clean and accessible water, improved sanitation, healthy housing, and decreased pollution.[2]

However, a large burden of preventable disease has developed and persists. The prevalence of chronic disease in U.S. adults and children has risen from 1.8% in the 1960s to over 7% today.[3] Over the past few decades, childhood cancer incidence, asthma prevalence, and other disorders have been on the rise.[4,5] The World Health Organization has estimated that 13% of all health conditions in the United States are caused by preventable environmental hazards.[6]

The environment influences our health in diverse ways. Environmental hazards that can affect health—both natural and man-made—are found in the air, water, soil, and parts of our built and socio-economic environment, like homes, communities, food, and consumer products. California has long been at the forefront of environmental protections, but still faces a variety of unique environmental challenges and public health concerns, especially among low-income communities and communities of color.[7,8,9] Notable environmental pollutants in California include air pollution, pesticides, contaminated drinking water, lead, plus several others (Table 1).

Table 1. Environmental factors associated with selected childhood conditions

Conditions	Environmental factors of concern
Asthma	Mold, dampness, environmental tobacco smoke, chemical cleaners, animal dander, pests, air pollutants, traffic proximity
Cancers	Radiation, pesticides, parental occupational exposures, in-utero exposures, solvents
Neurobehavioral disorders	Lead, methylmercury, PCBs, PBDEs, pesticides, perchlorate, air pollutants

Additionally, the social environment influences health. Inequities in preventable health conditions have been consistent and persistent across racial/ethnic groups and income levels.[10] While Asian Americans living in California can expect to live to 86 years, the average life span for African Americans is 73 years.[11] Across nearly all health outcomes, individuals from neighborhoods with lower educational attainment and lower income will see higher disease rates and die younger.[12]

Children, the Environment, and Health

Children are more susceptible than adults to many environmental pollutants. Children breathe, eat, and drink more than adults per pound of body weight, and their behaviors—such as placing their hands in their mouth or playing on the ground—often mean they have greater opportunity for contact with environmental contaminants compared to adults. As children grow and develop, their physiology is also going through complex and sensitive periods of change that can be disrupted by environmental contaminants.

Exposure to environmental pollutants may contribute to childhood disease by disrupting physiological development, altering complex gene-environment interactions, or modifying desirable behaviors (for example, a child forced to stay inside due to poor air quality may miss out on health-promoting exercise and social interactions with peers). Research has shown an association between environmental contaminants and asthma, cancer, and a variety of neurological conditions, including attention-deficit hyperactivity disorder (ADHD), intellectual disabilities (ID), and autism spectrum disorder (ASD).[4] The negative health consequences related to childhood lead exposure are also well-documented.

Growing evidence suggests that a variety of environmental pollutants may contribute to obesity and diabetes, as well as other diseases that are not considered in this report.[13] And though this report is focused on a select set of conditions diagnosed during childhood, environmental exposures during childhood can lead to various illnesses in adulthood, including cancer, cardiovascular disease, dementia, and others.[14,15]

Previous Estimates of Environmental Health Costs

The economic burden of environmental childhood health conditions is substantial, and estimated to cost $76 billion nationally.[16] Some costs are incurred through medical treatments, others by the child's family due to rehabilitation, therapy, disabilities, and/or reduced earnings.

Important health and economic benefits result from the prevention of environmental exposures. Removal of lead in gasoline reduced lead exposures by more than 90%, as evidenced by decreased mean blood lead levels, and contributed to increases in the average IQ among U.S. children. This has produced an economic benefit of nearly $200 billion each year since 1980 due to increased productivity.[17] Further efforts to reduce lead exposures from other contaminated materials could achieve additional cost savings.

Investing in Public Health Promotion and Disease Prevention

The vast majority of healthcare spending in the United States is devoted to medical expenses rather than primary prevention efforts. Today, only 3% of our nation's $2.5 trillion dollars in health spending goes toward public health and disease prevention, while 97% goes to direct healthcare and medical service expenses. Yet less than 20% of increased life expectancy is attributed to improvements in healthcare and medical services. Instead, the majority is believed to have resulted from public health services and disease prevention.[1,18] These data suggest that curbing the rise of healthcare costs must also include public health promotion and disease prevention efforts.

Reducing children's environmental exposures is one investment that will lower the incidence of disease, decrease healthcare costs, and provide many substantive long-term societal benefits. However, to better address chronic diseases and healthcare costs related to the environment, better data are needed. While environmental health costs have been estimated at the national level and for a few states, recent and comprehensive data have not been available for California.

Purpose of This Report

This report is part of the National Environmental Public Health Tracking (EPHT) Program's *Economic Burden of Childhood Environmental Illnesses Project*. Participating states included California, Connecticut, Florida, Minnesota, New Hampshire, Oregon, and Utah. The EPHT program provides data on environmental hazards, exposures, and health outcomes to better understand the complex relationship between them. Quantifying the burden of childhood conditions related to the environment highlights the seriousness of such conditions in both their human and economic impact.

Information that describes the health and economic burden resulting from exposures to environmental hazards can inform policies to improve public health. Furthermore, understanding the environmentally-related costs of health conditions is necessary when evaluating the costs and benefits of environmental policies, regulations, and remediation efforts. This report is intended to provide useful information to policy makers, public health practitioners, health advocates, and others interested in improving children's environmental health.

The following sections estimate the disease burden and the environmentally attributable economic impact of selected childhood conditions in California:

- **Asthma**
- **Cancer** (limited to leukemia, lymphomas, and brain/central nervous system cancers)
- **Lead exposures,** as measured by mean blood lead levels
- **Neurobehavioral disorders** (autism spectrum disorder, attention-deficit and hyperactivity disorder, and intellectual disability)

California Environmental Health Tracking Program

The California Environmental Tracking Program (CEHTP) improves public health by providing information on environmental health hazards and outcomes. CEHTP integrates environmental, health, and other data sources to improve the utility of public health data and to inform public health policy and practice.

CEHTP makes data available on a variety of environmental hazards that may impact children's health, including traffic, air pollution, water quality, and pesticides. For more information on CEHTP, visit www.CEHTP.org. Visit www.cdc.gov/ephtracking to learn more about the National Environmental Public Health Tracking Program.

Overview of Methods

The methodology relies heavily on work originally published by Landrigan et al., and a subsequent analysis by Trasande and Liu, that estimated costs of environmental disease among children nationally.[16,19] In general, methods to estimate costs for each condition varied and were based on disease etiology and progression, relationship with the environment, and existing peer-reviewed literature.

For this assessment, data specific to California were used when available. When these data were unavailable, national data were used to estimate California numbers. All costs are presented in 2013 U.S. dollars using the Consumer Price Index (CPI) calculator.[20] A brief description of the methods used is provided below. More detailed information on data sources and methods is available online at www.phi.org/CEHTPKidsHealthCosts.

Definition of Environmental Factors and Environmental Attributable Fraction

For the purposes of this report, **environmental factors** are defined as pollutants of human origin in the air, water, soil, and home. This definition includes only factors that are potentially preventable through public health prevention and pollution mitigation. Other physical substances (e.g., pollen), social factors (e.g., poverty), or individual behaviors (e.g., smoking) are excluded from this definition, though these factors have very substantive impacts on the selected environmental health conditions considered in this report.

To estimate the proportion of disease burden that is likely associated with preventable environmental hazards, the **environmental attributable fraction** (EAF) model was used. The EAF is defined as *the percentage of a particular disease category that would be eliminated if environmental factors were reduced to their lowest feasible levels.*[21]

Landrigan et al. published estimates of the EAF for asthma, cancer, and neurobehavioral disorders in 2002, and some EAFs were updated by Trasande and Liu in 2011. Since lead exposures are entirely due to lead in the environment, the EAF for lead is assumed to be 100%, as in previous studies. For this report, EAFs for asthma and cancer were calculated using California-specific data based on peer-reviewed literature available at the time of the analysis (Table 2). The EAF calculation included: (1) the prevalence of the disease in the population, (2) the risk of having the disease as associated with each specific hazard, and (3) the prevalence of the exposure to each hazard among children in California.

Table 2. Environmental Attributable Fraction (EAF) by condition

Condition	EAF (possible range of values)
Asthma	30% (20–41%)*
Cancer	15% (9–21%)*
Lead exposures	100%
Neurobehavioral disorders	10% (5–20%)**

*Calculated using California-specific data
**Landrigan et al., 2002

Estimating the Burden of Select Environmental Health Conditions

California-specific disease incidence and/or prevalence were used when available to estimate the burden of disease and to calculate cost estimates. Disease incidence is used when the condition is potentially preventable (e.g., cancer), while prevalence is used when reducing environmental hazards is likely to alleviate symptoms of the

condition (e.g., asthma). Data are generally presented for children younger than 18 years of age, though exact age classifications vary by condition. For example, data for childhood cancers are reported by the California Cancer Registry for children 0–14 years of age.

Estimating Costs of Childhood Conditions

The methods and data used to estimate costs of these select conditions are based on previous research efforts. Costs accrued over the course of one year (*annual costs*) are estimated, as well as costs and earnings that may accrue throughout the child's entire life (*lifetime costs*). Readers should note that other studies often do not make this distinction. The types of costs considered in this study include:

- Direct medical and non-medical costs
- Indirect costs, such as lost parental earnings due to school absenteeism
- Lost potential earnings during the child's lifetime due to disability or premature death

Estimating Disease Burden and Costs Due to the Environment

To estimate the burden of disease due to the environment, the EAF is combined with information on the size of the population at risk and the underlying rate of each condition. To estimate the cost of disease due to the environment, the EAF is combined with information on the size of the population at risk, the underlying rate of the condition, and the cost per case, expressed as:

Total costs due to the environment	=	EAF	x	size of population at risk	x	disease rate	x	cost per case

Limitations

The following considerations are important when interpreting and using these results:

- The data presented in this report are for four selected environmental health conditions among children, and are not inclusive of the total burden of the environment on children's health. For consistency, conditions assessed were limited to those studied in previous environmental cost reports and analyses.
- Exposures that occur during childhood and can contribute to adult illnesses are not included here. For example, we do not include adult onset cancer or neurological disorders that may be related to childhood exposures.
- There are many challenges in capturing the entire burden of any particular disease in children. For example, statewide surveillance systems do not exist for many of the neurobehavioral disorders; therefore, this report uses national estimates or data from local case studies to approximate statewide incidence rates as necessary.
- There are many other costs related to the impact of each disease that are difficult to measure and are therefore not included. For example, increased crime is often cited as an impact related to lead exposures, but not included here.
- The EAFs used in this study only consider environmental pollutants for which there is evidence of their impact on health. Many emerging environmental health threats have not been sufficiently studied to understand how they may impact health and are therefore not accounted for here.

Given these limitations, this report most likely **substantially underestimates the true disease burden and cost related to the environment.**

Childhood Asthma in California

Asthma is one of the most common chronic diseases among U.S. children.[4,22] It is a disease that affects the lungs and makes it difficult to breath. Symptoms can range in severity from mild to life-threatening.[23]

Untreated and undertreated asthma can lead to serious and costly outcomes, which can include:[24]

- Emergency room (ER) visits
- Hospitalizations
- Death

Serious asthma outcomes are considered preventable, as they can usually be minimized with:[25]

- Adequate health care
- Proper use of medications
- Avoidance and prevention of asthma triggers, such as mold

Asthma does not impact all children equally.

Asthma hazards and outcomes are more common among low-income communities and communities of color:[4,24]

- African American children have asthma ER visit rates that are 5 times that of White children
- Children from low income neighborhoods are more likely to encounter risk factors for asthma
- Communities with poor air quality have greater asthma risks
- Communities and households with inadequate healthcare access have fewer resources to manage their asthma

Childhood Asthma in California

Each year, there are an estimated 96,550 new cases of childhood asthma in California.[24] Although rates of asthma hospitalizations and deaths are decreasing over time, asthma prevalence is not.[4] Asthma is one of the leading causes of school absenteeism.[26]

Annual burden among children ages 0–17:

- Children with current asthma: **926,000**
- ER visits: **72,464**
- Hospitalizations: **10,715**
- Deaths: **14**
- Missed school days: **1.3 million**

Data sources: CHIS, 2011–2012; OSHPD, 2012; Vital Records, 2010

Asthma and the Environment

Both genetic and environmental factors influence asthma development. Many environmental factors can contribute to asthma attacks and worsen symptoms.[27]

Considering both indoor and outdoor factors related to asthma, it is estimated that the environment accounts for 30% (range: 20–41%) of the total childhood asthma burden in California. This is known as the environmental attributable fraction, or EAF. The following environmental hazards have been associated with asthma; not all were included in the calculation of the EAF because of a lack of data.

Indoor factors[27,28,29]

- Secondhand smoke
- Mold and/or dampness
- Pests (e.g., rodents, cockroaches)
- Pet dander
- Dust mites
- Chemicals (e.g., cleaning products, perfumes)

Outdoor factors[25,26]

- Air pollutants
- Wood burning
- Pollen
- Extreme weather events

How are Asthma Costs Calculated?

For childhood asthma, *annual costs* include direct medical costs and indirect costs. *Lifetime costs* include lost potential earnings due to premature death.

Annual Costs

The cost of childhood asthma for a single year includes:

- **Direct medical costs** for treatment, including physician visits, emergency room visits, hospitalizations, and prescription medication.
- **Indirect costs** related to parental/caregiver earnings lost to care for a child who misses school due to asthma.

In 2010, it is estimated that 530,100 children with asthma were treated in California. Based on this estimate, annual direct medical costs among children treated for asthma are almost $461 million, and indirect costs due to total parental earnings lost are nearly $233 million. For asthma in California, the annual total direct and indirect costs are $693 million (Table 3).

Lifetime Costs

Among children with asthma, relatively few cases result in death. However, any childhood death is tragic and premature and results in many years of life lost. For example, in 2010, there were 14 childhood deaths due to asthma, resulting in over 1,000 years of life lost and more than $21 million in lost potential earnings.

The Economic Impact of the Environment on Childhood Asthma

The direct and indirect cost of childhood asthma in California is $693 million each year (Table 4), and $21 million in lost potential earnings due to premature mortality. The percentage of asthma (and percentage of these costs) that is attributable to the environment is estimated to be about 30%, with a range of 20–41%.

In California, reducing environmental hazards related to asthma would

- **Alleviate asthma requiring medical attention among 280,000 children every year**
- **Prevent 4 deaths from childhood asthma every year**
- **Save $208 million annually in direct and indirect costs**
- **Contribute an additional $6 million in lifetime earnings**

These costs are conservative and do not include:

- Over-the-counter medications
- Direct non-medical costs (e.g., transportation for parents or other caregivers)
- Quality of life impacts on children and their families
- Cost of treating asthma over the lifetime

Table 3. Annual direct and indirect costs of childhood asthma in California

Type of cost	Included in cost	Inputs	Annual value (in millions, 2013$)
Direct Medical*	Physician visits, ER, hospitalization, prescription medication	$869 avg cost x 530,100 children treated	$460.7
Indirect**	Lost earnings due to missed school days	$175 (daily wage) x 1.3 million school days missed	$232.6
		TOTAL	$693.2

*CDC Chronic Disease Cost Calculator Version 2

**Mean daily wage from the ACS, 5-yr avg; School days missed from CHIS, 2011-2012

Table 4. Number of children with asthma and annual costs of asthma due to the environment

EAF	Number of children with current asthma*	Number of environmentally attributable cases per year	Total annual cost (2013$)	Annual cost of environmentally attributable asthma (in millions, 2013$)
20%	926,000	185,000	$693.2 million	$138.6
30%		278,000		$208.0
41%		380,000		$284.2

*"Current asthma" prevalence, CHIS, 2011-2012

Childhood Cancer in California

Cancer is the general name for a large group of diseases characterized by cells that grow out of control and have the potential to spread to other parts of the body.[30] If left untreated, many forms of cancer lead to serious illness and death.[31]

Although childhood cancer is rare, its occurrence is devastating for the child, the family, and the community.

The most common childhood cancers are:[32]

- Leukemia
- Lymphoma
- Brain/central nervous system (CNS) cancers

These three cancers account for approximately two-thirds of all childhood cancers in California.

Childhood Cancer in California

Over the last few decades, childhood cancer incidence has risen nationwide, while mortality rates have been declining due to better tools for diagnosis and treatment.[3,33] Rates of specific childhood cancers vary by age, sex, and race/ethnicity.[32] For example, acute lymphocytic leukemia is more frequently diagnosed among younger children, males, and Hispanic children.[34]

Annual burden among children ages 0–14*[35]

Children diagnosed with cancer:

- All types: **1,240**
- Most common cancers: **803****

Child deaths from cancer:

- All types: **194**
- Most common cancers: **135**

*Cancer registries often define childhood cancer as those diagnosed <15 years of age, and cancer diagnoses and treatments may be more similar to adult cancer by age 15

**Leukemia, lymphoma, and brain/CNS cancers

Data source: California Cancer Registry, 2010

Childhood Cancer and the Environment

Many factors may play a role in the development of childhood cancer, including genetics, environment, and parental behaviors and characteristics.[34,36]

It is estimated that the environment accounts for about **15%** (range: 9–21%) of the childhood cancer burden related to leukemia, lymphoma, and brain/CNS cancers. The following environmental hazards have been associated with childhood cancer; not all were included in the calculation of the EAF because of a lack of data.

Environmental hazards of concern[36,37]

Indoor	Outdoor
• X-rays	• Non-ionizing radiation
• CT scans	• Pesticides
• Radon	• Traffic pollution
• Solvents	• Nitrates in drinking water
• Secondhand smoke	

How are Childhood Cancer Costs Calculated?

For childhood cancer, *annual costs* include direct medical costs and indirect costs. *Lifetime costs* include lost potential earnings due to disability or premature death.

Annual Costs

The cost of childhood cancer for a single year includes:

- **Direct medical costs** for treatment, including physician visits, emergency room visits, hospitalizations, and prescription medication.
- **Indirect costs** related to parental/caregiver earnings lost to care for a child being hospitalized for treatment, estimated at an average of 19 lost work days per year at $175 per day.

In 2010 in California there were 803 children diagnosed with the three most common cancers: leukemia, lymphoma, and brain/CNS cancers. Based on this, the direct medical costs are almost $123 million, and the indirect costs due to loss wages are nearly $3 million annually. For California, the total annual cost for the most common childhood cancers is $125 million (Table 5).

Lifetime Costs

There have been great improvements in childhood cancer survival rates, but cancer mortality still accounts for a substantial disease burden among children. In 2010, there were 135 premature deaths due to the most common childhood cancers (lymphoma, leukemia, and brain/CNS cancers). Annually, mortality from these cancers accounts for nearly 10,000 years of life lost and represents over $202 million in lost potential earnings. In addition, radiation treatment for children with brain/CNS cancers results in $20 million in lost potential earnings over the lifetime due to reductions in IQ.

The Economic Impact of the Environment on Childhood Cancer

The cost of the three most common childhood cancers is $125 million annually (Table 6), and $222 million in lost potential earnings due to premature mortality and IQ reductions. The reduction in IQ is an anticipated outcome due to the long-term effects of required radiation on brain cell function and brain/CNS cancer treatments. The percentage of childhood leukemia, lymphoma, and Brain/CNS cancers (and percentage of these costs) that is attributable to the environment is estimated to be about 15%, with a range of 9–21%.

In California, reducing environmental hazards related to cancer would

- **Prevent 120 children from developing cancer every year**
- **Prevent 20 deaths from childhood cancer every year**
- **Save $19 million annually in direct and indirect costs**
- **Contribute an additional $33 million in lifetime earnings**

These costs are conservative and do not include:

- Over-the-counter medications
- Direct non-medical costs (e.g., transportation for parents or other caregivers)
- Secondary neoplasms (i.e., tumors that result from metastasis or that develop later due to treatment such as radiation)
- Disease reocurrence
- Costs for cancers besides leukemia, lymphomas, and brain/CNS cancers

Table 5. Annual direct and indirect costs of childhood cancer in California

Type of cost	Included in cost	Average cost per case (2013$)	Number of cases*	Annual value (in millions, 2013$)
Direct Medical	Physician visits, ER, hospitalization, prescription medication	$152,578	803	$122.5
Indirect	Lost earnings due to missed school days	$3,325	803	$2.7
			TOTAL	$125.2

*Incident cases of leukemia, lymphoma, and brain/CNS cancers among children 0-14 years of age, 2010

Table 6. Number of cases and annual costs of cancer due to the environment

EAF	Number of children (0-14) diagnosed with cancer*	Number of cases due to the environment	Total annual cost (2013$)	Annual cost of environmentally attributable cancer (in millions, 2013$)
9%	803	72	$125.2 million	$11.3
15%		120		$18.8
21%		169		$26.3

*Incident cases of leukemia, lymphoma, and brain/CNS cancers among children 0-14 years of age, 2010

Childhood Lead Exposures and Health in California

Lead is a naturally-occurring mineral that is known to be toxic to the human body even at low levels. It impairs the development of the nervous system and causes damage to other organs.[38] Exposure to lead is assessed by measuring blood lead levels.

No amount of lead in the body is known to be safe.

High levels of exposure:[39]

- Can result in seizures or death
- Damage the nervous system, kidneys, and other major organs

Low levels of exposure can cause:[40]

- Decreased IQ and learning problems
- Behavioral problems
- Reductions in school performance, educational attainment, and future earning potential

Lead does not impact all children equally, and higher levels of lead exposure have been found in children who are:[41]

- Living in poverty
- Enrolled in Medicaid
- Living in older housing
- African American

Lead exposure is preventable.

The best approach for lead exposure prevention is keeping homes lead-safe, making soil lead-free, and using consumer products that do not contain lead.

Childhood Lead Exposures in California

Although lead exposure in children has decreased over the past 30 years, it is still the most common environmental condition in California children.[42] In California, children considered at increased risk for lead exposure are required to be blood lead tested. Because not all children are tested, the average *blood lead level (BLL)* among all California children cannot be estimated with certainty, although it is thought to be lower than the national average (1.2 µg/dL).[43]

Annual burden as measured by blood lead levels among 675,000 children tested in California in 2011:

- **17,410** were at or above 5 µg/dL
- **2,160** were at or above 10 µg/dL

Data source: Childhood Lead Poisoning Prevention Branch, 2011.

Risk factors in California

Because of the historical use of lead in paint, older housing is a known risk factor for lead exposure. In California, 16% of housing units were built before 1950, and 62% were built before 1980. Children living in low-income households also face increased risk of lead exposure, and 23% of California children under five years of age live in poverty (American Community Survey, 2012).

Lead in the Environment

Lead exposure and related health consequences have greatly decreased due to its restricted use in paint, gasoline, and other prod-

ucts. However, lead continues to be a hazard in homes, other parts of the environment, and in some consumer products. Lead in paint, dust, and soil are the leading cause of high lead levels in U.S. children.[44,45] Lead can also be found in some imported foods, goods, certain traditional ethnic remedies, and metal jewelry.[46]

How are Lead Costs Calculated?

There are many costs that families of lead exposed children and society incur. This report narrowly focuses on *lifetime costs*, estimated as lost potential earnings over the lifetime for all children born in a single year.

Lifetime costs

The lost potential earnings due to lead exposure are calculated using the estimated mean:

- Blood lead level (BLL) among all children in California
- Loss in IQ points
- Loss in lifetime earnings

Mean BLL in California

Because of the skewed distribution of BLLs in the population, the *geometric mean* is used to describe the average BLL in a population.

In California, the geometric mean BLL is estimated to be **in the range of 0.9–1.2 µg/dL**. The lower estimate was based on examining results from several laboratories in California, and the upper estimate is the national average based on the 2009–2010 National Health and Nutrition Examination Survey (NHANES).[41]

Mean loss in IQ points

For each 1 µg/dL change in blood lead level, the estimated mean loss in IQ points is 0.57.[47] For the BLL range of 0.9–1.2 µg/dL, the mean loss of IQ points is estimated to be between **0.51 and 0.69**.

Mean loss in lifetime earnings

For each 1-point reduction in IQ, the estimated loss in lifetime earnings is 2.39%.[48] For the IQ loss range of 0.51 to 0.68, the estimated loss in lifetime earnings is **1.23% to 1.63%**. This was applied to total lifetime production estimates for boys and girls separately, since boys and girls on average have different earnings over their lifetime.[49]

The Economic Impact of the Environment on Childhood Lead Exposures

All lead exposure is attributable to environmental contamination. Therefore, the EAF for childhood lead exposure is 100%.

In California, preventing childhood lead exposure would contribute an additional $8–11 billion in lifetime earnings for all children born in a single year (Table 7).

This is a conservative cost estimate. It does not take into account many other medical, social, and personal costs related to lead exposure that are lacking cost data or are difficult to quantify, such as:

Health costs

- Treatment for children with high BLL
- Follow-up testing for lead exposure
- Resulting childhood illnesses (e.g., hypertension)
- Adult onset health conditions, such as cardiovascular, neurological, and reproductive disorders

Housing costs

- Housing relocation
- Environmental investigations and remediation
- Preventative maintenance of buildings to avoid toxic effects

Other costs

- Social welfare system costs
- Special education
- Tax revenue from earnings lost
- Crime

Table 7. Lost lifetime earnings due to lead based on estimated geometric mean blood lead levels among California children

	Geometric mean blood lead level among children less than 6 years old	
	Lower estimate 0.9 µg/dL*	Upper estimate 1.2 µg/dL**
Mean loss of IQ points***	0.51	0.69
Percent of lifetime earnings lost†	1.23%	1.63%
Lost lifetime earnings for boys born in 2012 (based on $1,638,041 lifetime earnings‡ x 257,457 boys x 1.23–1.63%)	$4.7 billion	$6.2 billion
Lost lifetime earnings for girls born in 2012 (based on $1,357,176 lifetime earnings‡ x 246,331 girls x 1.23–1.63%)	$3.7 billion	$4.9 billion
Total lifetime earnings lost for all children born in 2012	**$8.3 billion**	**$11.1 billion**

*Based on analyzing 2011 blood lead level results from 5 laboratories in California

**National geometric mean BLL among 1–5 year old children, NHANES, 2009-2010

***Based on IQ points lost per change in 1 µg/dL in blood lead (Canfield, 2003)

†Based on % of earnings lost per one IQ point reduction (Salkever, 1995)

‡Present value of lifetime total production for 0-4 year-olds at 3% discount rate inflated to 2013$ (Grosse, 2009)

Childhood Neurobehavioral Disorders in California

Neurobehavioral disorders include disabilities that impact the functioning of the brain and central nervous system.[4,50] Among others, they include:

- Attention-deficit/hyperactivity disorder (ADHD)
- Autism spectrum disorder (ASD)
- Intellectual disability (ID)

The impacts of these disorders can change over time and can occur throughout life.

Neurobehavioral disorders can impact:[4,16,19]

- Speech and language skills
- Motor skills
- Memory and learning
- Cognitive abilities
- Social and relationship skills
- Emotional and sensory regulation

Treatments commonly involve comprehensive assessments, medication, therapies, and special school programs. This study only focuses on ASD, ADHD, and ID. These conditions have been included in previous cost reports and have sufficient evidence linking them to environmental hazards.

Childhood Neurobehavioral Disorders in California

An estimated 15% of children in the United States have a neurobehavioral disorder, and ASD and ADHD rates have been rising over time.[51] In the U.S., 1 in 68 children have been identified with an ASD, and it is more common among boys and White children.[52] More than 1 in 10 children in the U.S. have been diagnosed with ADHD, with boys more likely to receive a diagnosis than girls.[53]

The prevalence rate of ID is estimated to be 1.2%.[54] ID often co-exists with ASD and/or ADHD. For example, 48.5% of children with ASD and 44.3% of children with ADHD also reported to have ID.[16]

Estimated number of children with each disorder among 2012 births in California:

- 7,410 with ASD
- 14,520 with ADHD
- 6,050 with ID

No registries exist for childhood neurobehavioral disorders in California. Therefore, estimates are based on national and regional sources.

Childhood Neurobehavioral Disorders and the Environment

Most neurobehavioral disorders likely have a complex etiology, beginning in utero and continuing into childhood, which may include genes, the environment, and complex interactions between the two.[3]

There are many environmental hazards that may be associated with the onset of neurobehavioral disorders in children. Previous research has suggested that the environmental attributable fraction of neurobehavioral disorders is about **10%** (range: 5–20%).[16,19]

Environmental hazards of concern include the following indoor and outdoor contaminants[4,16,20]

- Lead
- Chemicals in household products
- Pesticides
- Air pollutants
- Methylmercury and other metals that may be found in food and water

How are Neurobehavioral Disorder Costs Calculated?

Families with a child with a neurobehavioral disorder incur many costs throughout the child's lifetime. This report provides both *annual* and *lifetime* cost estimates for children born in a single year and diagnosed with ASD, ADHD, or ID.

Annual Costs

The annual cost of neurobehavioral disorders may vary from one condition to the next depending on available data, but generally includes:

- **Direct medical costs** for treatment, including physician visits, emergency room visits, hospitalizations, prescription medications, and therapy costs.
- **Non-medical costs,** such as special education, childcare, and modifications for the home and vehicles.

For all children born in a single year, the annual direct cost for ASD is $162 million (Table 8). The annual direct cost for ADHD is $165 million. The annual direct cost for ID is $96 million. Adjusting for co-existing conditions (occasions where a child may have two or more of these conditions), total annual costs for these selected neurobehavioral disorders for children born in a single year are $271 million.

Lifetime Costs

The impact of neurobehavioral disorders are felt over the lifetime of the child. Lifetime costs include future medical costs; other costs associated with managing the disorder (such as support programs, special education, and home modifications); and a loss in future potential earnings.

Total lifetime costs for ASD for children born in a single year are estimated to be $30 billion. Lifetime costs for ADHD for children born in a single year are estimated at $3 billion. For ID, lifetime costs are estimated to be $7 billion for children born in a single year (Table 9). With reductions for the co-existence of ID with ASD or ADHD, lifetime costs are estimated to total over $23 billion.

The Economic Impact of the Environment on Childhood Neurobehavioral Disorders

The cost of ASD, ADHD, and ID for a single birth cohort in California is $271 million each year, and $23 billion over their lifetime. The environment is estimated to account for 10% (5–20%) of the total burden of these disorders (Table 10).

In California, reducing environmental hazards related to neurobehavioral disorders would

- **Prevent nearly 1,800 children from developing neurobehavioral disorders each year**
- **Save around $27 million annually in direct medical costs for all children born in a single year**
- **Result in more than $2 billion in saved costs and additional earnings over the lifetime for all children born in a single year**

These costs are conservative estimates, and do not include:

- Other neurobehavioral disorders that may be related to the environment
- All children age 18 and under with these disorders (costs were estimated for a single birth cohort)
- Annual costs for behavioral therapies, special childcare needs, or home improvements
- Annual indirect costs, such as lost parental wages

Table 8. Annual costs for ASD, ADHD, or ID among children born in a single year in California

	Estimated cases among 2012 births	Annual costs per case (2013$)	Total annual costs (in millions, 2013$)
ASD	7,410	$8,296 for medical costs $13,600 for special ed	$162.2
ADHD	Boys: 11,070 Girls: 3,450	$3,126 for medical costs for boys $2,928 for medical costs for girls $13,600 for special ed*	$165.2
ID	6,050	$2,200 for medical costs $13,600 for special ed	$95.6
		Accounting for co-existing conditions	*-$151.9*
		With reductions for co-existing conditions, TOTAL	$271.1

*Special education costs applied to only 61% of children with ADHD

Table 9. Lifetime costs for ASD, ADHD, and ID among children born in a single year in California

	Estimated cases among 2012 births	Lifetime cost per case (2013$)	Lifetime costs (in billions, 2013$)
ASD	7,410	$1.6m for medical costs $1.1m for future productivity $1.2m for parental lost wages	$29.7
ADHD	Boys: 11,070 Girls: 3,450	$93,795 for medical costs for boys $87,846 for medical costs for girls $176,800 for special education* $2,285 for parental lost wages	$2.9
ID	6,050	$345,659 for medical costs $852,506 for future productivity	$7.2
		Accounting for co-existing conditions	*-$16.6*
		With reductions for co-existing conditions, TOTAL	$23.3

*Special education costs applied to only 61% of children with ADHD

Table 10. Number of children and costs due to the environment for ASD, ADHD, and ID among children born in a single year in California

	Estimated cases among 2012 births			Estimated annual costs due to the environment (in millions, 2013$)	Estimated lifetime costs due to the environment (in billions, 2013$)
EAF	ASD*	ADHD**	ID		
5%	190	400	300	$13.6	$1.2
10%	**380**	**810**	**600**	**$27.1**	**$2.3**
20%	760	1,620	1,210	$54.2	$4.7

*Estimated ASD cases without ID
**Estimated ADHD cases without ID

Discussion and Key Findings

Reducing environmental hazards could potentially save over $254 million annually in direct and indirect costs to care for children with environmentally-related conditions and $13 billion over the lifetime for all children born each year in California. These costs do not reflect the pain, suffering, and stress experienced by the child and family as they navigate a child's illness and long-term care. In addition, these costs do not account for many of special childcare needs that families must seek, nor the quality of life impacts faced by the children and their families. Using the most recent data available for California, we found that:

- Lead exposure, by far, has the greatest financial impact—between $8–11 billion for each birth cohort
- Reducing environmental hazards related to asthma could reduce annual costs by over $208 million and improve asthma outcomes for over 280,000 children every year
- Similarly, annual costs of childhood cancer could be reduced by $19 million, and 120 cancer diagnoses would be avoided each year
- The prevention of environmental hazards related to select child neurobehavioral disorders could reduce annual costs by over $27 million and lifetime costs by over $2.3 billion for each birth cohort

Report Strengths and Limitations

This report presents new and relevant information on the disease burden and costs associated with four selected environmental health conditions in California children. The estimates are based on the most recent data available for California at the time of the report. Environmental attributable fractions (EAF) that are more specific to California were quantified for childhood asthma and cancer, rather than using consensus-based estimates derived by Landrigan et al. It is noteworthy that calculated EAFs were similar to those presented by Landrigan et al. Final cost estimates are presented as both annual and lifetime costs. Many previous studies do not make this distinction, thus comparisons with this study should be made with caution.

Due to various factors, these cost estimates are most likely conservative. Other related costs were not included for consistency with previous research or because data were not available. Additionally, this assessment narrowly defined environmental factors and did not account for childhood disease burden related to other aspects of the physical environment, such as the built environment. Finally, these reported cost estimates are limited to the childhood onset of disease. Although there is extensive research linking early childhood environmental exposures to adult onset diseases, this report does not include the disease burden or costs associated with those adult diseases.[55,56,57,58] This report also does not include other childhood diseases that may be related to the environment (e.g., obesity).

EAFs are not absolute measures, but rather were calculated on the best evidence available at the time of this assessment. Every day, new chemicals and new technologies—some of which may be hazardous, others health promoting—come into the marketplace. There is no way to capture the potential hazard without additional research. In addition, our knowledge of existing, suspected environmental hazards will change over time as research progresses. It is reasonable to expect EAFs to change as more research is performed and as more hypotheses are generated regarding the environment and health.

Return on Investment of Environmental Health Protections

Data on the costs of environmental illnesses in children can help policymakers better understand the possible benefits of environmental remediation efforts. Cost-benefit analyses are often at the root of many successful policies and interventions. Evaluations of past efforts have shown that programs and policies that reduce harmful environmental exposures can have dramatic returns on investment. The Clean Air Act, originally passed in 1970 and revised in 1990 with broad support, has generated benefits of more than $30 for each dollar of regulatory costs.[59] The majority of benefits are due to declines in premature mortality resulting from reductions in particulate matter. Other benefits include reductions in mortality and morbidity associated with ozone reductions, such as myocardial infarctions and chronic bronchitis. Each year, these air standards save hundreds of thousands of lives, prevent millions of asthma exacerbations, and avert many millions of lost school and work days throughout the country.

For each dollar invested in controlling hazards from lead paint, there is a $17–$221 return in societal benefits.[60] Blood lead levels in children have dropped substantially since the 1980s, in large part due to a political consensus that emerged regarding the cost-effectiveness of lead poisoning prevention.[61] To date, the percent of 1–5 year olds with BLL greater than 10 µg/dL has dropped from 88% to 4% nationally. However, racial/ethnic and income inequities in lead exposure persist, and research continues to show the disproportionate exposure among non-Hispanic Black children.[62] Investment in primary prevention continues to be the only practical approach to the elimination of elevated BLLs. As this report shows, lead exposure continues to cost California up to $11 billion for a single birth cohort, but these costs are preventable.

Targeting successful public health interventions to communities with the greatest risks will continue to save both money and lives.

Using Data to Reduce the Environmental Health Burden in California

Ultimately, data are at the foundation of evidence-based policies that are both effective and cost-efficient at reducing the burden of environmental illness in California. To advance our understanding of children's environmental health in California, and to ultimately improve the public's health, there is a need to:

- Maintain current environmental health surveillance systems in California and expand these systems to address data gaps, particularly in regards to community-specific data on disease burden, environmental hazards, human exposures, and health costs
- Use health surveillance data to inform policies that impact health and to evaluate the effectiveness of public health interventions
- Collect and provide data that is accessible and relevant to stakeholder needs so that individuals, communities, and institutions can be engaged in supporting healthier environments

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