

Don't pollute my future!

THE IMPACT OF THE ENVIRONMENT ON CHILDREN'S HEALTH



**World Health
Organization**

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Introduction

In 2015, 5.9 million children under age five died (1). The major causes of child deaths globally are pneumonia, prematurity, intrapartum-related complications, neonatal sepsis, congenital anomalies, diarrhoea, injuries and malaria (2). Most of these diseases and conditions are at least partially caused by the environment. It was estimated in 2012 that **26% of childhood deaths and 25% of the total disease burden in children under five could be prevented through the reduction of environmental risks** such as air pollution, unsafe water, sanitation and inadequate hygiene or chemicals¹ (3).

Children are especially vulnerable to environmental threats due to their developing organs and immune systems, smaller bodies and airways. Harmful exposures can start as early as in utero. Furthermore, breastfeeding can be an important source of exposure to certain chemicals in infants (4, 5); this should, however, not discourage breastfeeding which carries numerous positive health and developmental effects (4). Proportionate to their size, children ingest more food, drink more water and breathe more air than adults. Additionally, certain modes of behaviour, such as putting hands and objects into the mouth and playing outdoors can increase children's exposure to environmental contaminants (6).

¹ Estimates based on a combination of Comparative Risk Assessments, evidence syntheses, epidemiological calculations and expert evaluation.

Children's health impacts from the environment by disease group

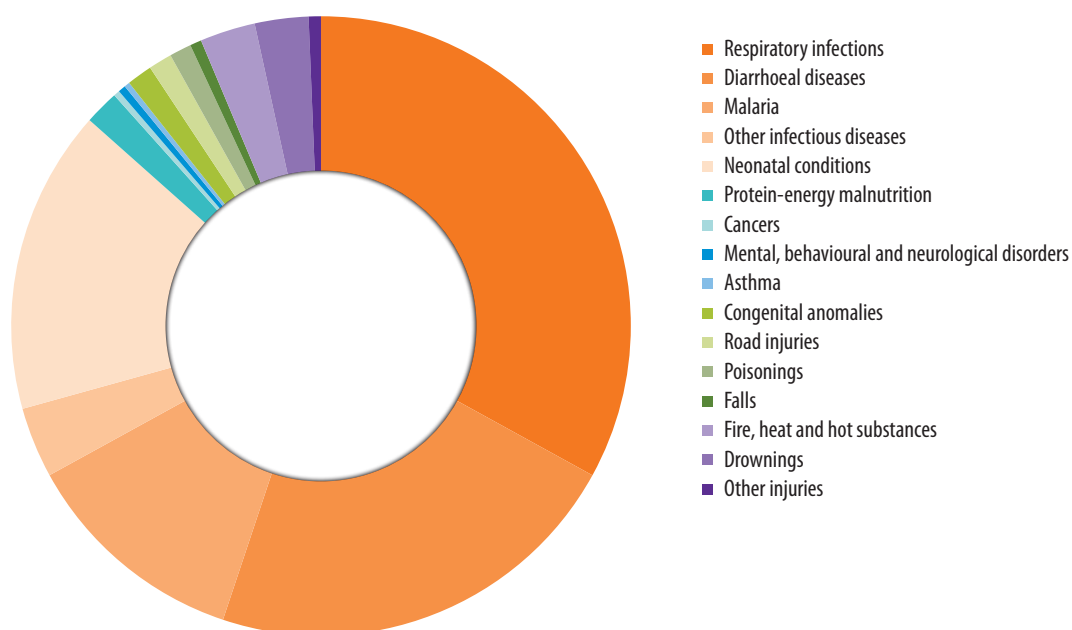
The following sections focus on the impacts of the environment in children under five years, although older children are also considered. Full details of attributable disease by age group are provided in Table 2.

Methods to quantify health impacts in children

The population attributable fraction (PAF) is the proportional reduction in death or disease that would occur if exposure to a risk was removed or maximally reduced to an alternative level. To quantify health impacts from environmental exposures, a systematic literature review compiled estimates and summaries of environmental exposure and links between the respective exposure and disease or injury. The preferred source was global estimates of population impacts based on comparative risk assessment (CRA), followed by estimates based on more limited epidemiological data or knowledge of the disease transmission pathway or, finally, expert opinion (see (3) for details).

In this document, disease burden is presented in disability adjusted life years (DALYs) which is a weighted measure of deaths and disability or, if specifically mentioned, of premature mortality.

Figure 1. Total disease burden (in DALYs) in children under five years attributable to the environment, by disease, 2012



Respiratory infections

Lower respiratory infections are among the largest causes of mortality in children, accounting for 16.5% of deaths in children under five in 2012 and 15.5% of deaths in 2015 (2, 7, 8). The most important environmental risks are **household air pollution** from exposure to smoke from cookstoves, **ambient air pollution** and **second-hand tobacco smoke** (8, 9). Household air pollution from the use of solid fuels for cooking and ambient air pollution together cause more than 50% of lower respiratory infections in children under five years in low- and middle

income countries. In high-income countries, where the exposure to air pollution tends to be smaller, 13% of lower respiratory infections are attributable to those factors. Also, upper respiratory infections, such as pharyngitis, laryngitis, sinusitis or otitis media, can be caused by environmental risks such as air pollution, second-hand tobacco smoke and housing-related risks like exposure to mould and crowding (10–17).

Globally, close to 570 000 deaths in children under five in 2012 from respiratory infections and 57% (44–67%) of the disease burden (in DALYs) of lower respiratory infections in children under five are attributable to the environment.

Box 1. Air pollution and children's health

Children around the globe are exposed to hazardous effects of air pollution. 92% of the global population, including billions of children, live in areas with ambient air pollution levels that exceed WHO limits. Over three billion people are exposed to household air pollution from the use of solid fuels.. Air pollution causes approximately 600 000 deaths in children under five years annually and increases the risk for respiratory infections, asthma, adverse neonatal conditions and congenital anomalies. Air pollution accounts for over 50% of the overall disease burden of pneumonia which is among the leading causes of global child mortality. Growing evidence suggests that air pollution adversely affects cognitive development in children and early exposures might induce development of chronic disease in adulthood (2, 8, 18, 19).

Diarrhoeal diseases

Diarrhoeal diseases are among the main contributors to global child mortality, causing about 10% of all deaths in children under five years (2). Children in sub-Saharan Africa and South East Asia are most affected by diarrhoea. A large proportion of diarrhoeal diseases are caused by faecal-oral pathogens and can be prevented through safe and adequate **drinking-water, sanitation and hygiene** and ending **open defaecation** (20, 21). WHO recently estimated that 361 000 diarrhoea deaths in children under five years, representing more than 5% of all deaths in this age group in low- and middle income countries, could have been prevented through reduction of exposure to inadequate drinking-water, sanitation and hygiene (22).

In total, it is estimated that around 57% (36–75%) of the disease burden (in DALYs) from diarrhoeal diseases in children under five years is attributable to the environment.

Malaria

Malaria, the most important vector-borne disease globally, is transmitted by the bites of infected *Anopheles* mosquitoes. It is estimated that malaria caused over 300 000 deaths in children under five years in 2015, which represents about 70% of all malaria deaths (23). The larval stages of malaria-transmitting mosquitoes mostly share a preference for clean, unpolluted, stagnant or slowly moving fresh water (24). Many malaria cases can therefore be prevented through the **management of those water bodies**.

It is estimated that 42% (28–55%) of the global malaria burden (in DALYs) in children under five years could be prevented by environmental management with considerable differences between locations, based on an expert survey.

Dengue

Dengue fever is the most rapidly spreading mosquito-borne viral disease in the world with half of the world's population being at risk (25). The severe form of dengue can be life-threatening, especially in children. There is no specific treatment though a vaccine has now been licensed for endemic settings (25). **Rapid urbanization**, unreliable drinking-water supply services, increased population mobility, global trade and **climate change** are important determinants of the resurgence of the disease (26, 27). The vector, a daytime biter, breeds in clean water collections close to human dwellings. Interventions to prevent dengue comprise a range of environmental management measures, the provision of reliable piped water, mosquito-proofing of water containers, solid waste management and well-enforced urban building design regulations.

The global mean fraction of the disease burden (in DALYs) in children under five years due to dengue fever attributable to modifiable environmental conditions is estimated to be 95% (89–100%), based on an expert survey.



(Intestinal nematode infections/soil-transmitted helminth infections)

Ascariasis, trichuriasis and ancylostomiasis/necatoriasis (roundworm, whipworm and hookworm disease, respectively) affect hundreds of millions children around the world (28). Infections of heavy intensity affect the physical growth and cognitive development of children, and are a cause of micronutrient deficiencies including iron-deficiency anaemia. These worms are transmitted when faeces that are contaminated with eggs contaminate the environment in areas with **poor sanitation**.

The fraction of the disease burden in children due to soil-transmitted helminth infections attributable to manageable environmental conditions is estimated to be 100% (29).

Tuberculosis

About one million children became ill with tuberculosis (TB) and 169 000 children under 15 years of age died in 2015 (30). Environmental risks for TB transmission include **poor housing** (especially crowding) and potentially indoor smoke from **solid fuels** and second-hand tobacco smoke (31–33). Malnutrition, itself related to environmental factors, increases the risk of TB progression and worsens the prognosis (34, 35).

Globally, 15% (4–29%) of the TB disease burden (in DALYs) in children under five years is attributed to environmental factors, based on an expert survey.

Schistosomiasis

Schistosomiasis can lead to long-term, irreversible health effects when left untreated. Transmission occurs through direct human contact with water contaminated by excreta of infectious humans. In children, who are often infected due to a **lack of hygiene** and to contact with infested water, the disease can cause anaemia, stunting and reduced ability to learn (36). The main modifiable environmental risks are inadequate sanitation and hygiene (37).

The global mean fraction of the disease burden (in DALYs) in children under five years due to schistosomiasis attributable to environmental conditions that can be managed is estimated to be 82% (71–92%), based on an expert survey.

Leishmaniasis

Leishmaniasis was responsible for 23 000 deaths in children 0 to 14 years in 2012 (2). It is an infectious disease caused by protozoans transmitted by sandflies. Three forms exist: visceral, cutaneous and mucocutaneous; the first being fatal when left untreated (38). Leishmaniasis is associated with **poverty**, malnutrition, population displacement, poor housing, a weak immune system and has been linked to environmental factors such as **climate change, deforestation, building of dams**, irrigation schemes and urbanization (38). Sandflies often live in the peri-domestic environment (39–41) and leishmaniasis can often be prevented by housing improvement, eliminating soil and wall cracks, and removing organic material close to homes (42).

Globally, according to an expert survey, the mean fraction of the leishmaniasis burden (in DALYs) in children under five years attributable to environmental conditions that can be managed is estimated to be 27% (9–40%), based on an expert survey.

Neonatal conditions

Neonatal conditions include low birth weight, prematurity, intrauterine growth restriction, stillbirth, neonatal sepsis and infection, birth asphyxia and trauma. Around 15 million preterm births occur each year and the rate of preterm births ranges from 5–18% across countries while the majority occur in low-income countries (43). Preterm birth complications are the leading cause of deaths in children and were responsible for nearly one million deaths in 2015 (43). Furthermore, preterm birth is associated with disease and disability throughout life. Other neonatal conditions lead to more than one million child deaths annually (2). Higher rates of adverse pregnancy outcomes were observed for mothers exposed to different environmental or occupational risks, like ambient air pollution (44–48), household air pollution (49–51) and second-hand tobacco smoke (45, 52). Further risks for unborn children include **chemicals** (45, 53–57) and **inadequate water, sanitation and hygiene** (58).

It is estimated that environmental causes accounted for 6% (1–11%) of the total disease burden (in DALYs) of neonatal conditions in children under five years in high-income countries, and for 11% (2–27%) in low-income countries (where exposures to environmental risks were estimated to be higher), based on an expert survey.

Box 2. Endocrine disrupting chemicals

Endocrine disrupting chemicals are a class of chemicals that are confirmed or suspected to disrupt the normal functioning of human and/or animal endocrine systems. Approximately 800 chemicals have been classified as known or suspected endocrine disruptors (59). They are common in everyday products, such as **metal** food cans, **pesticides, food** and **cosmetics**. Similar to many other environmental exposures, humans are most sensitive to endocrine disruption during periods of rapid development, including in utero, early childhood and puberty (59).

Although it is debated, there is evidence of an association between some endocrine disrupting chemicals, **low birth weight** and premature birth (45, 53–57, 60), limited evidence of an association with attention deficit disorder and autism (59, 61), and a possible association with cryptorchidism and hypospadias (3, 54, 62).

Protein-energy malnutrition

Globally, 156 million children under five years old were stunted in 2015 and 50 million were wasted (58). About 45% of all child deaths are linked to malnutrition (63) and malnourished children show poorer motor and cognitive development and educational outcomes (64). Environmental risks for malnutrition or food insecurity include **poor water, sanitation and hygiene** (65–69), climate change, and associated water scarcity, and land degradation (70, 71).

Limited epidemiological data result in the attribution of 15% (10–19%) of the disease burden (in DALYs) of malnutrition to inadequate water, sanitation and hygiene. This estimate relies on an expert survey and a number of assumptions, and does not take into account the other potential impacts of the environment outlined in this section. It may therefore be an underestimate of the impact of the environment on malnutrition.

Cancers

About 33 000 cancer² deaths in children under five occurred in 2012 (2). The most frequent childhood cancers include leukaemia, lymphoma and brain cancer (2, 72). Early exposure to environmental risks contributes to childhood cancers (72, 73) and continues to impact cancer development in later life (74). **Ionizing radiation** is an established risk factor for childhood leukaemia and thyroid cancer (72), while solar radiation increases the risk of developing melanoma (75), with childhood considered the most sensitive period for long-term harmful effects (76). Furthermore, there is sufficient evidence that **second-hand tobacco smoke** exposure in children increases the risk for liver and bile duct cancer (75). There is limited evidence that extremely low frequency magnetic fields, second-hand tobacco smoke and maternal exposure to painting increase the risk for childhood leukaemia (75, 77, 78). Many associations are supposed between environmental exposures and childhood cancer such as between ionizing radiation and brain cancer, **pesticides** and leukaemia, or benzene and leukaemia or lymphoma (72, 79, 80).

It is estimated that 17% (7–42%) of all cancer disease burden (in DALYs) in children under five can be attributed to environmental causes, based on an expert survey. This estimate does not include cancers that are provoked through environmental exposures in childhood but that manifest only in later life.

Mental, behavioural and neurological disorders

Mental, behavioural and neurological disorders account for 3.7% of the global disease burden in children under 15 years of age (2). A report on children aged 3–17 years old from the United States of America found that 6.8% suffered from attention-deficit disorder, 3.5% from behavioural or conduct problems, 3% from anxiety, 2.1% from depression and 1.1% from autism spectrum disorders (77, 81). Various chemicals have been associated with neurodevelopmental effects. Exposure to **lead** during childhood is associated with attention deficit disorder, and evidence on links between numerous other classes of chemicals, such as **flame retardants, plasticizers, endocrine disrupting chemicals**, and neurodevelopmental disorders is accumulating (82–84). Furthermore, lead and methylmercury exposure in childhood is associated with intellectual disability (85, 86). Certain perinatal exposures to endocrine disrupting chemicals, for example certain organophosphate insecticides, were associated with the occurrence of autism and attention deficit disorder, although evidence is limited (59, 61). Other chemical exposure in early life, such as to certain solvents or pesticides, may induce Parkinson's disease in later life (82). Exposure to methylmercury, a neurotoxic substance, has been linked to the development of epilepsy in children (87). Furthermore, epilepsy can result as a consequence of certain other conditions, such as congenital anomalies, which themselves are associated with the environment (88).

Adverse socioenvironmental exposures like child abuse, neglect and bullying have been shown to increase the risk of mental disease in children (89). Children exposed to traumatic events such as natural disasters, exacerbated by climate change, can suffer from post-traumatic stress disorders (88, 90).

The disease burden (in DALYs) of childhood neuropsychiatric disorders that is due to environmental risks is estimated to be 12% (2–27%) in children under five years of age, based on an expert survey.

² Numbers include deaths and DALYs from "other neoplasms".

Asthma

Asthma is one of the most important chronic diseases in childhood, with approximately 11–14% of children above 5 years around the world reporting current asthma symptoms (91). Global asthma prevalence in children has increased over the past decades with considerable differences between countries and regions (92, 93). Ambient **air pollution**, e.g. from motor vehicle exhaust, was associated with the development of childhood asthma (94–96). Both ambient and household air pollution and second-hand tobacco smoke can furthermore lead to increased asthma severity and exacerbations in young children (97, 98). Prenatal exposure to second-hand tobacco smoke can negatively affect lung growth and development (99) and both pre- and postnatal exposure can increase wheezing, asthma exacerbations and asthma incidence (100, 101). Other environmental exposures linked to asthma development and severity in children include indoor mould and **dampness** (102) and **indoor allergen exposure**, e.g. from dust mites, pollens, cockroaches or mice (98).

Environmental exposures are estimated to account for 44% (26–53%) of asthma disease burden (in DALYs) in children under five years, based on an expert survey.

Congenital anomalies

An estimated 6% of global infant deaths are due to congenital anomalies including chromosomal and non-chromosomal conditions (103). **Second-hand tobacco smoke** exposure in non-smoking pregnant women was estimated to increase the overall risk for congenital malformations by 13%, particularly heart, limb reduction, kidney/urinary tract, and cleft lip and palate defects (52). There are many further potential links between environmental factors and congenital anomalies including exposure to **pesticides**, organic solvents and air pollution linked to congenital heart disease (104, 105), exposure to some endocrine disrupting chemicals linked to cryptorchidism and hypospadias (54, 62), and pesticide exposure linked to urinary malformations (106).

It is estimated that 5% (1–10%) of the disease burden (in DALYs) of all congenital anomalies were attributable to environmental causes, based on an expert survey.

Road traffic accidents

Globally, road traffic injuries killed 135 000 children under 15 years in 2012 (2). Among young people aged 15 to 29 years road traffic injuries are the leading cause of death (107). Half of all deaths on the world's roads are among those with the least protection, including cyclists and pedestrians (107). Measures to reduce traffic accidents among children include speed limits, traffic calming, alcohol restrictions, pavements and bicycle lanes, and correct use of child restraints and helmets (107–109).

The global average for the disease burden (in DALYs) of road traffic accidents in children under five attributable to environmental factors is 41% (24–65%), based on an expert survey.

Unintentional poisonings

Unintentional poisonings are estimated to have caused 23 000 deaths in children under five years in 2012 (2). Drugs, **cosmetics**, personal care products, **household chemicals** including pesticides, and, in low- and middle income countries, kerosene, are among common causes of childhood poisoning (110–115). Acute childhood poisoning can also arise from environmental contamination, for example, mass lead poisoning resulting from informal recycling or gold extraction (116, 117). Interventions to prevent unintentional poisonings in children include: (a) restricting access to toxic agents, for example using child-resistant containers and locked cabinets, and storing household products out of children's reach; (b) packaging drugs in non-lethal quantities; (c) adequate drug disposal; (d) identifying poisonous plants and placing them out of children's reach; and (e) having the poison help number available (108, 118, 119).

It is estimated that 85% (60–99%) of the disease burden (in DALYs) in children under five due to unintentional poisonings can be attributed to environmental factors, based on an expert survey.

Falls

More than 30 000 deaths from falls in children under five occurred in 2012 (2). Children are among those most affected by falls both in terms of frequency and severity (120). Risk factors are inadequate adult supervision, which is often related to poverty and sole parenthood, interlinked with hazardous environments (120). Interventions to prevent falls in children include: (a) redesigning nursery furniture and other products; (b) establishing playground standards for materials and maintenance; (c) implementing window guards; and (d) implementing multifaceted community prevention programmes (108, 120).

Globally, 31% (15–60%) of the total disease burden (in DALYs) resulting from falls in children below five years can be attributed to environmental factors, based on an expert survey.

Fires, heat and hot substances

About 62 000 deaths occurred in 2012 in children under five years due to burns from exposure to fire, heat or hot substances; 92% of those occur in low- and middle income countries (2, 8). Risk factors for childhood burns include improper adult supervision, cooking, lighting or heating equipment and practices, in particular, open fires, unsafe stoves or use of candles, use of kerosene and/or inadequate safety measures for liquefied petroleum gas (121, 122). Accordingly, practical measures can be taken to reduce the risk of burns in children, including, for example: (a) enclosing fires and using safer cookstoves in the domestic environment, as well as installing stove guards; (b) implementing smoke alarm legislation; and (c) setting and enforcing laws on hot water temperature (108, 121). Additional domestic practices to prevent fires and childhood burns include never leaving food or water unattended on a stove and keeping matches and lighters out of the reach of children.

Overall, 80% (65–94%) of the disease burden (in DALYs) from fires, heat and hot substances in children under five years are attributable to the environment, based on an expert survey.

Drownings

Drowning is the leading injury in children under five years and caused about 66 000 deaths in this age group in 2012 (2, 123). Risk factors include being male, lack of physical barriers between children and water, particularly close to the home, as well as lack of child supervision (124). Strategies to prevent drowning in children are: (a) installing barriers around open water or removing water hazards entirely; (b) establishing community-based, supervised child care; (c) teaching school-age children swimming, water safety and safe rescue skills; (d) ensuring immediate resuscitation and pre-positioning rescue equipment; and (e) raising awareness of drowning risks (108, 124).

Globally, 74% (44–95%) of the disease burden (in DALYs) from drowning in children under five are attributed to environmental risks, based on an expert survey.

Interpersonal violence

An estimated 41 000 children under 15 died from interpersonal violence in 2012 (2). This number is likely to be an underestimate as many deaths from child maltreatment are incorrectly attributed to other causes. Child maltreatment includes all types of physical and emotional ill-treatment, sexual abuse, neglect, negligence and commercial or other exploitation. Violence against children can result in lifelong physical, behavioural and mental health problems. About a quarter of all adults report to have been physically abused, and one in five women and one in 13 men sexually abused as a child (125). Environmental risks for child maltreatment include, for example, **exposure to certain chemicals**, such as lead, which can affect neuropsychological development, cognitive functioning and might increase violent behaviour in later life (126, 127), and increased gun availability (128).

Environmental factors account for an estimated 16% (3–28%) of the disease burden (in DALYs) from violence in children under five years, based on an expert survey.

Trends

The health impacts on children attributable to the environment showed some improvement between 2002 and 2012 (3, 129). The fraction of deaths attributable to the environment decreased from 37% to 26%. The main reasons for this change are significant reductions in environment-attributable deaths and disease burden in communicable diseases and neonatal and nutritional conditions.

The 2012 estimates of burden of disease attributable to the environment, measured in DALYs, are not directly comparable to the 2002 estimates. Some of the basic parameters used in DALY estimation have changed. In particular, age weighting and discounting of DALYs have not been used in the analysis of 2012 data.

Limitations of the analysis

This analysis combines estimates from comparative risk assessments, approximate epidemiological data and surveys of expert opinion. The latter two usually indicate a more limited body of evidence and therefore more uncertain estimates. Only those risk factor-disease (or injury) links are included in this analysis that are supported by sufficient evidence and that could be quantified. Many important environmental risks, such as climate change, various chemicals and ambient noise, could not or not fully be considered (19). Also, many more diseases with an environmental link such as Japanese encephalitis, HIV/AIDS, and tick-borne diseases are not covered. Overweight is not considered though 42 million, or 6.2% of all children, under five years were overweight or obese in 2015, which corresponds to an increase of about 11 million over the past 15 years (130). The number of overweight children has increased most rapidly in low-income and lower middle income countries (130). Asia and Africa bear not only the greatest share of stunted and wasted but also of overweight children: Almost half of all overweight children under five years of age lived in Asia and one quarter in Africa (130). Overweight in childhood increases the risk of noncommunicable diseases later in life. The estimates presented in this report are therefore likely to be an underestimate of the true environmental disease burden in children.

Many adverse environmental exposures during childhood might not manifest themselves in disease or early death until adult age. These effects are not covered in our estimates. There is growing evidence that early life exposures, such as to chemicals, can lead to chronic diseases including diabetes, cardiovascular diseases and cancer in later life (19) (see Box 3 for more details). The long latency periods between exposure and manifestation of health effects as well as the complexity of factors underlying chronic disease risk make early environmental developmental origins of disease especially challenging to study. However, knowledge about these linkages and potential time lags between exposure and outcome is crucial to understand the importance of reducing or, if possible, eliminating early life adverse environmental exposures (19).

Box 3. Environmental exposures and the early life origins of disease

While evidence is growing of chemical, physical, biological and social environmental factors and their effects on the developing child (131–134), studying the long-term effects of the complex mixture of toxicants most individuals are exposed to poses many challenges. Even at lower dose exposures, environmental insults in early life may still result in more subtle symptoms later in life. Additionally, environmental exposures can induce various epigenetic processes which alter disease susceptibility, a field of research that is just emerging (89).

Environmental exposures may increase the risk of premature birth and infants born small for gestational age, which are major risk factors for chronic respiratory disorders, neurodevelopmental behavioural consequences, hypertension and cardiovascular disease, obesity and diabetes and cancers (135, 136). Low lung function resulting from environmental exposures during fetal development, infancy and early preschool years, may increase the risk of acute respiratory disease in childhood and impose a lifelong increased risk of chronic respiratory disease (137). Exposure to air pollution may also increase lifelong risk of cardiovascular disease and cancer (138–140). Prenatal and perinatal chemical exposure may contribute to the risk of childhood obesity (141, 142).

Table 1. Population attributable fractions for the environment (in DALYs) and children under five years, by disease, 2012

	Population attributable fraction (%)	
	Mean	(95% confidence interval)
Infectious and parasitic diseases		
<i>Respiratory infections</i>		
Lower respiratory infections	57	(44–67)
Upper respiratory infections and otitis	13	(5–21)
Diarrhoeal diseases	57	(36–75)
Intestinal nematode infections	100	—
<i>Parasitic and vector diseases</i>		
Malaria	42	(28–55)
Schistosomiasis	82	(71–92)
Leishmaniasis	27	(9–40)
Dengue	95	(89–100)
Tuberculosis	15	(4–29)
Neonatal and nutritional conditions		
Neonatal conditions	11	(2–27)
Protein-energy malnutrition	15	(10–19)
Noncommunicable diseases		
Cancers	17	(7–42)
Mental, behavioural and neurological disorders	12	(2–27)
Asthma	44	(26–53)
Congenital anomalies	5	(1–10)
Injuries		
<i>Unintentional injuries</i>		
Road injury	41	(24–65)
Poisonings	85	(60–99)
Falls	31	(15–60)
Fire, heat and hot substances	80	(65–94)
Drownings	74	(44–95)
<i>Intentional injuries</i>		
Interpersonal violence	16	(3–28)

Table 2. Childhood deaths and burden of disease (in DALYs) attributable to the environment, 2012

	Deaths		DALYs		Method
	0–4 years	5–14 years	0–4 years	5–14 years	
Population	651 316 807	1 206 032 430	651 316 807	1 206 032 430	
Total deaths/DALYs	6 550 241	1 445 662	635 842 474	186 957 581	
Total environmental deaths/DALYs	1 709 859	341 512	161 224 280	37 689 857	
Burden attributable to the environment	26%	24%	25%	20%	
Infectious and parasitic diseases					
<i>Respiratory infections</i>					
Lower respiratory infections	566 361	0 ¹	51 752 605	0 ¹	CRA
Upper respiratory infections and otitis	426	73	143 165	205 177	Expert survey 2005
Diarrhoeal diseases	360 751	84 299	34 775 075	7 428 745	CRA
Intestinal nematode infections	1 132	762	555 077	1 644 548	Disease transmission pathway
<i>Parasitic and vector diseases</i>					
Malaria	199 623	13 398	18 667 064	1 707 644	Expert survey 2005
Schistosomiasis	875	14	511 892	609 732	Expert survey 2015
Leishmaniasis	2 190	3 982	200 132	333 498	Expert survey 2005
Dengue	3 392	3 768	308 325	314 397	Expert survey 2005
Tuberculosis	8 279	2 122	755 331	215 107	Expert survey 2005
Other infectious diseases	28 908	28 750	3 471 484	3 200 349	Expert survey 2005
Neonatal and nutritional conditions					
Neonatal conditions	270 049	21	24 967 476	227 099	Expert survey 2005
Protein-energy malnutrition ²	27 291	0 ¹	2 834 186	0 ¹	Limited epidemiological data
Noncommunicable diseases					
Cancers ³	5 476	8 903	500 635	736 527	Expert survey 2005
<i>Mental, behavioural and neurological disorders</i>					
Anxiety disorders	0	0	72	551 033	Expert survey 2015
Pervasive developmental disorders	0	0	38 227	108 021	Expert survey 2015
Childhood behavioural disorders	0	0	0	483 618	Expert survey 2015
Idiopathic intellectual disability	1	3	8 164	57 019	Expert survey 2015
Epilepsy	2 866	4 795	357 174	639 768	Expert survey 2015
Other mental, behavioural and neurological conditions	2 278	2 722	209 810	487 544	Expert survey 2015
Asthma	2 943	3 179	452 706	2 705 135	Expert survey 2005
Congenital anomalies	22 471	1 651	2 088 287	193 167	Expert survey 2005
Injuries					
<i>Unintentional injuries</i>					
Road injury	21 091	34 306	1 929 893	3 103 484	Expert survey 2005
Poisonings	19 837	10 070	1 800 107	837 247	Expert survey 2005
Falls	10 162	9 528	942 880	948 086	Expert survey 2005
Fire, heat and hot substances	49 974	33 973	4 544 990	2 929 162	Expert survey 2015
Drownings	48 565	54 584	4 403 865	4 520 982	Expert survey 2005
Other unintentional injuries	51 813	34 208	4 722 549	2 976 162	Expert survey 2005
<i>Intentional injuries</i>					
Self-harm	0	2 897	0	232 252	Limited epidemiological data
Interpersonal violence	3 103	3 503	283 108	294 354	Expert survey 2005

Note: CRA: comparative risk assessment; ¹ Zero because evidence is less strong for that age group; ² Malnutrition and consequences; ³ Includes "other neoplasms".

Figure 2. Percentage of disease group of total environmental disease burden (in DALYs), by age group, 2012

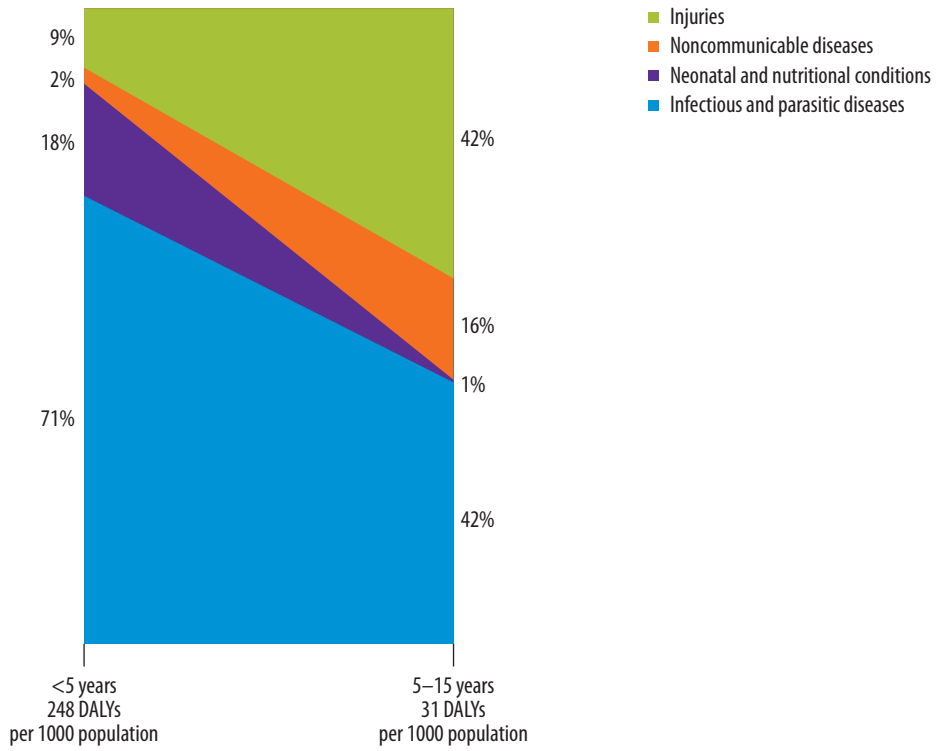
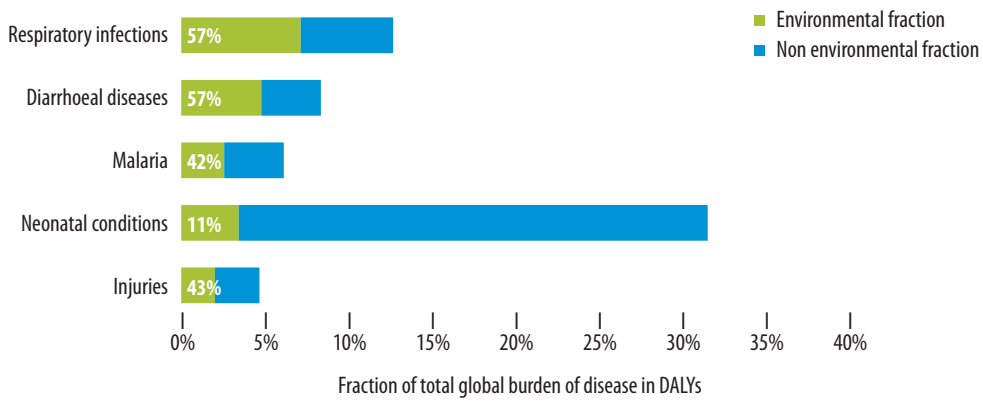
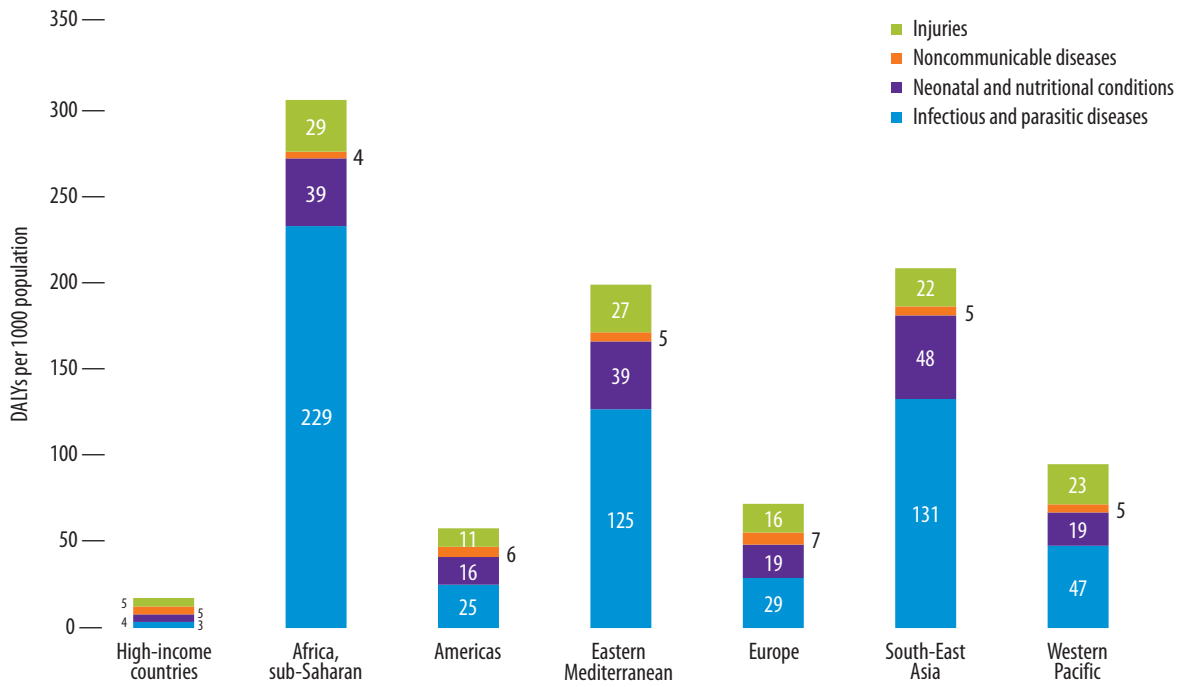


Figure 3. Selected diseases in children under five years with strong environmental contributions globally, 2012



Note: Percentages within bars relate to the environmental share of the respective disease.

Figure 4. Total age-standardized DALY rate attributable to the environment in children under five years, by region and disease group, 2012



Note: High-income countries are listed separately, the remaining regions contain low- and middle-income countries only.



Selected interventions by disease group



Infectious and parasitic diseases

- ✓ It is estimated that a 75% reduction in cookstove smoke reduces child pneumonia between 22% and 46% in specific settings, and one study found that increased handwashing reduced pneumonia by 50% (143, 144). The RESPIRE study, the first randomized controlled trial on improved solid fuel stoves, suggests a mean carbon monoxide exposure reduction of 50% was required to reduce physician-diagnosed childhood pneumonia (145).
- ✓ Interventions that improved access to drinking-water, sanitation and hygiene effectively reduced diarrhoeal morbidity in children (by 45%, 28% and 23% respectively) (20, 21).
- ✓ Environmental management interventions acting on the habitat of mosquitoes showed large reductions in malaria infections in children (146). Results are consistent with a Cochrane systematic review on mosquito larval source management in water bodies that included studies on children and adults in malaria-endemic areas (147).
- ✓ Access to and use of facilities for the safe disposal of human excreta, use of treated water and soap and handwashing before eating and after defecation have shown to reduce the likelihood of intestinal nematode infections. Many of the included studies examined infections in children (148).
- ✓ Comprehensive community control programmes successfully reduced schistosomiasis prevalence (149, 150).
- ✓ Integrated vector management (IVM) was shown to be the most effective dengue vector control measure to reduce dengue vector infested houses and water containers (151).
- ✓ Interventions and strategies to reduce exposure to solid fuel smoke and unsafe water, sanitation and hygiene are provided in the following WHO guidelines and plans (152–158).

Neonatal and nutritional conditions

- ✓ Indoor tobacco smoke-free legislation in Belgium was associated with significant reductions in preterm birth risk (159). Similar results were seen after an introduction of a citywide smoke-free policy in the United States of America (160).
- ✓ A systematic review and meta-analysis on interventions to improve water quality, water supply, sanitation and hygiene practices found suggestive evidence that those interventions can improve nutritional status in children (66).

Noncommunicable diseases

- ✓ The US Preventive Services Task Force recommends counselling children, adolescents and young adults with fair skin about minimizing exposure to ultraviolet radiation to prevent skin cancer (161).
- ✓ Interventions decreasing the exposure to house dust might reduce physician-diagnosed asthma in high-risk children (162).
- ✓ Tailored multifaceted interventions reducing several environmental asthma triggers are promising to reduce morbidity in children with asthma (163). Smoke-free legislation reduced hospital attendance for childhood asthma by about 10% (164).
- ✓ The European (EUROCAT and EUROPLAN) “Recommendations on Policies to Be Considered for the Primary Prevention of Congenital Anomalies in National Plans and Strategies on Rare Diseases” list evidence-based actions for the reduction of congenital anomalies in Europe and include reduction of exposures to methylmercury, second-hand tobacco smoke and endocrine disruptors (165).

Injuries

- ✓ Child restraints reduce infant deaths by approximately 70% and deaths among small children by between 54% and 80% (107).
- ✓ Home safety interventions were effective in increasing the proportion of families with safe hot water temperature, functional smoke alarms, a fire escape plan, storing medicines and cleaning products out of children's reach, having the poison centre numbers accessible and having fitted stair gates (166).
- ✓ A drowning prevention intervention for children aged between 4 and 12 years in Bangladesh, including swimming lessons, increased supervision, raised risk awareness, and water safety and safe rescue skills, decreased the risk of drowning by more than 90%. Collective supervision of children between one and five years in child-care centres reduced drownings by more than 80%. Both interventions were evaluated as being very cost-effective (167).
- ✓ Pool fencing reduces the risk of drowning or near drowning in children by about 73% (168).

Selected economic evaluations by disease group



Infectious and parasitic diseases

- Interventions that improved water supply, water quality and access to sanitation were shown to be cost-effective and cost-beneficial. A US\$ 1 investment led to a return of between US\$ 5 and US\$ 6 (169).
- Hygiene promotion in six low-income countries was promoted at costs ranging from US\$ 1.05 to US\$ 1.74 per person per year and was highly effective in reducing open defecation and improving personal hygiene (170).
- National behaviour change handwashing programmes in India and China would produce large economic gains from reduced diarrhoea and acute respiratory infections such as a 92-fold return to investment in India and a 35-fold return to investment in China (171).
- Environmental management, including vegetation clearance, modification of river boundaries, draining swamps, oil application to open water bodies and house screening, strongly reduced malaria mortality and morbidity in sub-Saharan Africa at an estimated cost of US\$ 858 per malaria death and US\$ 22.20 per malaria attack averted. The strategy would become more cost-effective in the longer term, as maintenance costs are much lower, with an estimated US\$ 22–92 per DALY averted (172).
- An integrated environmental schistosomiasis control programme was more cost-beneficial than a health sector-confined programme based on diagnosis and treatment of humans and cattle, health education and focal mollusciciding (173, 174). Also, an evaluation of the integrated Chinese national schistosomiasis control programme emphasizing environmental management for snail control and health education, concluded that US\$ 6.20 was gained for every US\$ 1 spent (175).
- Integrated vector management (IVM) in Cuba was more efficient and effective than routine dengue vector control. The average cost-effectiveness ratio was US\$ 831 per focus for IVM and US\$ 2 466 for routine vector control (176).

Noncommunicable diseases

- An evaluation of the The SunWise School Program, a school-based sun safety education programme for children in the United States of America, concluded that for every US\$ 1 invested, between US\$ 2 and US\$ 4 in medical care costs and productivity losses were saved (177).
- Lead-safe window replacements in all pre-1960 homes in the USA would yield considerable monetary benefits from increased lifetime earnings through prevented IQ loss in children. Additional benefits include, for example, avoided attention deficit hyperactivity disorders and reduced crime and delinquency (178).
- Lead paint hazard control in homes to prevent children's exposure would yield a net saving of US\$ 181–269 billion in the United States of America if considering costs of health care, lifetime earnings, tax revenue, special education, attention deficit disorder and direct costs of crime associated with elevated lead exposure (179).
- The annual childhood asthma-related costs attributable to air pollution in two United States of America communities were large (estimated at US\$ 18 million) and mainly borne by the children's families (180). Exposure to PM_{2.5} was positively associated with increased costs of childhood asthma hospitalizations (181).
- Dampness and mould exposure in the home were estimated to lead to US\$ 3.5 billion annual asthma costs in the United States of America (182).
- Different environmental interventions were judged as cost-effective strategies against childhood asthma, including housing interventions (183), multi-component interventions reducing a range of indoor asthma triggers (184) and environmental education (185, 186).
- Costs of childhood asthma attributable to the environment were US\$ 1 550 million in the European Union in 2008 (187).
- A study in the European Union estimated the annual economic costs of the health and economic effects of endocrine disrupting chemical exposure in all age groups to be €163 billion and 1.28% of gross domestic product. The study estimated that organophosphate pesticides alone cost an estimated €146 billion a year in the European Union through IQ loss and intellectual disability (188).

Injuries

- A study in the United States of America found that the ratio of the costs of smoke detectors to the savings in health-care costs was 1:26 (189). Another study estimated benefit-cost ratio of 2.1 and 2.3 for smoke detector giveaway and installation programmes respectively (190).
- In 1992, a campaign against hot water scalds was launched in Australia, and a law was implemented to limit bathroom water temperature to 50°C. Following that campaign, rates of the most serious scalds declined by 30%, resulting in an annual saving to the health-care system of between Aus\$ 3.8–6.5 million (191).

Children's environmental health and the Sustainable Development Goals

The United Nations has recently developed and published a series of Sustainable Development Goals which provide strong targets for reducing the disease burden from environmental risks for children around the world.



Goal 1: End poverty in all its forms everywhere.

Poverty is a major determinant of ill health in children. Many environmental hazards such as unsafe water and sanitation and air pollution disproportionately affect poor children and those living in lower income countries. Adverse environmental impacts often increase poverty among families and communities through, for example, increased health-care expenditures, less childhood education and lost income. Land degradation, desertification and extreme weather events resulting from climate change can have large detrimental impacts on livelihoods and poverty.



Goal 2: End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.

Climate change, land degradation and desertification impact food and water supplies and threaten nutrition and health, especially among children. Unsafe water, sanitation and hygiene can contribute to childhood undernutrition through repeated diarrhoeal diseases and intestinal worms. On the other hand, poor nutrition can lead to overweight and obesity already in childhood – risk factors for many chronic diseases in later life.



Goal 3: Ensure healthy lives and promote well-being for all at all ages.

Over one quarter of the global disease burden in children under five years can be attributed to the environment. The greatest potential for health gains through healthy environments can be achieved in this age group.



Goal 4: Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Inadequate sanitation facilities in schools may prevent children, particularly girls, from attending primary school. Inadequate access to safe water and energy sources through deforestation, land degradation and desertification may require children to spend substantial amounts of time fetching water and wood, which may interfere with school attendance. Children may also need to look after younger siblings who get sick due to repeated infections from poor water and sanitation or smoke from unclean fuels used for cooking or heating. Furthermore, environmental exposures that happen inside school buildings, such as to asbestos, lead, certain chemicals and mould, threaten children's health and development. Ensuring access to basic services and resources can improve nutrition – a prerequisite for productivity and learning ability.



Goal 5: Achieve gender equality and empower all women and girls.

Inadequate access to safe water and clean energy sources often requires fetching water and collecting wood over considerable distances. Often girls are considered responsible for these hard, time-consuming and even dangerous tasks. This time could instead be dedicated to education, empowerment activities or leisure time.



Goal 6: Ensure availability and sustainable management of water and sanitation for all.

Safe and adequate water, sanitation and hygiene could save more than 350 000 deaths in children under five years annually, representing 5.5% of total deaths in that age group. Inadequate sanitation, including open defecation, may contaminate water sources and environments where children live and play, and cause repeated infections which hamper their growth and nutrition. Global environmental change, population growth and water over use may put further pressure on access to safe water and adequate sanitation.



Goal 7: Ensure access to affordable, reliable, sustainable and modern energy for all.

Access to clean fuels for cooking and heating will reduce exposure to household air pollution, which caused more than 500 000 deaths in children under five years in 2012, and will also be an important step in tackling climate change and deforestation.



Goal 8: Promote inclusive and sustainable economic growth, employment and decent work for all.

Many million children worldwide are exposed to child labour and hazardous work. Ending child labour is crucial to allow these children to enjoy their childhood and realize their full potential.



Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.

Resilience, sustainable industrialization and innovation are all required to progress towards a more health-protective environment. Critical changes are needed to mitigate key environmental health risks such as climate change, air pollution and unsafe water and inadequate sanitation, which can have detrimental effects on children's health. Access to electricity and safe and appropriate water, sanitation and hygiene in households and institutions like hospitals and schools will especially benefit children's health.



Goal 10: Reduce inequality within and among countries.

Children from different socioeconomic, cultural and geographic backgrounds experience different levels of environmental risks. Improving the environment for those most affected will greatly contribute to reducing inequalities in health, access to services, income and education.



Goal 11: Make cities and human settlements inclusive, safe, resilient and sustainable.

In a world becoming increasingly urbanized, more children now than before are living in cities. Key environmental risks include air pollution, unsafe water, sanitation, hazardous waste and road accidents. Some 92% of the world's population live in places where air pollution exceeds WHO limits. Walkable neighbourhoods promoting physical activity in childhood teaches children healthy habits and helps to avoid overweight, obesity and related chronic diseases. Climate change, land degradation and desertification threaten community resilience. Adequate housing protects children from unintentional injuries and offers them a secure place to thrive.



Goal 12: Ensure sustainable consumption and production patterns.

Sustainable consumption and production, including the management of hazardous waste, are closely linked to key environmental risks such as ambient air pollution, exposure to chemicals, and water and sanitation which can be detrimental for children's health. These are crucial to maintaining a healthy environment and planet that will meet the needs of future generations.



Goal 13: Take urgent action to combat climate change and its impacts.

Climate change is one of the major health challenges of the future and its mitigation a prerequisite for sustainable development. Climate change is related to many of the SDGs, affecting water resources, food production, desertification, air pollution and, therefore, human health. Children are likely to be particularly affected through increases in diarrhoea, malnutrition and vector-borne diseases.



Goal 14: Conserve and sustainably use the oceans, seas and marine resources for sustainable development.

Sustainable use of oceans has many links with environmental determinants of health. Examples include oceans as a sustainable food resource, and the need for adequate sanitation regarding excreta management.



Goal 15: Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.

Forests and stable ecosystems are critical for the world's climate, food and water supplies, and protect against soil erosion and natural disasters. Deforestation, land degradation and desertification contribute to climate change, and may increase respiratory diseases through burning of solid fuels and prevalence of vector-borne diseases. Biodiversity loss further threatens food and water supplies, ecosystems and community resilience against natural disasters.



Goal 16: Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.

Inequitable access to ecosystem services, such as safe water and energy sources, and extreme weather events are potential sources of conflict, displacement, inequality and exclusion. Today about half of the world's refugees are children (7). Armed conflict has escalated in many countries, putting more children at risk of displacement.

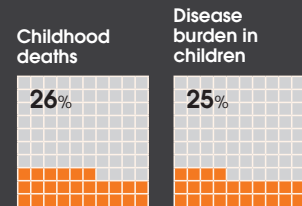


Goal 17: Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Both health and non-health sector actors at local and global level can and need to take joint action to effectively address environmentally mediated causes of disease. Many alliances already exist in the field of children's environmental health which need to be strengthened and reinforced, harnessing the full range of policy tools, strategies and technologies that are already available.

Conclusions

Reducing environmental risks could prevent a quarter of childhood deaths and disease



Some 26% of childhood deaths and 25% of the total disease burden in children under five were attributed to environmental exposures in 2012. This estimate indicates the potential burden of disease that could be prevented by environmental interventions.

The disease burden from environmental risks based on these calculations is especially large in children under five years of age and is largely composed of infectious and parasitic diseases and neonatal and nutritional conditions. In children 5 to 15 years old, injuries and noncommunicable diseases become relatively more important. The largest contributors to environmental DALYs in children under five years are respiratory infections, followed by diarrhoeal diseases and neonatal conditions. The bulk of the disease burden in children attributable to the environment occurs in low- and middle income countries.

Many adverse environmental exposures such as to chemicals during childhood lead to disease or early death at adult age (19). Preventing these exposures during childhood could therefore contribute importantly to reducing the growing worldwide numbers of diabetes, cardiovascular diseases and cancer.

Effective preventive interventions exist that protect children from adverse environmental exposures, many of which are listed in this report. A strong focus on primary prevention through reducing environmental risks will not only improve children's health but also lead to health-care savings. The environment is a key element of protecting children's health and reducing health inequalities. Intersectoral action such as between the health, energy, transport, industry/commerce, housing and water sectors will be required to appropriately reduce environmental risks. Interventions that reduce environmental risks have the potential to greatly contribute to achieving the Sustainable Development Goals and these interventions generally benefit health, the climate, the environment and overall development at the same time.

While the relationship between environmental risks and many infectious diseases has been documented quite extensively, the early life exposures leading to longer term effects, in particular, in the area of noncommunicable diseases, have not yet been assessed extensively. They are more difficult to gather due to the delayed effect between exposure and outcome. Targeted research would establish the evidence base to act to improve children's environmental health.

Interdisciplinary science has made tremendous advances in helping to understand the role environmental exposures play in increasing disease risk, including: genetics; the potential of environmentally induced epigenetic changes to increase disease risk; GIS spatial technologies to improve exposure assessment; biomarker development to link exposures to disease risk; functional imaging to improve early disease assessment; among others. As science is alerting us to greater potential consequences of environmental exposures affecting not only a child's lifespan but also subsequent generations, the urgency to critically evaluate exposures and act

collectively to avoid or reduce exposures is increasing. Awareness of the state of the science is not enough. Careful consideration of social and economic impacts on vulnerable groups and a multisectoral approach are required to solve environmental health dilemmas (193).

In the last century genetic inheritance predicted an individual's health. Environmental factors considered modifiable have been the focus of protective policies. Current epigenetic research is identifying mechanisms and pathways where modifiable environmental factors may be affecting gene expression and activity that is capable of affecting future generations (194). These potential transgenerational effects are particularly concerning and speak to the importance of considering long-term protective policies where immediate benefits may not be measurable.

Escalation of research interest is leading to new knowledge on windows of vulnerability that increase feasibility for targeted and specific actions (195, 196). The current focus on the prenatal life stage is identifying opportunities to, at least in theory, reduce or eliminate disease risk. By reducing or eliminating exposure to environmental neurotoxins the incidence of neurodevelopmental behavioural disorders could be reduced (82). However, while it is possible to eliminate some developmental neurotoxins, such as lead or tobacco smoke, eliminating others will be much more difficult (82). New knowledge identifying fetal origins of adult chronic diseases promise significant opportunities for protective actions.



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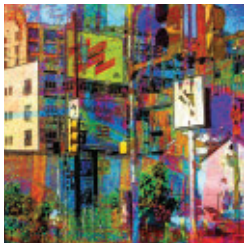
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