Costs of Environmental Health Conditions in California Children

Appendix A: Methods and data sources for estimating the economic burden of select environmental health conditions in children

California Environmental Health Tracking Program

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Contents

Overview

This assessment focuses on the following selected childhood conditions:

1. Asthma
2. Cancer (leukemia, lymphoma, and brain/central nervous system (CNS))
3. Lead exposures
4. Neurobehavioral disorders (Autism Spectrum Disorders (ASD), Attention Deficit Hyperactivity Disorder (ADHD), and Intellectual Disabilities (ID)).

The methodology is modeled on work originally published by Landrigan et al. (2002),[1] and a subsequent analysis by Trasande and Liu (2011).[2] In addition, the Centers for Disease Control and Prevention (CDC) Chronic Disease Cost Calculator v2[3] was used to calculate costs for asthma.

The environmental attributable fraction (EAF) of disease is the proportion of a childhood condition that could be avoided if preventable environmental hazards were mitigated. For this report, the EAF of the neurobehavioral disorders estimated by Landrigan et al. were used. The EAF of asthma and cancer were calculated for this report using the most recent, California-specific data available (See Appendix B). The EAF for lead exposures is assumed to be 100%, since lead is entirely attributable to the environment.

To estimate the economic burden of select environmental health conditions in children, 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:

$$\textbf{Total costs} = \textbf{EAF} \times \begin{array}{c}\textbf{Size of}\\\textbf{population}\\\textbf{at risk}\end{array} \times \begin{array}{c}\textbf{Disease}\\\textbf{rate}\end{array} \times \begin{array}{c}\textbf{Cost per}\\\textbf{case}\end{array}$$

Occurrence of a Disease or Condition and the Population at Risk

Data regarding a disease or condition's incidence or prevalence in the California population are necessary to derive cost estimates. Prevalence is the number of children suffering from a condition, while incidence is the number of new cases that develop in a given time period. Prevalence is used when disease severity or exacerbations are expected to decline following removal of environmental factors and other triggers, such as with asthma. Incidence is used if the removal of environmental factors is expected to prevent new cases from occurring, such as with cancer and neurobehavioral disorders.

When to use prevalence or incidence is not always clear cut, and some assumptions have to be made. For example, recent data support a causal relationship between new-onset asthma and traffic-related air pollution.[4] Since the EAF estimate is focused on the relationship between environmental hazards and asthma exacerbations, rather than asthma etiology, asthma prevalence data were used, and the EAF is assumed to underestimate environmental contributions to total asthma burden since it may not entirely capture new-onset asthma. Likewise, asthma costs attributable to the environment will also be conservative. For neurobehavioral disorders, it may not always be known at what age the disease onset has begun. Therefore we estimate prevalence within a birth cohort, which we term "cohort prevalence".

Types of Costs Estimated

Estimates are included for both *annual* costs and *lifetime* costs. Annual costs accrue in a single year, while lifetime costs accrue over the child's life course. Annual and lifetime costs can be classified as direct costs, indirect costs, and lost potential earnings, described in more detail below:

- **Direct Costs** include both medical and non-medical costs. Medical costs are total expenditures of being treated for the condition, which may include hospital stays, emergency department visits, physician visits, and prescription medication. Non-medical costs may include transportation, home care, child care, and special education.
- **Indirect Costs** include lost parental wages to care for a child missing school because of the condition or related medical treatment.
- **Lost Potential Earnings** are earnings that do not accrue due to premature mortality, a reduction in IQ, or disability related to the condition.

When available, methods that estimated *excess* or *incremental* costs were used. These are the excess costs associated with treating the specific disease beyond average medical costs. This approach was used for annual asthma costs, annual ADHD costs, and lifetime costs for all neurobehavioral disorders. Cancer costs included total charges incurred for treating the cancer, without accounting for other non-cancer related costs.

Data derived from California datasets were prioritized over national data. If unavailable, then estimates were based on national data. All costs were inflated to 2013 U.S. dollars using the Consumer Price Index (CPI) calculator.[5]

Table 1. Measures of disease burden and data sources

Condition	How burden is measured	Data Source
Asthma	Prevalence of asthma in children less than 18 years of age Prevalence of "treated" asthma cases in children less than 18 years of age	California Health Interview Survey (CHIS), 2011–2012 Medical Expenditure Panel Survey (MEPS), 2004–2008
Cancer	Incidence of cancer in children less than 15 years of age	California Cancer Registry (CCR), 2010
Neurobehavioral disorders	Prevalence of condition within a single birth cohort	Autism and Developmental Disability Monitoring Network (ADDM), 2010 Metropolitan Atlanta Developmental Disabilities Surveillance Program (MAADSP), 2006 National Survey of Children's Health (NSCH), 2011–2012
Lead exposures	Geometric mean blood lead level among children less than 6 years of age	Childhood Lead Poisoning Prevention Branch (CLPPB), 2011

Table 2. Types of costs estimated, by condition

Condition	Costs included	Type of costs
Asthma	Annual and lifetime	Annual direct and indirect Lifetime lost potential earnings*
Cancer	Annual and lifetime	Annual direct and indirect Lifetime lost potential earnings**
Neurobehavioral disorders	Annual and lifetime	Annual direct Lifetime direct, indirect, and lost potential earnings***
Lead exposures	Lifetime	Lifetime lost potential earnings***

*Due to premature mortality

**Due to premature mortality and reduced IQ for children treated for brain/CNS cancer

***Due to reduced IQ

Cost Methods and Data Sources By Condition

A. Asthma

Athma Prevalence and Outcome Data

Estimates of current or active asthma prevalence came from the 2011–2012 California Health Interview Survey (CHIS), a population-based phone survey that provides statewide and county-level estimates on the health of Californians. The "treated" population is defined as the number of people receiving care for asthma in the previous year, estimated by age, sex, and region. The prevalence of "treated" asthma cases is an estimate from the CDC Chronic Disease Cost Calculator (Cost Calculator) using the 2004–2008 Medical Expenditure Panel Survey (MEPS). MEPS is a nationally representative longitudinal survey that collects information on health care utilization and expenditures, as well as social, demographic, and economic characteristics for the U.S. civilian non-institutionalized population. Data for asthma mortality were compiled from the 2010 Death Statistical Master File (DSMF) from the CDPH Center for Health Statistics.

Annual Costs for Asthma

Direct Medical Costs

Direct medical costs were derived from the CDC Cost Calculator. The Cost Calculator uses a two-part regression model to estimate *incremental* medical expenditures at the state level for select chronic diseases, including asthma, on a cost-per-case basis. Costs include expenditures for office based visits, emergency room visits, inpatient hospital stays, dental visits, home health care, vision aids, other medical supplies and equipment, prescription medication, and nursing homes. The expenditure data are from MEPS, 2004–2008. The Cost Calculator provides estimates in 2010$, and were inflated to 2013$ using a general CPI conversion calculator.

Table 3. Total direct medical costs associated with treated asthma, children aged 0–17 years

Population age 0–17	Percent treated for asthma	Treated cases	Average cost per case (2013$)	Total costs (2013$)
9,364,530	5.70%	530,100	$869	$460,656,900

Data source: CDC Cost Calculator

Table 4. Parental lost income due to school days missed due to asthma

Total days missed due to asthma in one year*	Mean daily wage (2013$)**	Total wages lost (2013$)
1,328,969	$175	$232,569,575

*Among children with lifetime asthma, CHIS 2011–2012

**ACS 5-yr average was $168 for females in 2011$, and inflated to 2013$

Indirect Costs

Indirect costs included lost parental/caregiver earnings due to school absenteeism. There were an estimated 1.3 million missed school days due to asthma among children with lifetime asthma (CHIS 2011–12). Estimates of mean daily earnings were from the 2011 American Community Survey (ACS) 5-year average. Estimates were derived from average daily earnings for females in the labor force, assuming that female parents were more likely to stay home with the child.

The total direct medical costs for the treated population were $461 million, and the total indirect costs in lost parental wages were $233 million for a total of **$693 million (2013$) for childhood asthma in California**.

Lifetime Costs for Asthma

Lost Potential Earnings

Estimates of potential lifetime earnings lost due to premature death were taken from lifetime production values among 0–19 year olds calculated by Grosse et al. (2009) and inflated to 2013$.[6] Age-specific values were multiplied by the total number of deaths within each age group to calculate the loss in future lifetime earnings. Total years of life lost (YLL) were calculated using estimates of life expectancy at birth.[7]

Costs Not Included

Costs were not included for over-the-counter medications, direct non-medical costs (e.g., transportation expenditures), and reductions in quality of life. Therefore, these cost estimates for asthma (as for all other diseases assessed here) should be considered conservative.

Environmental Burden of Asthma

The EAF for asthma was estimated to be 30% (20–41%) (Appendix B). Therefore, over 280,000 children are estimated to suffer from asthma as a result of environmental factors, and the estimated cost of environmentally-related asthma is $208 million ($139–$284 million)(Table 7). Similarly, 4 asthma deaths are attributed to the environment, resulting in 280 years of life lost and an estimated $6 million in lost potential earnings (Table 8).

Table 5. Estimated direct and indirect costs associated with children's asthma

Type of cost	Annual value (2013$)
Direct medical costs*	$460,656,900
Indirect costs**	$232,569,575
Total costs	$693,226,475

*See Table 3
**See Table 4

Table 6. Estimated lost potential earnings and years of life lost due to premature death from asthma

Age group (years)	Number of deaths due to asthma*	Present value of lifetime production** (2013$)	Lost potential earnings (2013$)	Years of life lost
<1	0	$1,333,460	$0	0
1–4	4	$1,333,460	$5,333,840	310
5–14	9	$1,550,779	$13,957,011	634
15–17	1	$1,771,405	$1,771,405	64
Total	14		$21,062,256	1,008

*Death Statistical Master File, 2010
**Present value of lifetime production among 0–19 year olds, by 3% discount rate (Grosse et. al, 2009)

Table 7. Number of cases and annual costs of asthma due to the environment

EAF*	Number of children with current asthma**	Number of environmental attributable cases per year	Total annual cost (2013$)***	Annual cost of environmental attributable asthma (in millions, 2013$)
20%	926,000	185,000	$693,226,475	$138,645,295
30%		278,000		$207,967,943
41%		380,000		$284,222,855

*Environmental attributable fraction calculated for this report (See Appendix B)
**CHIS, 2011–2012
***See Table 5

Table 8. Number of deaths and lifetime costs of asthma due to the environment

EAF*	Number of deaths due to asthma**	Number of asthma deaths due to the environment	Years of life lost (YLL)***	YLL due to the environment	Lost potential earnings (2013$)***	Lost potential earnings due to the environment (2013$)
20%	14	3	1,008	202	$21,062,256	$4,212,451
30%		4		282		$5,897,432
41%		6		413		$8,635,525

*Environmental attributable fraction calculated for this report (See Appendix B)
**Death Statistical Master File, 2010
***See Table 6

B. Cancer

This assessment is limited to the following childhood cancers: leukemia, lymphoma, and brain/CNS cancers. These three cancer types are the majority of childhood cancers, and have the most evidence suggesting an association with environmental risk factors. Cancer cases were limited to children 0–14 years of age, as cancer diagnoses and treatment regimes may be more similar to adult cancer by age 15, and cancer registries often define childhood cancer as those diagnosed <15 years of age, and adolescent and young adult cancers as those diagnosed age 15–39 years. The assessment does not consider cancers that may develop after childhood, though there is evidence that environmental exposures in childhood and through adolescence can result in adult onset cancers.[8]

Cancer Incidence and Mortality Data

Cancer incidence data are from the California Cancer Registry (CCR). CCR is California's statewide population-based cancer surveillance system, collecting information about all cancer diagnosed in California. In 2010, the most recent year of complete case counts, there were 223 cases of brain/CNS cancers, 453 leukemia cases, and 127 lymphoma cases for a total of 803 incident cases of cancer among children age 0 to 14. There were a total of 135 deaths due to these three cancer types, accounting for 69.5% of all pediatric cancer deaths (n=194).

Annual Costs for Cancer

Direct Costs

Direct medical costs were based on estimates from Trasande and Liu, which were obtained from the following national sources: 2006–08 data from the National Hospital Ambulatory Medical Care survey/National Ambulatory Medical Care Survey (NHAMCS/NAMCS), Nationwide Inpatient Sample (NIS), Medical Expenditure Panel Survey (MEPS), and Nationwide Emergency Department Sample (NEDS). Their estimate for the average cost per cancer patient, when inflated to 2013$, was $152,578 in direct medical expenditures. For 803 cancer cases, total annual direct medical costs were $123 million (Table 9).

Indirect Costs

Indirect costs were based on lost parental earnings due to a child being hospitalized for cancer treatment. Similar to Landrigan et al., it was assumed that for every 7 days of hospitalization, a parent would miss 5 days of work. From Price et al. (2012), it was estimated that children with cancer had an average of 26 hospital days per year, which calculates to 19 days of missed work for a parent.[9] Using a mean daily wage of $175 (ACS), that totals $3,325 in lost parental wages per child with cancer annually. For 803 children with cancer, that's a total of $2,669,975 in lost parental wages. Total annual costs for childhood cancer were $125 million (Table 9).

Lifetime Costs for Cancer

Lost Potential Earnings

Cranial irradiation among children with brain/CNS cancer has been associated with an average loss of 2.8 IQ points,[10] which corresponds to a 6.69% loss in lifetime earnings.[11] Using the present value of lifetime production among 0–4 year olds,[6] total estimated lifetime loss per child is $89,208 (2013$). For the 223 incident cases of brain/CNS cancer, that totals $19,893,485 in lost lifetime potential earnings (Table 10). We also calculated lost po-

Table 9. Annual costs for children living with cancer

Type of cost	Included in cost	Average cost per child with cancer (2013$)	Cases in 2010*	Annual value (2013$)
Direct medical costs**	Physician visits, ED, hospitalization, medication	$152,578	803	$122,519,741
Indirect costs***	Lost parental wages	$3,325	803	$2,669,975
				Total: $125,189,716

*California Cancer Registry, 2010

**Trasande and Liu (2011)

***Estimate based on an average of 19 days of parental work missed (Landrigan, 2002, Price, 2012); mean daily wage $175 (ACS, 2011)

Table 10. Estimated lost potential earnings due to cranial irradiation among children with brain/CNS cancer

Indicator change	Value
Mean loss of IQ points due to cranial irradiation*	2.8
Loss in lifetime earnings**	6.69%
Present value of lifetime production among 0–4 year olds***	$1,333,460
Therefore, 6.69% of $1,333,460 (2013$)	$89,208
Number of cases of brain/CNS cancer cases	223
Total lost potential earnings due to cranial radiation (2013$)	**$19,893,485**

*Silber et al. (1992)

**1 point = loss of 2.39% of lifetime earnings (Salkever, 1995)

***Inflated to 2013$ (Grosse et. al, 2009)

Table 11. Estimated lost potential earnings and years of life lost due to premature death from cancer

Age group	Number of deaths due to cancer*	Present value of lifetime production** (2013$)	Lost potential earnings (2013$)	Years of life lost
0–4	35	$1,333,460	$46,671,090	2,730
5–9	48	$1,474,298	$70,766,296	3,504
10–14	52	$1,627,260	$84,617,520	3,536
Total	**135**		**$202,054,906**	**9,770**

*Deaths due to leukemia, lymphoma, and brain/CNS, California Cancer Registry (CCR), 2010

**Present value of lifetime production among 0–14 year olds, by 3% discount rate. (Grosse et. al, 2009) tential earnings and years of life lost due to premature mortality. With 135 deaths due to cancer among children, that totaled $202,054,906 in lost potential earnings, and nearly 10,000 years of life lost (Table 11). In total, lifetime lost potential earnings for childhood cancer totaled $222 million (Table 12)

Costs Not Included

Costs were not included for over-the-counter medications, direct non-medical costs (e.g., transportation, wigs, etc.), and reductions in quality of life. Therefore, cost presented here should be considered conservative.

Environmental Burden of Childhood Cancer

The EAF for childhood cancer was estimated to be 15% (range: 9–21%) (Appendix B). Therefore, 120 children are estimated to suffer from cancer each year as a result of environmental factors, and the cost of environmental cancer is $19 million ($11–27 million) (Table 13). Lost potential earnings due to the environmental burden of childhood cancer exceeded $33 million ($20–47 million) (Table 14).

Table 12. Estimated total lost potential earnings associated with childhood cancer

Type of cost	Included in cost	Lost earnings per cancer case (2013$)	Cases/ deaths in 2010	Lifetime value (2013$)
Lost potential earnings	Loss in IQ	$89,208	223*	$19,893,485**
	Lost earnings due to premature mortality	—	135***	$202,054,906†
				Total: $221,948,391

*Number of cases of brain/CNS , CCR, 2010
**See Table 10
***Number of deaths due to leukemia, lymphoma, and brain/CNS, CCR, 2010
†See Table 11

Table 13. Number of children diagnosed with cancer and annual costs of children living with cancer due to the environment

EAF*	Annual number of new cancer cases**	Cancer cases due to the environment each year	Total annual cost for cancer (2013$)***	Annual cost of environmental attributable cancer (2013$)
9%	803	72	$125,189,716	11,267,074
15%		120		18,778,457
21%		169		26,289,840

*Environmental attributable fraction calculated for this report (See Appendix B)
**Number of cases of leukemia, lymphomas, and brain/CNS cancers, CCR, 2010
***See Table 9

Table 14. Number of deaths, years of life lost, and lifetime costs of childhood cancer due to the environment

EAF*	Annual number of cancer deaths**	Cancer deaths due to the environment	Years of life lost	Years of life lost due to the environment	Lifetime cost for cancer*** (2013$)	Lifetime cost of environmental attributable cancer (2013$)
9%	135	12	9,770	879	$221,948,391	$19,975,355
15%		20		1,466		$33,292,259
21%		28		2,052		$46,609,162

*Environmental attributable fraction calculated for this report (See Appendix B)
**Number of deaths due to leukemia, lymphoma, and brain/CNS, CCR, 2010
***Lifetime costs due to premature mortality and reduced IQ (See Table 12)

C. Lead Exposures

It is well established that lead exposures result in a reduction in IQ,[11] impacting the future earning potential of the exposed child. The most common approach to estimate costs associated with lead is to calculate lost lifetime potential earnings among a single birth cohort. This approach was used by Landrigan et al.

Blood Lead Level Data

Each state has different laws and regulations governing what age groups should be targeted for blood lead testing and how often. In California, by regulation, children considered at increased risk for lead exposure (i.e., those in government-assisted programs and living in deteriorated older housing) are required to be blood lead tested at ages one and two years. Families of other children receive anticipatory guidance on avoiding lead exposure; these children receive blood testing if thought to be at risk by their family's health care providers.

Since not all children are tested, the average BLL among all children in California cannot be estimated with certainty. Thus, this report uses a range for the mean blood lead levels (BLL) in California. Since the population distribution of BLLs is skewed, the *geometric mean* is used to describe the average BLL in a population.

The National Health and Nutrition Examination Survey (NHANES) is a population-based survey of a national sample and includes testing for blood lead. Its most recent estimate for the geometric mean BLL among 1 to 5 year-olds nationally is 1.2 µg/dL.[12] It is thought the California mean would be lower than the national average, because California blood lead test results show a lower percent of children at the higher range of blood lead levels than the national numbers, even with testing those most at risk. To estimate the geometric mean BLL for these children in California, the CDPH Childhood Lead Poisoning Prevention Branch (CLPPB) examined the distribution of BLLs for laboratories that reported at least 1,000 BLLs to CLPPB in 2011 and had a detection level of less than 1.0 µg/dL. Based on the range of geometric means for 5 laboratories, CLPPB concluded that a plausible estimate would be 0.9 µg/dL.

Table 15. Lost lifetime earnings due to lead based on estimated geometric mean blood lead levels among California children (2013$)

	Lower estimate	Upper estimate
Geometric mean blood lead level among children aged 0–5 years	0.9 µg/dL*	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[5] x 257,457 boys x 1.23–1.63%)	$4,651,791,202	$6,202,388,269
Lost lifetime earnings for girls born in 2012 (based on $1,357,176 lifetime earnings‡ x 246,331 girls x 1.23–1.63%)	$3,689,407,321	$4,919,209,761
Total lifetime earnings lost for all children born in 2012	$8,341,198,523	$11,121,598,030

*Based on analyzing 2011 blood lead level results from five 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 et. al, 2003)
†Based on the percent 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 et. al, 2009)

Therefore, this report employs these numbers as the upper and lower limits of the plausible range and considers the geometric mean for California children to be between **0.9 and 1.2 µg/dL**.

Lifetime Costs for Lead Exposures

Lost potential earnings

The majority of costs from lead exposures are not due to direct or indirect expenditures for disease treatment. Rather, most lead exposure costs are the result of decreased earning potential resulting from reductions in IQ. Previous research has found that for each 1 µg/dL change in blood lead level, the estimated loss in IQ points is 0.57 (adjusted, lifetime average, at 5 years of age),[13] and that each 1 point decline in IQ is associated with a 2.39% loss of lifetime earnings.[11]

Based on these assumptions, the 2012 cohort of children born in California can expect to earn nearly **$8–11 billion (2013$)** ***less*** throughout their lifetime as a result of the cognitive and neurological impacts related to lead (Table 15).

Costs Not Included

This cost estimate does not take into account many other costs that may be associated with lead exposures, including: direct health care expenditures/treatment costs for children with high BLL; follow-up testing costs; costs associated adult onset health conditions; costs to the social welfare system; tax revenue from earnings lost; crime; special education; other childhood illnesses (e.g., hypertension); housing relocation costs; environmental investigations and remediation efforts; or preventative maintenance to avoid toxic effects. The estimate should therefore be considered to be very conservative.

D. Neurobehavioral disorders

For this assessment, neurobehavioral disorders were limited to autism spectrum disorder (ASD), attention deficit hyperactivity disorder (ADHD), and intellectual disability (ID). These three disorders were included in previous work by Trasande and Lui based on the growing evidence of an association with various environmental hazards. A registry for childhood neurobehavioral disorders does not exist in California. Therefore, to estimate California incidence rates for each disease, we applied various national and state data sources to California birth cohort data from 2012. We calculated both annual and lifetime costs.

In addition to receiving medical treatment, many children with these disorders also require special education services, which incur substantial costs. In 2010–2011, the California Legislative Analyst Office (LAO) reported that the average excess cost for a student with a disability is approximately $12,700, or $13,600 inflated to 2013$.[14]

Autism Spectrum Disorder (ASD)

ASD Cohort Prevalence Data

The ASD incidence rate in California is unknown. In the absence of an ongoing statewide surveillance system, the rate from the 2010 Autism and Developmental Disability Monitoring Network (ADDM) was used.[15] ADDM is an active surveillance system that estimates the prevalence of ASD among 8 year olds based on medical and school records and clinician verification within 14 ADDM sites in the United States. Since the prevalence rate is based on one age group, the rate can be used as a proxy for the prevalence among each birth cohort. In 2010, this rate was 14.7 per 1,000.[16] Applied to 2012 births in California, the estimated number of ASD cases for a single birth cohort is 7,410 (Table 16).

Annual Costs for ASD

Direct Costs

For ASD, annual costs included both direct medical and non-medical costs. Direct medical cost estimates were derived from an analysis by Liptak et al. of national data (MEPS and NHAMS, 1999–2000) to estimate annual health care expenditures for children with ASD.[17] The estimate for direct medical costs included: hospital visits, emergency department visits, physician visits, outpatient costs, prescription medication, non-physician costs, home health care, other, and total self-pay.[17] The estimated annual direct medical cost per ASD case was $8,296 (2013$). Assuming each child with ASD receives special education, the average excess costs for special education was $13,600.[14] In total, annual direct costs for children with ASD is $162 million for each birth cohort. This does not include annual costs related to behavioral therapies, childcare, and home improvements.

Lifetime Costs for ASD

Lifetime costs associated with ASD were derived from Trasande and Liu, which included direct and indirect cost estimates from Ganz (2007).[18]

Direct Lifetime Costs

Ganz estimated incremental direct medical costs non-medical costs based on cross-sectional cost data from literature reviews and national sources such as the National Interview Health Survey (NHIS) and MEPS. Direct medical costs included: physician and dental visits, prescription medication, therapies (e.g., behavioral), hospital and ER visits, home health needs, and medically related travel. Direct non-medical costs included: child care, adult care, respite care, home improvements, special education, and employment support programs. For special education costs, the national estimate used by Ganz was replaced with the California specific estimate ($13,600).[14] The direct medical costs per ASD case were $388,900 and direct non-medical costs per ASD case were $1,230,400, for a total direct lifetime cost of $1,619,300 (2013$) per ASD case.

Indirect Lifetime Costs

Indirect costs included those for lost parental/caregiver earnings due to a child missing school. Ganz estimated indirect costs by calculating average parental earnings, benefits, and household productivity with adjustments for employment rates and average work-life expectancies.

Lost potential lifetime earnings

Ganz estimated lost potential earnings for children with ASD over the lifetime by calculating average lifetime earnings, benefits, and household productivity with adjustments for employment rates, and average work-life expectancies. The estimates consider that adults with ASD have different levels of disability, and while some are able to work, others are not. For example, 35% of adults with low disability/high functioning are employed, whereas 10% of adults with high disability/low functioning are employed.[18] Ganz's data files can be found here: http://costsofautism.com/index.html. In total, the lifetime costs for ASD in California are $29.7 billion (2013$).

Table 16. Estimate of the number of ASD cases for a single birth cohort in California

Prevalence rate*	Births in 2012 in California	Number of ASD cases
0.0147	503,788	7,410

*Prevalence rate from ADDM 2010, Baio et al. (2014)

Table 17. Estimated annual direct medical costs for ASD for a single birth cohort in California

Direct costs	Average annual cost per child with ASD (2013$)	Estimated number of children*	Total annual direct medical costs (2013$)
Medical costs**	$8,296	7,410	$61,473,360
Special education***	$13,600		$100,776,000
Total	**$21,896**		**$162,249,360**

*Based on the prevalence rate from ADDM 2010, Baio et al. (2014)
**Liptak et al. (2006)
***California Legislative Analysts Office (LAO)

Table 18. Estimated lifetime costs associated with ASD for a single birth cohort in California

Type of lifetime cost	Cost per ASD case* (2013$)	Estimated number of cases**	Lifetime costs (2013$)
Direct costs	$1,619,254	7,410	$11,998,673,918
Indirect costs	$1,149,804		$8,520,048,826
Lost potential earnings	$1,234,301		$9,146,171,299
Total	**$4,003,360**		**$29,664,894,043**

*All cost per case estimates taken from Ganz (2007)
**Based on the prevalence rate from ADDM 2010, Baio et al. (2014)

Attention Deficit Hyperactivity Disorder (ADHD)

ADHD Prevalence Data

Data from the 2011–2012 National Survey of Children's Health (NSCH) were used to estimate the prevalence of ADHD in California. NSCH is population-based survey that estimates ADHD prevalence based on parental reporting and has a California-specific sample. Prevalence estimates were limited to children with ADHD ages 2–17 who are currently on ADHD medication. Prevalence rates for boys and girls were applied to the 2012 birth cohort to estimate the number of cases in a single birth cohort.

Annual Costs for ADHD

For ADHD, annual costs include both direct medical and non-medical costs. Direct medical cost estimates were derived from the same source used by Trasande and Liu—Birnbaum et al.[19] Birnbaum et al. used a large claims database from a medical insurer to estimate excess direct medical costs for boys and girls with ADHD, ages 4 to 17. For direct non-medical costs, the California LAO estimate for special education ($13,600) was applied to 61% of children with ADHD (8,860 cases); the amount of children with ADHD estimated to receive special education.[20] Annual direct costs associated with ADHD were estimated to total $165 million (2013$) in California (Table 20).

Lifetime Costs for ADHD

Lifetime costs included both direct and indirect costs. To estimate lifetime costs, Trasande and Liu assumed that annual direct costs estimated by Birnbaum et al. accrued over 30 years for each child with ADHD. Birnbaum estimated indirect costs as lost parental wages estimated from disability data or imputed from medically-related lost work days due to caring for a child (i.e., days in the hospital or physician visits). Indirect costs (parent work loss) are assumed to accrue

Table 19. Estimated prevalence of ADHD for a single birth cohort in California

	Births in 2012 in California	Prevalence rate*	Estimated number of ADHD cases
Boys	257,457	0.043	11,070
Girls	246,331	0.014	3,450
Total	**503,788**		**14,520**

*California sample from National Survey of Children's Health (2011–2012)

Table 20. Estimated annual direct costs for ADHD in California

Type of cost	Annual cost per ADHD case (2013$)	Estimated number of cases*	Total annual direct medical costs (2013$)
Medical care for boys**	$3,126	11,070	$34,602,717
Medical care for girls**	$2,928	3,450	$10,102,325
Special education***	$13,600	8,860	$120,496,000
			Total: $165,201,041

*Based on the California sample from National Survey of Children's Health (2011–2012)
**Birnbaum et al. (2005)
***California LAO

Table 21. Estimated lifetime costs for ADHD in California

Type of cost	Lifetime cost per ADHD case (2013$)	Estimated number of cases*	Lifetime costs (2013$)
Medical care for boys**	$93,795	11,070	$1,038,313,750
Medical care for girls**	$87,846	3,450	$303,070,391
Special education***	$176,800	8,860	$1,566,448,000
Indirect costs**	$2,285	14,520	$33,182,266
			Total: $2,941,014,406

*Based on the California sample from National Survey of Children's Health (2011–2012)
**Birnbaum et al. (2005)
***California LAO

up to age 18 for each child with ADHD. Lifetime costs are estimated to total $2.9 billion (2013$) for a single birth cohort (Table 21).

These costs do not take into account costs due to delinquency, law enforcement, or reduced future earnings.

Intellectual Disability (ID)

ID Prevalence Data

The prevalence rate for intellectual disability (ID) from the Metropolitan Atlanta Developmental Disabilities Surveillance Program (MAADSP)[21] was applied to the California 2012 birth cohort to estimate the prevalence of ID. The MADDSP estimates the prevalence of select developmental disabilities among 8-year-old children in metropolitan Atlanta.

Annual Costs for ID

Annual health care expenditure estimates for children with ID are derived from an analysis by Liptak et al. of national data from MEPS and NHAMS (1999–2000).[17] Direct medical cost estimates included: hospital visits, emergency department visits, physician visits, outpatient costs, prescription medication, non-physician costs, home health care, other, and total self-pay. The estimated direct medical cost per ID case is $2,200, totaling $13.3 million (2013$) for all children with ID within a single birth cohort in California. Special education costs for all children with ID total $82 million. The total annual costs associated with ID for a single birth cohort is $95.5 million (Table 23). This does not include annual costs related to behavioral therapies, child care, and home improvements.

Lifetime Costs of ID

Lifetime costs were estimated using the same approach as Trasande and Liu, and derived from research by Honeycutt et al.[22] Lifetime costs included both direct costs and lost potential earnings.

Table 22. Estimate of the number of children with ID for a single birth cohort in California

Prevalence rate*	Births in 2012 in California	Estimated number of children with ID
0.012	503,788	6,050

*Based on MADDSP 2000 data, Bhasin et al. (2006)

Table 23. Estimated annual costs associated with ID for a single birth cohort in California

Type of direct cost	Annual cost per case (2013$)	Estimated number of ID cases*	Total annual direct medical costs (2013$)
Direct medical**	$2,200	6, 050	$13,310,000
Special education***	$13,600		$82,280,000
Total	**$15,800**		**$95,590,000**

*Based on MADDSP 2000 data, Bhasin et al. (2006)
**Liptak et al. (2006)
***California LAO

Table 24. Estimated lifetime costs associated with ID for a single birth cohort in California

Type of cost	Cost per case (2013$)	Estimated number of cases*	Lifetime costs (2013$)
Direct**	$345,659	6,050	$2,091,236,769
Lost potential earnings***	$852,506		$5,157,661,966
Total	$1,198,165		$7,248,898,734

*Based on MADDSP 2000 data, Bhasin et al. (2006)
**Direct costs from Honeycutt et al. (2003); special education costs from California LAO
***Lost potential earnings estimate from Honeycutt et al. (2003)

Direct Costs

Honeycutt estimates both *incremental* direct medical and *incremental* direct non-medical costs. Direct medical costs included: physician visits, prescription medication, inpatient stays, assistive devices, therapy and rehabilitation, and long-term care. Direct non-medical costs included: home and auto modifications, special education, and respite care. Incremental direct medical and non-medical costs were calculated using the NHIS, MEPS, and Healthcare Cost and Utilization Project (HCUP). Special education costs were from the California LAO.[14] The estimated lifetime direct costs per case of ID totaled $345,659 (2013$).

Lost Potential Earnings

Honeycutt estimates reduced future potential earnings due to an inability to work or reductions in work. Employment rates and earnings reductions were derived from the NHIS Disability Survey and from the U.S. Census Bureau's Survey on Income and Program Participation. The lifetime indirect costs per case of ID total $852,506 (2013$). This does not include costs related to premature mortality. Total lifetime costs per ID case are $1.2 million for a total of $7.2 billion (2013$) for a single birth cohort.

Total Costs of Neurobehavioral Disorders in Children

Adjustment for Co-existing Conditions

Neurobehavioral conditions often co-exist. To minimize double-counting, the costs associated with all neurobehavioral disorders are reduced by the percentage of co-existence. Estimates for co-existence are derived from Trasande and Liu. They analyzed the National Survey of Children's Health (2007) to estimate (1) the percentage of children with ASD who were also reported to have an ID (48.5%), (2) the percentage of children with ADHD who were reported to have an ID (44.3%), and (3) the percentage of children with ID suspected to be from lead poisoning (12.3%). Reductions for lead poisoning were only applied to lifetime costs, and not annual costs (since costs associated with lead poisoning were only estimated over the lifetime, see Section C).

Table 25. Total annual neurobehavioral costs with reductions for co-existing conditions for a single birth cohort in California

	Total annual costs (2013$)	Reduction for co-existing conditions	Reduced annual cost (2013$)
ASD	$162,249,360*	48.5% for intellectual disability	$83,558,420
ADHD	$165,201,041**	44.3% for intellectual disability	$92,016,980
ID	$95,590,000***	NA†	$95,590,000
Total annual costs for neurobehavioral disorders: $271,165,400			

*See Table 17
**See Table 20
***See Table 23
† Did not reduce for lead poisoning since this analysis does not include an estimate for the annual costs of lead poisoning

Table 26. Total lifetime neurobehavioral costs with reductions for co-existing conditions for a single birth cohort in California

	Total lifetime costs (2013$)	Reduction for co-existing conditions	Reduced lifetime cost (2013$)
ASD	$29,664,894,043*	48.5% for intellectual disability	$15,277,420,432
ADHD	$2,941,014,406**	44.3% for intellectual disability	$1,638,145,024
ID	$7,248,898,734***	12.3% for lead poisoning	$6,357,284,190
Total lifetime costs for neurobehavioral disorders: $23,272,849,646			

*See Table 18
**See Table 21
***See Table 24

Adjusting for co-existing conditions, annual costs associated with neurobehavioral disorders for a single birth cohort are estimated to be $271 million (Table 25), and lifetime costs for a single birth cohort are estimated to be $23 billion (Table 26).

These estimates do not take into account the consideration that costs associated with ASD and ADHD *without* intellectual disability are likely lower than the costs associated *with* ASD and ADHD with intellectual disability.

Environmental Cost of Neurobehavioral Disorders in Children

The environmental attributable fraction, or EAF, of neurobehavioral disorders was drawn from Landrigan et al.'s estimate of 10% (5–20%). Based on this estimate, 1,800 new cases of ASD, ADHD, and ID could be prevented within a single birth cohort by reducing environmental hazards (Table 27). This would save an estimated $27 million ($13.6–54.2 million) in annual costs (Table 28), and $2.3 billion ($1.2–4.7 billion) in lifetime costs for each future birth cohort of children in California (Table 29).

Table 27. Estimated number of cases of neurobehavioral disorders attributable to the environment

EAF*	ASD cases without ID	ADHD cases without ID	ID	Total cases
5%	190	400	300	890
10%	380	810	600	1,790
20%	760	1,620	1,210	3,590

*Environmental attributable fraction (EAF) from Landrigan et al. (2002)

Table 28. Estimated total annual costs of neurobehavioral disorders due to the environment

EAF*	ASD	ADHD	ID	Total (2013$)
5%	$4,177,921	$4,600,849	$4,779,500	$13,558,270
10%	$8,355,842	$9,201,698	$9,559,000	$27,116,540
20%	$16,711,684	$18,403,396	$19,118,000	$54,233,080

*Environmental attributable fraction (EAF) from Landrigan et al. (2002)

Table 29. Estimated total lifetime costs of neurobehavioral disorders due to the environment

EAF*	ASD	ADHD	ID	Total (2013$)
5%	$763,871,022	$81,907,251	$317,864,209	$1,163,642,482
10%	$1,527,742,043	$163,814,502	$635,728,419	$2,327,284,965
20%	$3,055,484,086	$327,629,005	$1,271,456,838	$4,654,569,929

*Environmental attributable fraction (EAF) from Landrigan et al. (2002)

E. Summary Annual and Lifetime Costs

Table 30. Total environmental costs for all diseases

	EAF	Annual costs (2013$)	Lifetime costs (2013$)
Asthma	30% (20–41%)	208.0 million (138.6–284.2 million)	6.3 million (4.2–8.6 million)
Cancer	15% (9–21%)	18.8 million (11.3–26.3 million)	33.3 million (20.0–46.6 million)
Lead Exposures	100%	NA	8.3–11.1 billion
Neurobehavioral disorders	10% (5–20%)	27.1 million (13.6–54.2 million)	2.3 billion (1.2–4.7 billion)
Total		**$253.9 million (163.5–364.7 million)**	**$9.5–15.9 billion**

Endnotes

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