Clear the air for children

unicef 70
70 YEARS FOR EVERY CHILD

Please contact:
Division of Data, Research and Policy, UNICEF
3 United Nations Plaza, New York, NY 10017, USA

Note on maps: All maps included in this publication are stylized and not to scale. They do not reflect a position by UNICEF on the legal status of any country or area or the delimitation of any frontiers. The dotted line represents approximately the Line of Control agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the Parties. The final boundary between the Republic of the Sudan and the Republic of South Sudan has not yet been determined. The final status of the Abyei area has not yet been determined.

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Clear the air for children

The impact of air pollution on children

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Policy, Strategy, Networks Section (PSN)
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AUTHOR AND PROJECT MANAGER
Nicholas Rees

EDITOR-IN-CHIEF
David Anthony

DESIGN CONCEPT AND CONTENT STRATEGY
Olga Oleszczuk

TECHNICAL ADVISORS
Alex Heikens, Christine Klauth, Hayalnesh Tarekegn

RESEARCH AND CASE STUDIES
Zainab Amjad, Yoonie Choi, Marita Haug, Christine Klauth, Olga Oleszczuk, Julia Worcester

COPYEDITING
Ruth Ayisi, Laura Evans, Timothy DeWerff

OVERALL GUIDANCE AND DIRECTION
George Laryea-Adjei, Deputy Director, Policy, Strategy and Networks Section
Jeffrey O'Malley, Director, Division of Data, Research and Policy

CONTRIBUTIONS, INPUTS AND/OR REVIEW
UNICEF: Liliana Carvajal, Lucia Hug, Priscilla Idele, Guy Taylor, Danzhen You, Mark Young
UNEP: Fanny Demassieux, Valentin Foltescu, Maaike Jansen, Rob de Jong
Global Alliance for Clean Cookstoves: Jessie Durrett, Cecilia Flatley, Sumi Mehta
Children's Investment Fund Foundation: Megan G. Kennedy-Chouane, Sonia Medina, Byford Tsang
University of California, Irvine: Rufus Edwards
Dalhousie University: Aaron Van Donkelaar

MAPS AND ANALYSIS
Blue Raster LLC: Stephen Ansari, Michael Lippmann, Kevin McMaster

MEDIA
Rose Foley

PHOTOGRAPH CREDITS
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Foreword

It causes miscarriages, early delivery, and low birth weight.

It contributes to diseases that account for almost 1 in 10 of all deaths of children under the age of five.

It can harm the healthy development of children's brains.

It is a drag on economies and societies, already costing as much as 0.3 per cent of global GDP – and rising.

And in many parts of the world, it is getting worse.

'It' is air pollution. And as both this litany and this report show, the magnitude of the danger it poses – especially to young children – is enormous.

Children breathe twice as quickly as adults, and take in more air relative to their body weight. Their respiratory tracks are more permeable and thus more vulnerable. Their immune systems are weaker. Their brains are still developing.

Ultrafine, airborne pollutants -- caused primarily by smoke and fumes -- can more easily enter and irritate children's lungs, causing and exacerbating life-threatening disease. Studies show these tiny particles can also cross the blood-brain barrier, which is less resistant in children, causing inflammation, damaging brain tissue, and permanently impairing cognitive development. They even can cross the placental barrier, injuring the developing fetus when the mother is exposed to toxic pollutants.

So urban children growing up too close to industrial sites, smoldering dumps, and electrical generators that burn biomass fuels like dung … rural children living in unventilated homes where food is prepared on smoking cook stoves … refugee and migrant children staying in tents filled with wood smoke … All these children are breathing in pollutants night and day that endanger their health, threaten their lives, and undermine their futures.

Many of these children are already disadvantaged by poverty and deprivation. Some are already at heightened risk from conflicts, crises and the intensifying effects of climate change. Air pollution is yet another threat to their health and wellbeing – and yet another way in which the world is letting them down.

The sheer numbers of children affected are staggering. Based on satellite imagery, in the first analysis of its kind, this report shows that around the world today, 300 million children live in areas with extremely toxic levels of air pollution. Approximately 2 billion children live in areas where pollution levels exceed the minimum air quality standards set by the World Health Organization. These data don't account for the millions of children exposed to air pollution inside the home.

The impact is commensurately shocking. Every year, nearly 600,000 children under the age of five die from diseases caused or exacerbated by the effects of indoor and outdoor air pollution. Millions more suffer from respiratory diseases that diminish their resilience and affect their physical and cognitive development.

As population grows … as countries continue to develop through rapid industrialization … and as urbanization increases, experts expect all these numbers to climb.

Unless we act now.

Developed countries have made great strides in reducing outdoor air pollution and protecting children from indoor pollutants. Developing countries – both low and middle income – can and must do so too.

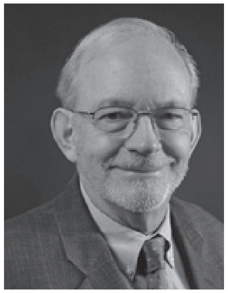
Most urgently, this means promoting greater understanding of the dangers of air pollution – among governments, communities, and families. And it means providing parents with more information on how to protect their children from indoor pollutants. This includes improved ventilation, so smoke does not linger … better insulation, so less heating fuel is burned … and cleaner cook stoves. These are all practical solutions that can make a big difference.

Outside the home, it means improving urban planning so schools and playgrounds are not located in close proximity to sources of toxic pollution. It means improving waste disposal systems and increasing public transportation options to reduce automobile traffic and the harmful fossil fuel emissions it produces. It means investing in sustainable energy solutions to reduce reliance on pollution-causing sources of energy.

It also means monitoring air pollution levels more carefully and including this critical data in our approach to other issues, like child health. Health workers who know a sick child has been exposed to high levels of pollution can diagnose illness more quickly, treat it more effectively, and prevent the compounding harm that pollution can cause.

Protecting children from air pollution is not only in their best interests; it is also in the best interests of their societies – a benefit realized in reduced health costs … in increased productivity … in a cleaner, safer environment … and thus, in more sustainable development.

We can make the air safer for children. And because we can, we must.



Anthony Lake
Executive Director, UNICEF

Executive summary and key messages

Around 300 million children currently live in areas where the air is toxic – exceeding international limits by at least six times.

Using satellite imagery of outdoor air pollution, this study found that around 300 million children currently live in areas where outdoor air pollution exceeds international guidelines by at least six times. In total, around 2 billion children live in areas that exceed the World Health Organization annual limit of 10 μg/m^3 (the amount of micrograms of ultra-fine particulate matter per cubic metre of air that constitutes a long term hazard).

Air pollution is linked directly with diseases that kill. In 2012, air pollution was linked with 1 out of every 8 deaths, globally – or around 7 million people.[1] Around 600,000 of those were children under 5 years old, globally.[2] Almost one million children die from pneumonia each year, more than half of which are directly related to air pollution.

Air pollution can considerably affect children's health. Studies have shown that air pollution is strongly associated with respiratory conditions such as pneumonia, bronchitis and asthma, among others. It can also exacerbate underlying health issues and prevent children from going to school,[3] and there is emerging evidence that it can disrupt physical and cognitive development.[4] Left untreated, some health complications related to air pollution can last a lifetime.

Air pollution is worsening in many parts of the world. As countries continue to industrialize and urbanize, energy, coal and fuel use tends to increase. A recent publication from the World Health Organization (WHO) indicates that urban outdoor air pollution has increased by about 8 per cent between 2008 and 2013.[5] Projections are unfavourable. According to the Organisation for Economic Co-operation and Development (OECD), under-five mortality could be 50 per cent higher than current estimates by 2050 as a result of outdoor air pollution.[6] Another study published in *Nature* found it could be even worse – doubling by 2050.[7]

Children are uniquely vulnerable to air pollution – due both to their physiology as well as to the type and degree of their exposure.

Air pollution can seriously affect the health of the foetus. Pregnant mothers are advised to avoid air pollution – just as they should avoid smoking or breathing secondhand cigarette smoke. Studies have shown that chronic exposure to high levels of particulate matter (PM2.5 – which consists of particulate matter with a median diameter of less than 2.5 microns, approximately one thirtieth the width of average human hair) is associated with higher rates of early foetal loss, preterm delivery – and lower birthweight.[8,9]

Children's lungs are in the process of growing and developing, making them especially vulnerable to polluted air. The cell layer on the inside of the respiratory tract is more permeable among young children.[10] Children's respiratory airways are also smaller than adult airways, so infections are more likely to cause blockages than in adults.[11] Children breathe twice as fast, taking in more air per unit of body weight, compared to adults.[12]

Furthermore, children's immune systems are still developing, especially at young ages. During early childhood, children are highly susceptible to viruses, bacteria and other infections.[13] This both increases the risks of respiratory infection and reduces the ability of children to combat it.

Moreover, the effects of air pollution on a child can have lifelong health implications. Air pollution can impair the development of children's lungs, which can affect them through to adulthood. Studies have shown that the lung capacity of children living in polluted environments can be reduced by 20 per cent – similar to the effect of growing up in a home with secondhand cigarette smoke.[14] Studies have also shown that adults who were exposed to chronic air pollution as children tend to have respiratory problems later in life.[15]

Poor children are among the most at risk.

Globally, air pollution affects children in low- and middle-income countries more. Up to 88 per cent of all deaths from illnesses associated with outdoor air pollution[16] and over 99 per cent of all deaths from illnesses associated with indoor air pollution occur in low- and middle-income countries.[17] Asia currently accounts for the vast bulk of total deaths attributable to air pollution.[18] The proportions, however, are changing. In Africa, increasing industrial production, urbanization and traffic is causing the rapid rise of outdoor air pollution.[19,20,21] As this happens, the number of African children exposed to outdoor air pollution is likely to increase, especially as the continent's share of the global child population is set to increase markedly. By mid-century, more than one in three children globally is projected to be African.[22]

Outdoor air pollution tends to be worse in lower-income, urban communities.[23] Lower-income areas are often highly exposed to environmental pollutants such as waste and air pollution.[24] Factories and industrial activity are also more common near lower-income areas, and there is often less capacity to manage waste. This can result in burning, including of plastics, rubber and electronics, creating highly toxic airborne chemicals which are highly detrimental to children. Poorer families are also less likely to have resources for good quality ventilation, filtration and air conditioning to protect themselves from harmful air.

Indoor air pollution is most common in lower-income, rural areas. Over 1 billion children live in homes where solid fuels are used in cooking and heating. While outdoor air pollution tends to be worse in poor urban communities, indoor air pollution tends to be worse in rural communities where biomass fuels are more frequently used in cooking and heating due to lack of access to other forms of energy. Eighty-one per cent of rural households in India use biomass fuel, for instance, because it is relatively inexpensive and readily available.[25] Even at national levels, income is linked with the use of solid fuels for household energy needs: Thailand – with a per capita income of US$5,816 – uses biomass to meet 23 per cent of household energy needs, while the United Republic of Tanzania – with a per capita income of US$864 – uses biomass to meet 95 per cent of household energy needs.[26]

A lack of adequate health services and poor initial health makes the poorest children even more at risk. When a child is sick, lacks good nutrition or does not have access to clean water, adequate sanitation and hygiene, respiratory infections, such as pneumonia are more common and potentially more deadly.[27] A body's defences require good overall health. A lack of access to health care not only prevents treatment, but can also mean that conditions could go undiagnosed in the first place.[28]

Reducing air pollution is one of the most important things we can do for children. Research shows that reductions in air pollution have led to improvements in children's respiratory functions.[29,30,31] A World Health Organization study estimates that meeting global air quality guidelines for PM2.5 could prevent 2.1 million deaths across all age groups per year based on 2010 data.[32] It could also improve the overall health of millions more, help to reduce the incidence of acute and chronic respiratory infections among children, and reduce complications during pregnancy and childbirth. Finally, studies show it could improve children's physical and cognitive development, helping them to lead longer and more productive lives.

The benefits of reducing air pollution extend well beyond child health – actions and investments that reduce air pollution can also help grow economies and combat climate change.

Climate change already threatens the well-being of children. Cutting back on fossil fuel combustion and investing in renewable energy sources can help reduce both air pollution and greenhouse gases that contribute to climate change. The multiplier effect of reducing fossil fuel combustion on the well-being of children stands to be enormous.

Reducing air pollution can also significantly help improve productivity and economic performance. As this report shows, air pollution matters greatly to health; the relationships between improved health, cognitive and physical development, higher incomes and improved economic performance are well documented.[33] Furthermore, reduced air pollution can also help lower health expenditures at household and government levels – which add up to billions of dollars of savings at the national level. An OECD study shows that the total annual costs of air pollution currently account for approximately 0.3 per cent of global GDP, and are expected to increase to approximately 1 per cent of GDP by 2060.[34] A World Bank/Institute for Health Metrics and Evaluation study found that deaths from air pollution cost the global economy about US$225 billion in lost labour income and more than US$5 trillion in welfare losses in 2013.[35]

Reducing air pollution is crucial to making progress on the Sustainable Development Goals. Reducing air pollution will directly influence our progress in achieving the Sustainable Development Goals (SDGs). Issues relating to air quality are mentioned in four places in the SDGs: in the Declaration itself, as well as in three of the SDGs: SDG 3) *Good Health and Well-being*, SDG 11) *Sustainable Cities and Communities* and 12)

Ways in which air pollution relates to the Sustainable Development Goals

1 NO POVERTY

Reducing air pollution can help families become healthier, save on medical expenses, and improve productivity.

2 ZERO HUNGER

Air pollution can cause crop damage and affect food quality and security.

3 GOOD HEALTH AND WELL-BEING

Air pollution poses a major threat to human health. It is linked to respiratory infection and cardiovascular disease. It causes increases in population morbidity and mortality.

6 CLEAN WATER AND SANITATION

Pollutants such as sulfur dioxide (SO_2) and nitrogen oxide (NO_x) from open fires and the combustion of fossil fuels mix with precipitation causing harmful acid rain that can compromise water quality.

7 AFFORDABLE AND CLEAN ENERGY

Electricity from renewable energy rather than fossil fuels offers significant public health benefits through a reduction in air pollution.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Power generation, industry and transportation are large contributors to air pollution. A new focus on decreasing energy consumption and on improving sustainable and public transportation could progressively reduce pollution.

11 SUSTAINABLE CITIES AND COMMUNITIES

Urban areas significantly contribute to air pollution. Making cities sustainable could progressively improve the air quality.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Chemicals released into the air increase air pollution and contribute to harmful effects on human health. Responsible production and consumption could help to reduce these harmful chemicals.

13 CLIMATE ACTION

Combustion of fossil fuels plays a key role in the process of climate change, which places food, air and water supplies at risk, and poses a major threat to human health.

15 LIFE ON LAND

Emissions from combustion of fossil fuels mixed with precipitation cause acid rains that pose a major threat to forests and ecosystems.

Responsible Consumption and Production. Reducing air pollution also indirectly affects progress on a multitude of SDGs, including SDGs 1, 2, 6, 7, 9, 13 and 15. Further, it helps reduce poverty and food insecurity, improve water quality and preserve forests and ecosystems. It is also often related to developing sustainable cities, cleaner energy sources, responsible production and consumption, and combatting climate change.

Protecting children from air pollution requires actions to reduce air pollution, reduce children's exposure to it and better monitor it.

Children should be kept away from anything that harms them - we need to minimize children's exposure to air pollution. Even though the toxic cocktail of chemicals in air pollution is largely invisible to the naked eye, these elements are deadly and affect children's health and well-being. Minimizing exposure requires actions by families and individuals, as well as communities and governments. These can include providing better ventilation, as well as insulation, depending on the source of pollutants in homes; the provision of cleaner cookstoves; and preventing exposure to tobacco smoke. They can include greater knowledge and awareness of how to protect oneself and one's family. Finally, they can include better urban planning and making sure that polluting sources are not built within the immediate vicinity of schools and playgrounds.

We also need to focus efforts on reducing air pollution. Reducing air pollution will translate into millions of saved lives, and lead to better, healthier lives for our children and future generations. At the governmental level, actions should be implemented to reduce fossil fuel emissions, and increase investments made in sustainable energy and low-carbon development. These include commitments made as part of the COP21 Climate Change Paris Agreement and Nationally Determined Contributions (NDCs). Within communities, better management of community resources, including safe waste disposal, better public transportation options, and information and knowledge on reducing pollution, is needed.

We need better monitoring of air pollution. Air quality can fluctuate rapidly in every environment. For example, cooking or heating with biomass in the home can cause a rapid spike in indoor air pollution. Urban outdoor pollution spikes during rush hour in most cities. Waste-burning tends to be practised at certain times of the day in many places. Monitoring systems can help individuals, parents, families, communities and local and national governments become more aware of how air pollution might affect them, and adjust to immediately prevailing conditions to minimize exposure. These measures will not in themselves stop the problem of air pollution – but they are a necessary and important first step. The more we know about air pollution, the better we can figure out how to protect children from its negative effects.

Together, outdoor and indoor air pollution are directly linked with pneumonia and other respiratory diseases that account for almost one in 10 under-five deaths, making air pollution one of the leading dangers to children's health.


MCM

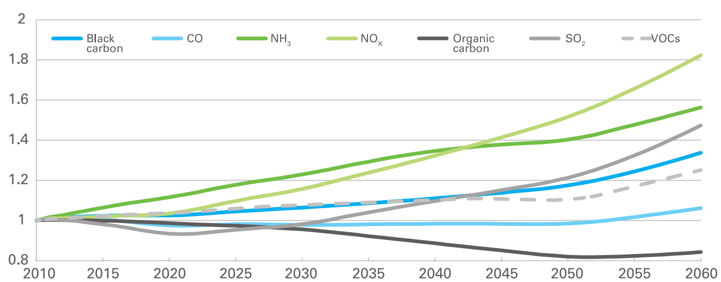
Chapter 1: Air pollution causes and trends

Air pollution can be human-made or occur naturally in the environment. Human-made pollutants are caused by fossil fuel combustion, industrial manufacturing, waste-burning, dust from traffic, smoke, and exhaust from vehicles, ships and airplanes, for example.[1] Fires from brush/forest clearing are also a major source of pollution in the form of smoke and black carbon.[2] There are also a variety of natural causes, including volcano eruptions that emit large amounts of sulfur and other gases,[3] and dust storms that contribute considerably to airborne particulate matter.[4] Weather patterns can transfer pollutants, both human-made and natural, over long distances and across regions.[5]

Outdoor air pollution

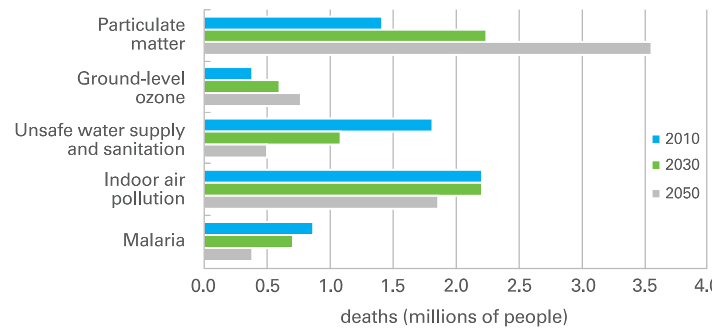
Outdoor air pollution is a growing problem. Recent estimates indicate that urban outdoor air pollution has risen by 8 per cent globally between 2008 and 2013.[6] Urbanization, which is often associated with rising air pollution, is increasing too – by 2050, up to two thirds of the global population is expected to live in urban areas.[7] Unless action is taken to control outdoor air pollution, studies show that outdoor air pollution will become the leading cause of environment-related child death by 2050.[8]

Fig. 1: Emission projections over time, index with respect to 2010



Source: The economic consequences of outdoor air pollution, OECD, 2016

Fig. 2: Global premature deaths from selected environmental risks: Baseline, 2010 to 2050



Source: OECD Environmental Outlook Baseline; Output from IMAGE. The economic consequences of outdoor air pollution, OECD, 2016

Air pollution can be high in parts of North America and Europe, but it has improved slightly over the past decade with new environmental regulations and progress in technology.[9,10] Meanwhile, China and India have been frequently cited as areas where air pollution is at its worst.[11]

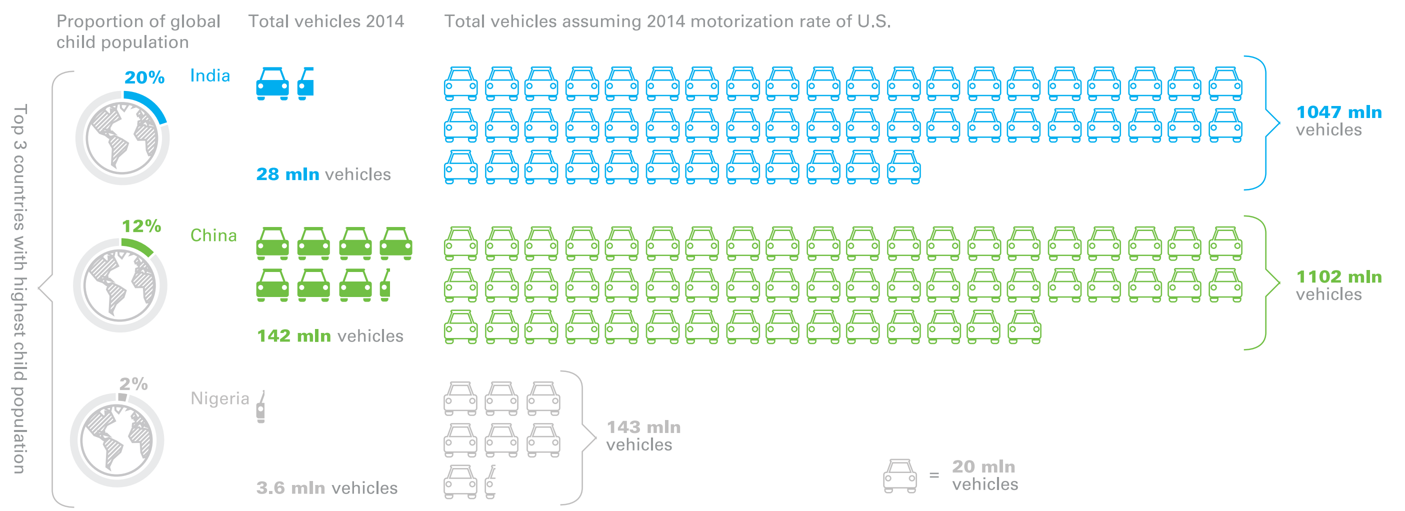
In some cities in Asia, it has exceeded 20 times the WHO guidelines.[12] Nevertheless, there is considerable variation within those countries both regionally and locally, especially in recent years.[13] In Beijing, for example, latest estimates show an improvement compared to previous years. In fact, data from WHO unveil a striking new analysis: the most polluted city in the world (by PM10 measurements) is now Onitsha, Nigeria. Two other Nigerian cities, Kaduna and Aba, are also among the top 10 most polluted cities. Zabol, Iran, is the most polluted city by PM2.5 measurements. Asian cities continue to occupy the majority of the top of the list for PM2.5 measurements.[14] (For recent lists, see page 57)

Motorization and the investment case for clean transport

As economies industrialize, demand for vehicles is likely to increase. The effect of this can go in two directions: either those cars can be reliant on fossil fuel combustion, or they can be reliant on renewable energy. The difference could be huge for children in those affected countries. Hybrid and electrical vehicles can dramatically reduce the air pollution from vehicles.[15]

In the three countries with the highest child populations (India, China and Nigeria), the number of cars is likely to grow considerably in the coming decades, which will be particularly marked in Africa, and substantial too in South Asia. For comparison, if those countries were to have the same motorization rate per capita as the United States of America currently, the number of vehicles would increase by nearly 40 times for India and Nigeria, and 8 times for China. This also does not account for the growth in population over the coming decades. The imperative for green investments could not be stronger.

Fig. 3: Number of vehicles in three most child populous countries (India, China and Nigeria), and if the motorization rate were that of the United States.



Source: The International Organization of Motor Vehicle Manufacturers (2014). World Vehicles in Use – All Vehicles.
UN Population Division, World Population Prospects 2015

Indoor air pollution

Burning of solid fuels for household cooking, heating and lighting is a major cause of household, or indoor, air pollution. Indoor air pollution puts nearly 3 billion people worldwide at risk of ill health and early death.[16] Indoor pollutants include particulate matter (PM10 and PM2.5), mould, dust mites and bacteria, as well as chemicals and Volatile Organic Compounds (such as formaldehyde and benzene) from paints, personal care products and building materials.[17,18]

The effects of indoor air pollution kill more children globally than outdoor air pollution, especially in Africa and Asia. Eighteen of the nineteen countries where 95 per cent or more of the population use solid fuels for cooking are in sub-Saharan Africa.[19] More than 60 per cent of the population in India continue to use solid fuels in household cooking – contributing to over 100,000 child deaths associated with indoor air pollution in 2012.[20]

Outdoor air pollution is growing fast. Indoor air pollution, however, is linked to diseases which kill more children.

While outdoor air pollution tends to be an urban issue, indoor air pollution tends to be more of a rural one. However, there is considerable overlap, significant challenges of indoor air pollution in urban areas, as well as outdoor air pollution in rural settings.

The distinction between outdoor and indoor air pollution is more useful for analytical purposes than it is for practical prevention of exposure in day-to-day life. Throughout the course of a day, we move between indoor and outdoor environments almost seamlessly, and the many microenvironments between indoor and outdoor are hard to classify.

Furthermore, indoor air and outdoor air are not completely distinct. Burning of biomass fuels for heating, lighting and cooking, for example, is a major source of ambient, or outdoor, pollution in many cities.[21] Families also cook outside. Concentrations and types of pollutants vary considerably by time and location, depending on cooking schedules and other daily activities including working hours and transportation rush hours.

Analysis of children's exposure is much more complex than characterizations of 'indoor' and 'outdoor' environments; and awareness of the air quality in all types of environment, across a continuum of micro-environments, is important to maintaining overall health, and the first step to action.

Health-damaging air pollutants

There are many different types of air pollution. Among the most common outdoor pollutants that affect human health are particulate matter (PM), ozone (O_3), nitrogen oxides (NO_x), sulfur dioxide (SO_2), carbon monoxide (CO) and chemicals such as polycyclic aromatic hydrocarbons (PAHs). Many of the pollutants are highly linked, however, and it is difficult to separate their effects. There are also considerable interactions between pollutants, which makes it difficult to determine the cause and effect of a single pollutant.

Most outdoor pollution monitoring systems measure two types of PM: PM_{10} (which is less than 10 microns in diameter) and $PM_{2.5}$ (which is less than 2.5 microns in diameter). Ozone is also frequently monitored.

PM_{10} is roughly one-seventh the diameter of a normal human hair. It consists of sulfate, nitrates, ammonia, sodium chloride, and black carbon; it may also include concentrations of natural windblown dust. PM_{10} is harmful to health because it can block and inflame nasal and bronchial passages, causing a variety of respiratory-related conditions that lead to illness or death. PM_{10} is a major component of indoor air pollution and forest fires.[22,23]

$PM_{2.5}$ is often considered even more dangerous to human health because of its ultrafine size (about 1/30th the average width of a human hair). Not only can $PM_{2.5}$ penetrate deep inside the lungs, but it can also enter the bloodstream, causing a variety of health problems including heart disease and other cardiovascular complications. $PM_{2.5}$ is often the result of fossil fuel combustion from vehicle exhaust, industrial production and power plants, as well as from natural sources such as windblown dust and volcanic activity.[24]

Ozone (O_3), another major pollutant, is formed by a chemical reaction involving sunlight, nitrogen oxides (NO_x) and volatile organic compounds (VOCs). As a result, the highest levels of ground-level ozone occur during warm, sunny days, particularly in the afternoon. Ozone is a powerful respiratory irritant that can cause lung inflammation, shortness of breath, chest pain, wheezing, coughing and exacerbation of respiratory illnesses such as pneumonia and asthma. Long-term exposure has been linked with chronic respiratory illnesses.[25,26,27] Approximately 142,000 people died as a result of exposure to ozone in 2010 – an increase of about 6 per cent since 1990.[28]

Nitrogen oxides (NO_X) are one of the principal pollutants that result from fossil fuel combustion. It occurs closer to roads and factories, or indoors where gas is used for cooking. Nitrogen oxides plays a significant role in the exacerbation of pneumonia, asthma, bronchial symptoms, lung inflammation and reduction in overall lung function.[29]

Polycyclic aromatic hydrocarbons (PAHs) are produced when burning of fossil fuels is incomplete, and often associated with diesel engines and black carbon.[30,31] Prenatal exposure to PAHs has been shown to increase the risk of infection, coughing, breathing difficulties and 'nasal symptoms' in infants.[32] It has also been linked with higher risk of Attention Deficit Hyperactivity Disorder and other learning disabilities.[33]

Sulphur dioxide (SO_2) is a colourless gas with a very sharp odour. It is formed when sulfur-based coal and oil is burned, or during the smelting of mineral ores that contain sulfur. Sulfur dioxide can become acidic when combined with water, creating acid rain, which causes deforestation.[34] SO_2 can affect the respiratory system, causing coughing, mucus secretion, aggravation of asthma and chronic bronchitis.[35] Studies have shown that exposure increases mortality rates, especially among those with cardiac and lung diseases.[36]

Carbon monoxide (CO) is a colourless, odourless gas, produced most principally by vehicles. Other sources include fuel combustion boilers and incinerators.[37,38] Exposure to elevated levels is also associated with headaches, visual impairment, reduced cognitive functioning and ability, and reduced ability to perform complex tasks.[39] Very high levels can result in unconsciousness and eventually death.[40]

There are other air pollutants such as mercury, fluoride, lead and other heavy metals, often related to the burning of low quality coal for electricity production, heating and brick production.[41] Others include dioxins and furans, some of which are extremely toxic. These are of particular concern in the context of uncontrolled burning of municipal/household waste.[42]

Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids contained in a number of indoor sources varying from paints to cosmetics, dry cleaning fluids, and automotive products.[43]

Ammonia (NH_3) is a naturally occurring substance characterized as a colourless alkaline gas with pungent smell. It is hazardous in concentrated forms. It is used extensively in the production of a wide range of pharmaceutical products and commercial cleaning products.[44]

WHO Guideline Limit[32, 33]

$PM_{2.5}$
10 μg/m³ annual mean
25 μg/m³ 24-hour mean

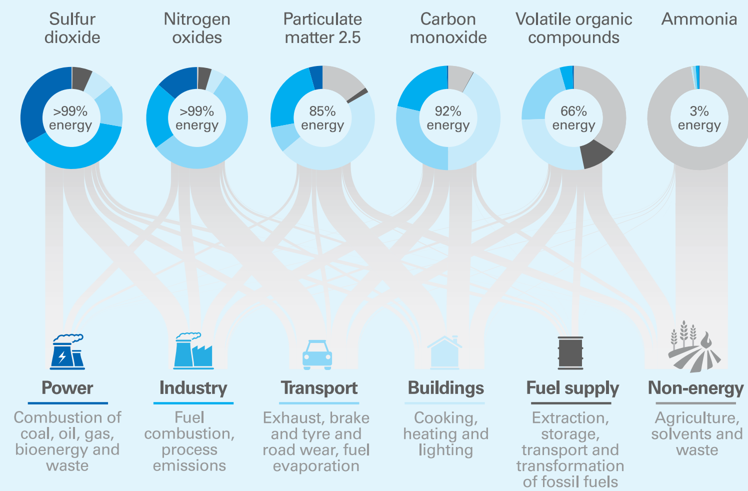
PM_{10}
20 μg/m³ annual mean
50 μg/m³ 24-hour mean

O_3
100 μg/m³ 8-hour mean

NO_2
40 μg/m3 annual mean
200 μg/m3 1-hour mean

SO_2
20 μg/m³ 24-hour mean
500 μg/m³ 10-minute mean

Fig. 4: Selected primary air pollutants and their sources, 2015



Source: Energy and Air Pollution, *World Energy Outlook Special Report*, International Energy Agency, 2016

Outdoor air pollution is an increasing risk to children, especially in many rapidly growing urban centres around the world.

Chapter 2: Impact of air pollution on children

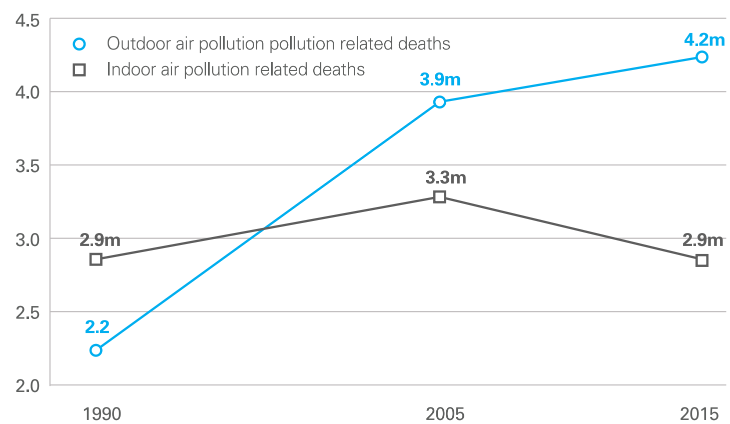
Mortality

Air pollution is linked with diseases and infections that kill around 600,000 children under 5 years of age per year.[1] Pneumonia accounts for up to 16 per cent of all under-five deaths;[2] more than half of childhood pneumonia deaths are associated with air pollution.[3]

Globally, according to the World Health Organization indoor air pollution killed about 4.3 million people and outdoor air pollution killed about 3.7 million in 2012.[4,5] Focussing on under-5 mortality, the World Health Organization found that approximately 531,000 children under the age of 5 died from household air pollution in 2012, and around 127,000 children under the age of 5 died from outdoor air pollution in 2012.

A 2016 comparative risk assessment of the Global Burden of Disease 2015 study found similar estimates. It found that air pollution exposure was linked with almost 6.5 million deaths worldwide (ranging from 5.7–7.3 million), with 4.2 million due to outdoor air pollution (ranging from 3.7–4.8 million), and just under 2.9 million due to indoor air pollution (ranging from 2.2–3.6 million). For outdoor air pollution, this represents a considerable increase compared to 2013 estimates, when it was linked with 2.9 million deaths. The number of indoor air pollution deaths remained largely the same between both 2013 and 2015 studies.

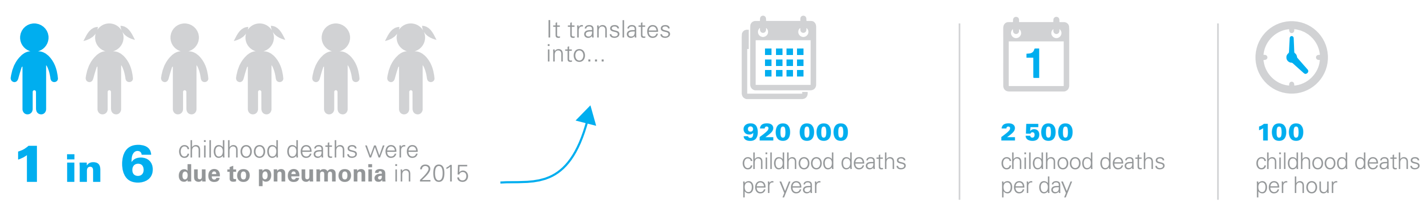
Fig. 5: Deaths caused by outdoor and indoor air pollution, 1990 - 2015



Source: IMHE, Global Burden of Disease, 2016

Pneumonia is the biggest killer of children. Air pollution is responsible for about half of pneumonia cases.

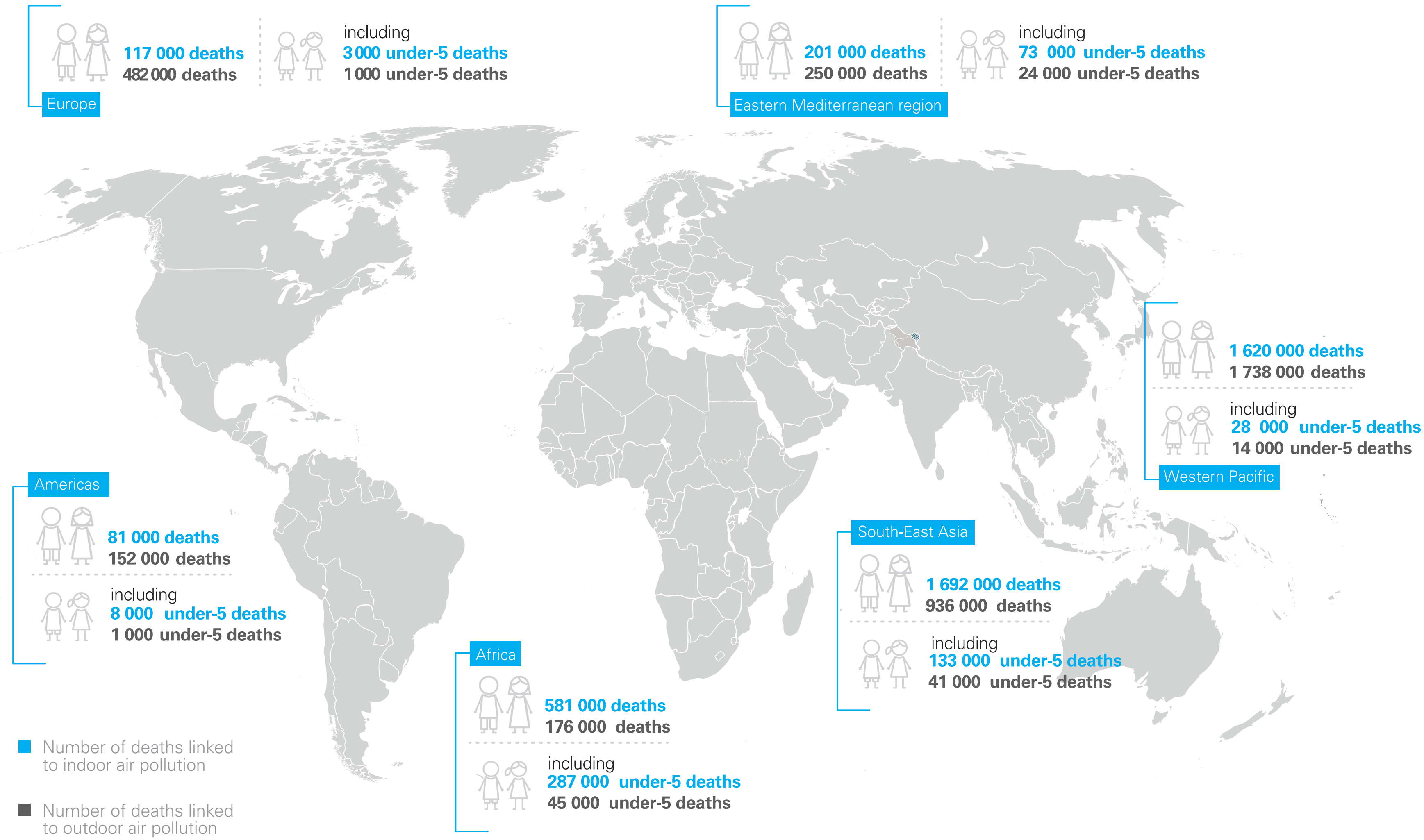
Fig. 6: Number of childhood deaths due to pneumonia, 2015



Source: WHO estimates of child cause of death, 2015

Nearly 1 in 10 under-5 deaths is linked to air pollution

Fig. 7: Regional breakdown of deaths from outdoor and indoor air pollution, 2012



This map is for illustrative purposes only.
This map does not reflect a position by UNICEF on the legal status of any country or territory or the delimitation of any frontiers. The dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. The final boundary between the Sudan and South Sudan has not yet been determined. The final status of the Abyei area has not yet been determined.

Sources: WHO (2012) Burden of disease from Ambient Air Pollution 2012;
WHO (2012) Burden of disease from Household Air Pollution 2012

As air pollution continues to grow, so too will mortality. One meta-analysis of 108 studies found that with every 10 $\mu g/m^3$ increase in short-term particulate matter exposure, there is approximately a 0.34 per cent increase in risk of death among younger populations in particular.[6] Other research shows even more severe effects among adults: a 10 $\mu g/m^3$ increase in exposure to particulate matter increased the risk of premature death by 3 per cent.[7] World Health Organization guidelines indicate that premature mortality could be reduced by up to 15 per cent where PM10 is reduced from 70 to 20 $\mu g/m^3$.[8]

Looking forward, the prospects do not look good. Research published in the scientific magazine *Nature* suggest the under-five mortality from acute lower respiratory illness as a result of air pollution could increase by about 50 per cent by 2050.[9] The same research points to a projected 6.5 million premature deaths among all age groups in 2050. These are roughly in line with recent OECD projections of the number of premature deaths due to outdoor air pollution of 6–9 million by 2060.[10]

It should be noted, however, that we do not know the actual health impact of air pollution in all places, in part due to the lack of monitoring of both air pollution and health status. Air pollution monitoring is particularly sparse at ground level in Africa. The health impacts recorded could potentially be an underestimation from what actually is happening in many places. These data gaps need to be addressed in order to better understand the scale of impact on children's health as well as how to respond to it.

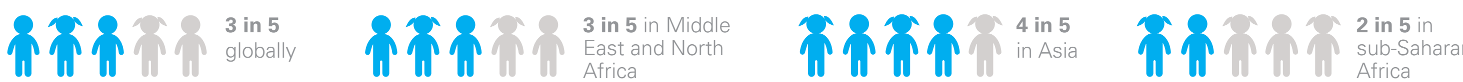
Health

Air pollution is linked not only with diseases that kill, but also with poor health and morbidity among millions more children. It causes difficulty breathing. Studies show it is linked with asthma, bronchitis, airways inflammation and even eye irritation.[12] It can cause wheezing, coughing and phlegm production.[13]

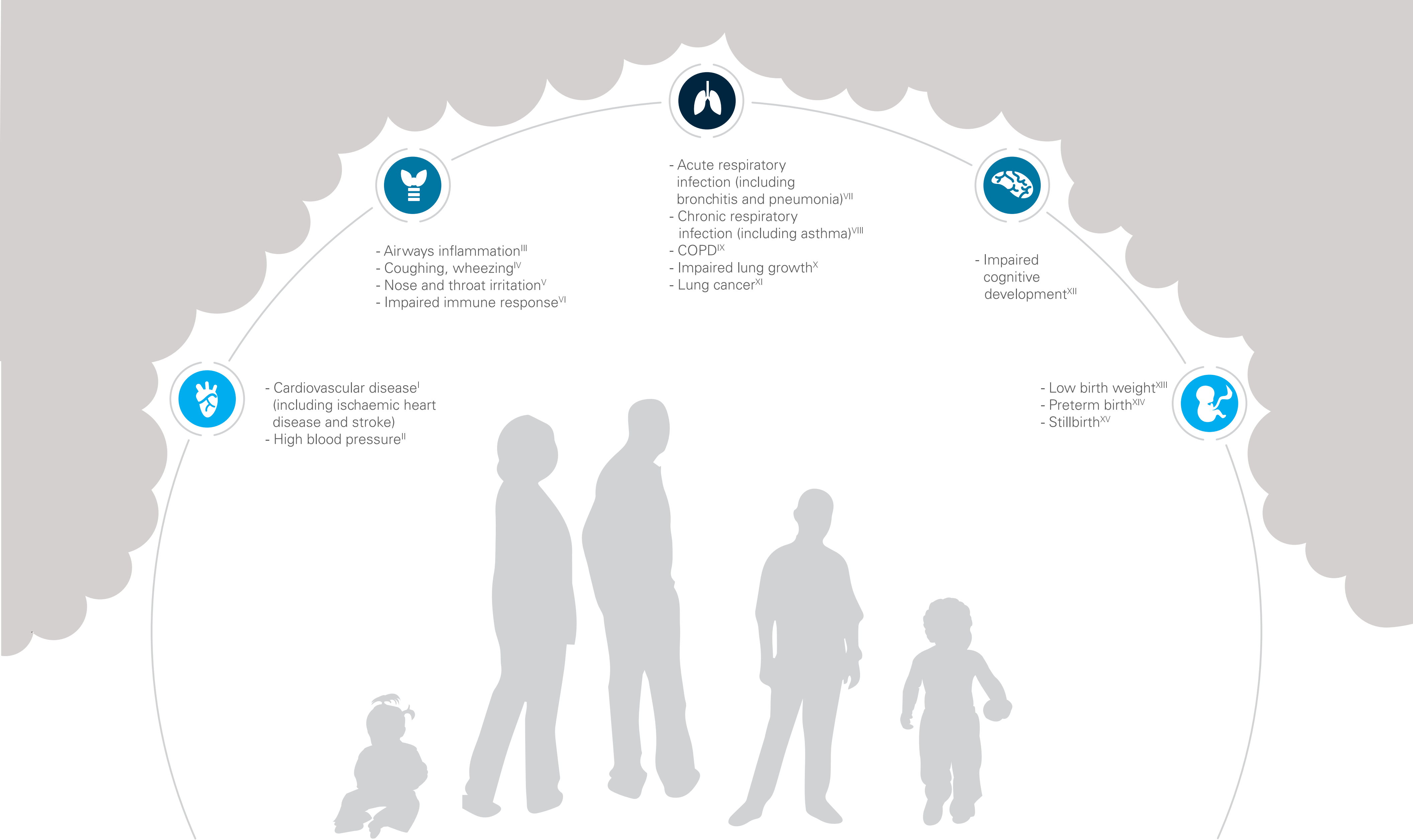
Children who breathe polluted air are at higher risk of potentially severe health problems, in particular, acute respiratory infections such as pneumonia.[14] When these diseases do not kill them,

Careseeking

Fig. 8: Not enough children with symptoms of Acute Respiratory Infection (ARI) are taken for appropriate care



Source: UNICEF Global databases 2016 – data.unicef.org



Air pollution not only kills children and adults – it affects their health as well.

Fig. 9: Health effects of air pollution.

*COPD - Chronic obstructive pulmonary disease they still severely affect their overall health and development. Exposure can also affect lung growth among children, as the cell layer on the inside of the respiratory tract is more permeable among young children.[15] A mother's chronic exposure to severe air pollution during pregnancy is linked with low birthweight at term, intrauterine growth retardation and small for gestational age embryos.[16,17,18] These complications can also have longer-term effects on a child's health and development.

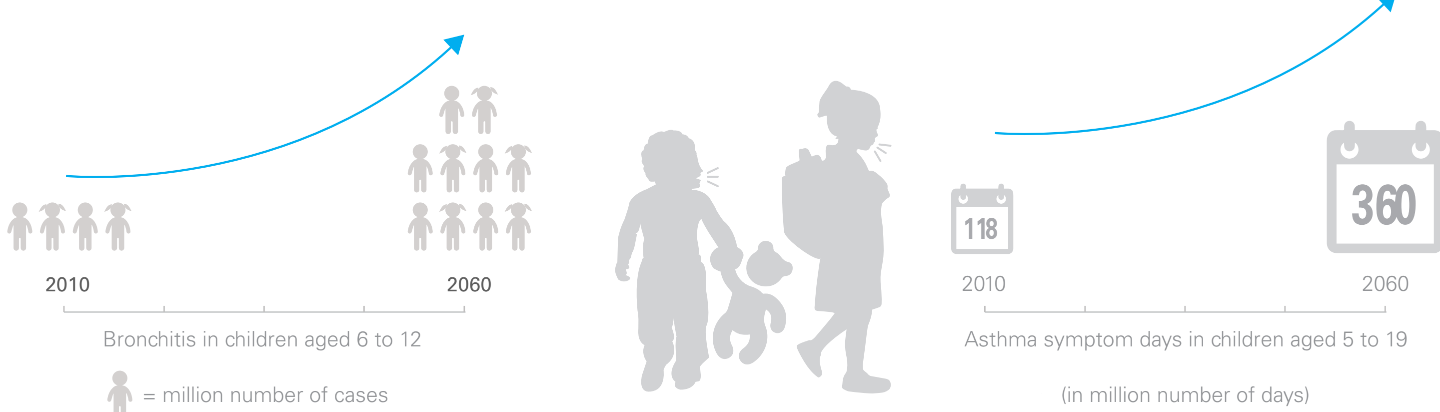
Air pollution can further exacerbate underlying health issues. Consistent evidence shows that long-term exposure is associated both with new-onset asthma, as well as with exacerbation of existing asthma.[19] Studies have shown that children are up to four times more likely to have significantly reduced lung function in adulthood if they live in highly polluted areas.[20]

"Every day billions of people are breathing polluted air and raising their risk of succumbing to a pollution-caused illness." World Bank

Asthma already affects up to 14 per cent of children globally according to recent analysis.[21] And it does not appear to be slowing down: one report found that it increases at rates of about 50 per cent every decade.[22]

Bronchitis and asthma are likely to increase significantly in coming decades due to air pollution.

Fig. 10: Projected health impacts at global level



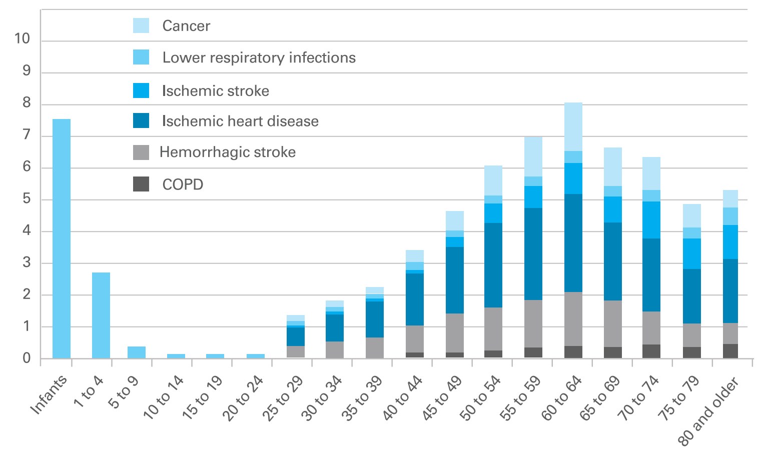
Source: *The economic consequences of outdoor air pollution*, OECD, 2016

Air pollution also contributes to at least half of all pneumonia cases.[23] Evidence suggests that air pollution can cause oxidative stress and inflammation in the smaller airways, leading to the exacerbation of asthma and chronic bronchitis, airway obstruction and decreased gas exchange. It can also undermine normal lung antimicrobial defense functions by interfering with the clearance and inactivation of bacteria in the lung tissue.[24] Health complications can then last throughout the rest of their lives.[25] Studies show that halving of indoor air pollution exposure with a chimney stove rather than open fires reduced severe pneumonia by 33 per cent.[26]

Adults can suffer a variety of health complications due to air pollution. Exposure to air pollution exacerbates existing cardiovascular disease, and is associated with a wide range of cardiovascular effects such as stroke and heart failure.[27] Furthermore, there is strong evidence that outdoor air pollution causes lung cancer.[28] Emerging evidence shows an association between air pollution and new-onset type 2 diabetes in adults.[29,30]

Many millions of children live in homes where burning of solid fuels is commonplace – considerably affecting their health. In Africa, more than 350 million children are estimated to live in households where solid fuels are used, while in Asia, over 640 million children are estimated to live in such households (estimates c.a. 2013).†

Fig. 11: Disability-Adjusted Life Years (DALYs) from ambient PM2.5 pollution by age group, 2013



Source: IHME, GBD 2013.

Cognitive development

New research is demonstrating that air pollution might also affect cognitive development. Inhaled ultrafine particles, such as PM2.5, are so small that they can enter the bloodstream, and recent medical research indicates that this can cause the degeneration of blood-brain barriers, leading to oxidative stress, neuroinflammation and damage of neural tissue.[31,32,33] As these blood-brain barriers are still developing in children, studies show that their tissue could be less resistant and more vulnerable.[34]

† These are only rough estimates for illustrative purposes. No age disaggregated data are available for population in households using solid fuels and therefore it is difficult to estimate the number of children in homes using solid fuels. These numbers were estimated by assuming that the proportion of children in a country using solid fuels is the same as the proportion for the total population. They are generated by taking the proportion of the population using solid fuels in every country and multiplying it by the number of children in the country from the United Nations Population Division. The number of children in households is likely to vary, which can bias the estimates. Solid fuels in rural areas tends to be higher and so too are the numbers of children per household, which is likely to result in an overall underestimate. Furthermore, countries where the proportion of the population using solid fuels is less than 5 per cent are not included, as a precise figure could not be obtained; and in countries where the proportion is greater than 95 per cent, 95 per cent is used. Furthermore, because women and children, especially young children, tend to spend more time near or around the kitchen than male adults, these numbers are likely to be underestimates of actual exposure levels of women and children.

While there is not yet complete scientific consensus on the impact of air pollution on cognitive development, the evidence base on this topic is growing rapidly. The American Psychological Association has stated, "Over the past decade, researchers have found that high levels of air pollution may damage children's cognitive abilities, increase adults' risk of cognitive decline and possibly even contribute to depression."[35] The Royal College of Physicians (UK) published a report in February 2016 explaining: "Because the central nervous system is still developing rapidly after birth, children remain susceptible to harmful effects of air pollution on their neurodevelopment and long-term cognitive health. Several types of air pollution have been associated with harmful effects on neurocognitive development . . . impair[ed] cognitive development and lower[ed] IQ. . . . Children exposed to high indoor NO2 levels from cooking and heating sources have been shown to have poorer cognitive function and seem to be at increased risk of ADHD." The European Commission recently released a report about a study that states that green spaces are linked to improved cognitive development in schoolchildren because of lower traffic-related emissions levels.[36]

Researchers at government agencies, think tanks and academic institutions around the world are examining possible connections between exposure to air pollution (at different stages of life, from pre-natal to elderly) and reduced cognitive function.[37,38,39,40,41] Much of the literature explores the connection between ambient air pollution and neurotoxicity on brain structure, whether air pollution contributes to neurodegenerative diseases and the response of human brain cells to urban particulate matter from traffic and diesel exhaust.[42,43,44,45,46] Some studies look at the benefits of green spaces and well-ventilated offices on the cognitive health and well-being of children and office workers due to reductions in air pollution.[47,48]

The National Bureau of Economic Research and the Clean Air Research Center at Harvard University studies have found associations between short- and long-term exposure to air pollution and cognitive impacts.[49,50] Physicians for Social Responsibility investigates how exposure to air pollution can reduce human intelligence and lead to mild cognitive impairment in the elderly.[51,52]

Other studies examine the social impacts directly on school children. Air pollution has been found to reduce improvement in cognitive development among school children,[53,54,55] lower attendance rates in school[56] and lower academic achievement rates.[57,58,59] Furthermore, as much of this report shows, air pollution can cause sicknesses, which can in turn prevent children from going to school. The effects of air pollution on learning could occur through other channels as well.

Evidence of the impact of air pollution on cognitive development is also found through its impact on the foetus. Studies have shown that because these particles enter the bloodstream, they can also cross the placental barrier and affect the development of the foetus, including both physical and cognitive development.[60,61] Several studies have shown that pregnant women's exposure to polycyclic aromatic hydrocarbons (PAHs) (a pollutant associated with fossil fuel combustion) affects the white matter of the unborn child's brain significantly – which is responsible for the communication between different parts of the brain. In consequence, studies have shown that PAHs can cause future developmental delays, lower verbal IQ, and increased signs of anxiety, depression, and problems with attention.[62,63] Even very low levels of PAHs and lead in a child's blood have been found to result in cognitive delays.[64,65,66]

The links between cigarette smoking and cognitive development has also been firmly established, including where pregnant mothers are exposed to either primary or secondary cigarette smoke.[67,68]

Lead in air pollution has long been known to have serious harmful effects on the development of the brain and nervous system

While lead in air pollution has been largely phased out with the introduction of unleaded gasoline, many of the effects are still being felt. Moreover, lead can still be emitted into the air through other processes – such as burning of waste containing lead (including vehicle batteries or leaded paint).[69]

Lead is distributed into the brain, liver, kidney and bones, where it accumulates over time.[70] It can even transfer from the bones to blood, and affect the foetus during pregnancy – causing intergenerational effects.[71] Lead has shown to reduce intelligence quotient, as well as cause behavioural issues such as reduced attention span, increased antisocial behaviour and reduced educational attainment.[72] Aside from cognitive impairment, high levels of exposure can cause coma, convulsions and even death.[73]
It has also been shown to cause anemia, hypertension, renal impairment, immunotoxicity and toxicity to the reproductive organs.[74]

Lead is especially harmful to young children. They absorb about 4–5 times more lead compared with adults from a given source.[75]

Over the past few decades, most countries have phased out leaded gasoline. The economic benefits of reducing lead have been tremendous. One recent study found that the phaseout of leaded gasoline has had an economic benefit of US$2.45 trillion per year (within a range of US$2.05–2.83 trillion).[76]

Lifetime effects

Children have their whole lives ahead of them, so anything that has irreversible impacts on their development is especially burdensome. The cell layer on the inside of the respiratory tract is particularly permeable during childhood.[77] This makes them very vulnerable to intrusions or infections from air pollution. Furthermore, the effects might not become apparent until later in life – potentially decades later.[78]

The lifetime effects from air pollution might also be felt through its impact on cognitive development (as illustrated above). Studies have also shown that air pollution can have negative effects on cognitive development and coordination – which can have lifelong implications in terms of schooling outcomes and future careers.[79,80]

Air pollution can lead to respiratory infections that can be reoccurring and/or chronic. These conditions can cause more rapid deterioration of lung capacity.[81,82] Where children are exposed to high levels of air pollution, as adults they can be more vulnerable to chronic obstructive pulmonary disease,[83] cardiovascular disease and lung cancer.[84]

The combination of respiratory, cardiovascular, cognitive, morbidity and reproductive health effects of air pollution have biological as well as social and economic effects that last a lifetime. These include health conditions, school attendance, school performance, health costs and productivity, which affect income, poverty and inequities. Air pollution, through its massive and cumulative impact on the overall health and well-being of children and parents, can perpetuate intergenerational cycles of inequity.

Effect of smoke-free legislation on childhood asthma

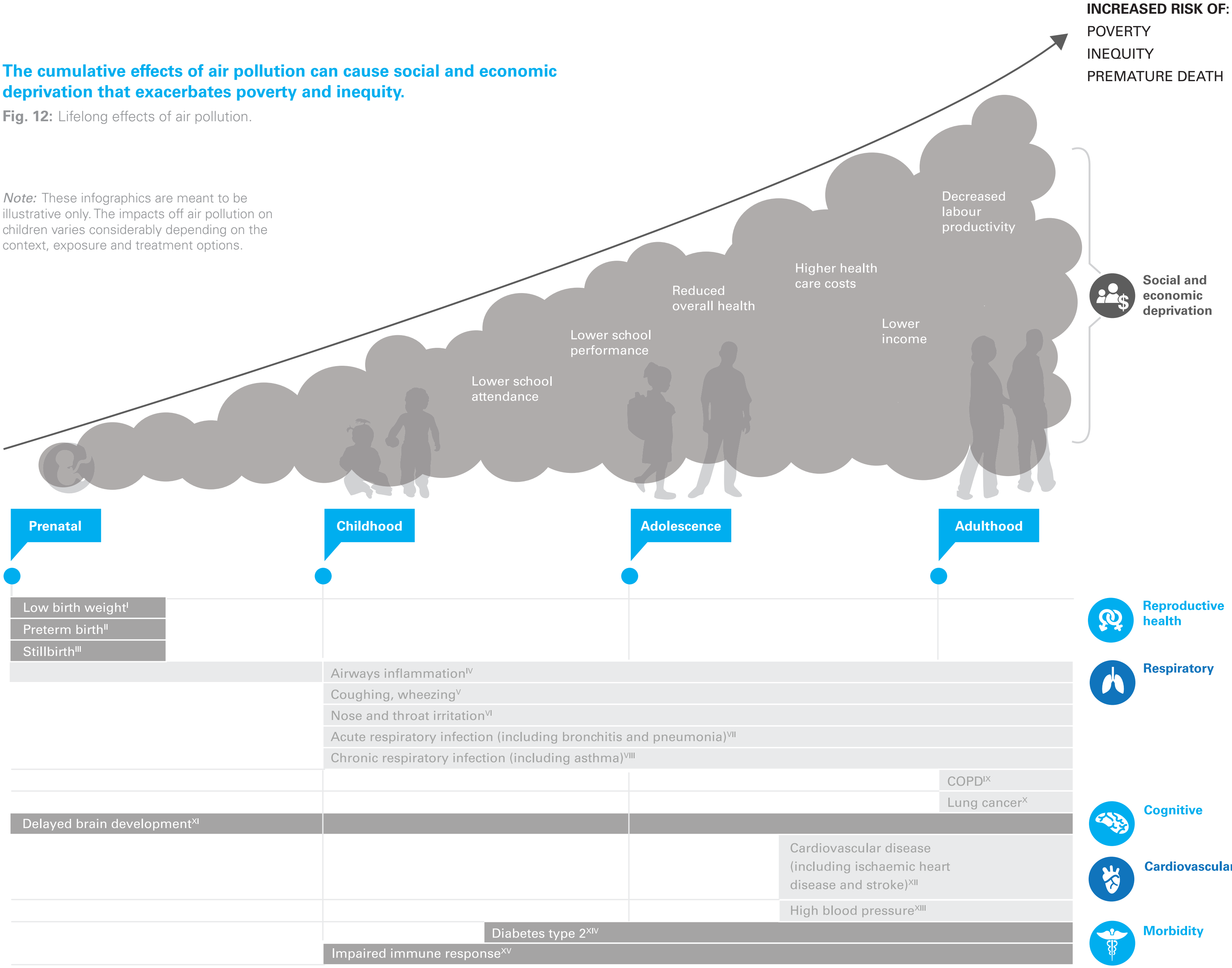
A meta-analysis of 20 studies found a significant relationship between exposure to secondhand smoke and development of childhood asthma.[85] A number of studies also found the impact of smoke-free legislation on the reduction of childhood asthma. The bans have been associated with at least a 10 per cent reduction in hospital visits for childhood asthma. The review suggested that protection from secondhand smoke in early life prevents instances of asthma and other associated diseases in later life.[86]

According to researchers, cases of childhood asthma declined because a ban on smoking in public places initiated a self-imposed ban on smoking at home, reducing children's exposure to tobacco smoke both inside and outside the home.[87]

The cumulative effects of air pollution can cause social and economic deprivation that exacerbates poverty and inequity.

Fig. 12: Lifelong effects of air pollution.

Note: These infographics are meant to be illustrative only. The impacts off air pollution on children varies considerably depending on the context, exposure and treatment options.



Waste management and open burning of waste

Open burning of waste is highly hazardous for public health.

The open burning of waste is a large source of toxic air pollutants such as particulates, carbon monoxide, black carbon, dioxins, furans and mercury. These are highly toxic and/or carcinogenic pollutants.[88] More than 40 per cent of the world's municipal garbage is openly burned[89] in over 160 countries.[90,91] In these countries, the most deprived communities without reliable waste collection services are affected the most. Mostly an unmonitored practice, the open burning of waste is often not reported to environmental agencies, and therefore tends to be forgotten in policy responses – an omission that has a particularly heavy cost for women and children.

Poverty and exploitation aggravate the issue.

Women and children are typically responsible for dealing with household waste, and often carry out hazardous disposal practices such as the open burning of waste in the absence of regular collection services.[92] Research shows that children in Ethiopian households where waste is burned are six times more likely to suffer from acute respiratory infections than children in areas where waste is collected regularly.[93]

Recycling of valuable elements has become a source of income mostly in the informal sector of developing or emerging industrialized countries, often by burning other elements to retrieve valuable materials. For example, burning of e-waste, such as televisions, computers and mobile phones, is done to extract metals like copper or gold. This process also often produces toxic fumes.[94] E-waste recycling workers are often women or children. Their continuous exposure to concentrated levels of air pollutants like lead, aluminium and zinc has devastating consequences, including birth defects and infant mortality.[95] Other studies found that children at e-waste recycling sites were reported to suffer from breathing ailments, skin infections and stomach diseases as well as significantly higher levels of leukaemia.[96]

Urgent tasks in waste management piling up.

Estimates from 2012 project that worldwide municipal waste is going to almost double by 2025, making the issue all the more pressing to solve.[97] The United Nations Environment Programme (UNEP) reports that, globally, 3 billion people lack access to controlled waste disposal facilities.[98] Several countries, municipalities and communities, however, have developed promising practices pairing environmentally sound management of waste with action on waste prevention and improved social justice for those working in the sector.

Examples of sources of air pollution

Fig. 13: This image represents illustrative examples of sources of air pollution and some of the major pollutants. It is not meant to include every possible source - there are many more.

Human-made pollutants are caused by fossil fuel combustion, industrial manufacturing, waste-burning, dust from traffic, smoke, and exhaust from automobiles, ships, and airplanes. Fires and brush clearing are also a major source of pollution in the form of smoke and black carbon.

Burning of solid fuels for household cooking, heating and lighting is a major cause of household, or indoor, air pollution.

Poor children are among the most at-risk from air pollution.

Chapter 3: Unique vulnerabilities of children

Physiological vulnerability

Children are more physiologically vulnerable to air pollution than adults. Children's lungs are still developing, and the inner lining is especially permeable during the early years of life. The number of alveoli (air sacs) in the human lung increases from about 24 million at birth to about 257 million by the age of four.[1] From these air sacs, life-sustaining oxygen is transferred to the blood. Children's lungs and air passages are also smaller. If they become inflamed, it can result in blocked airways. In adults, on the other hand, air can be distributed deeply and throughout the lung, circumventing obstructed areas.[2]

Children's immune systems are also still developing, and are therefore more vulnerable to respiratory infections resulting from exposure to harmful pollutants. Pneumonia, the single largest infectious cause of death in children under 5 worldwide, is often linked to exposure to air pollution.[3] Similarly asthma, one of the most common chronic health conditions in children, is often caused by air pollution.[4] Additionally, lead that is inhaled is more easily deposited in the growing bones of children.[5] Sulfuric acid that is inhaled has been shown to interfere with the mucociliary clearance system of the lungs.[6] Ozone has been shown to

Children are physiologically highly vulnerable to air pollution.

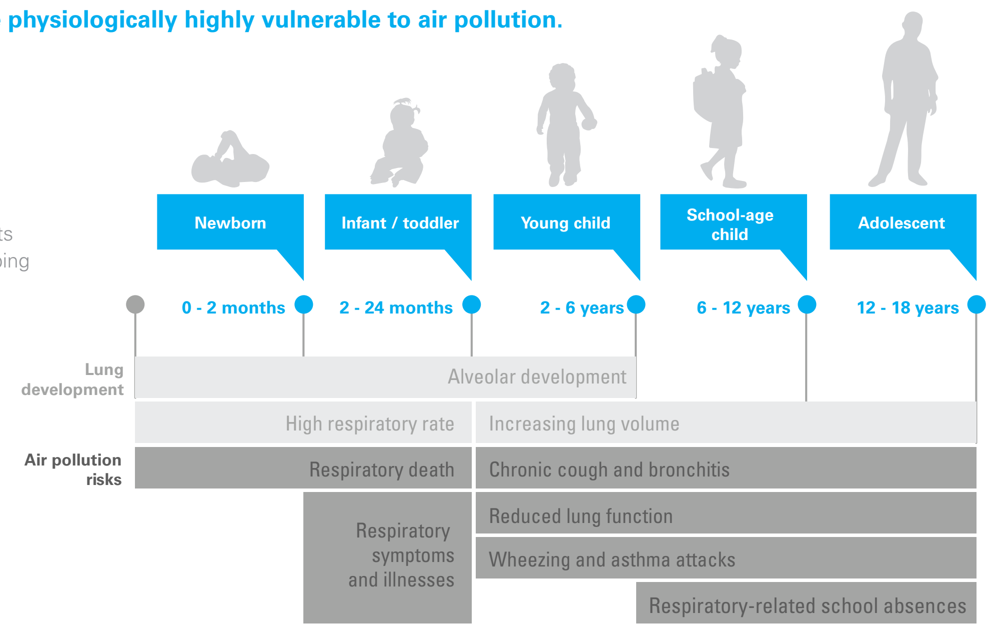


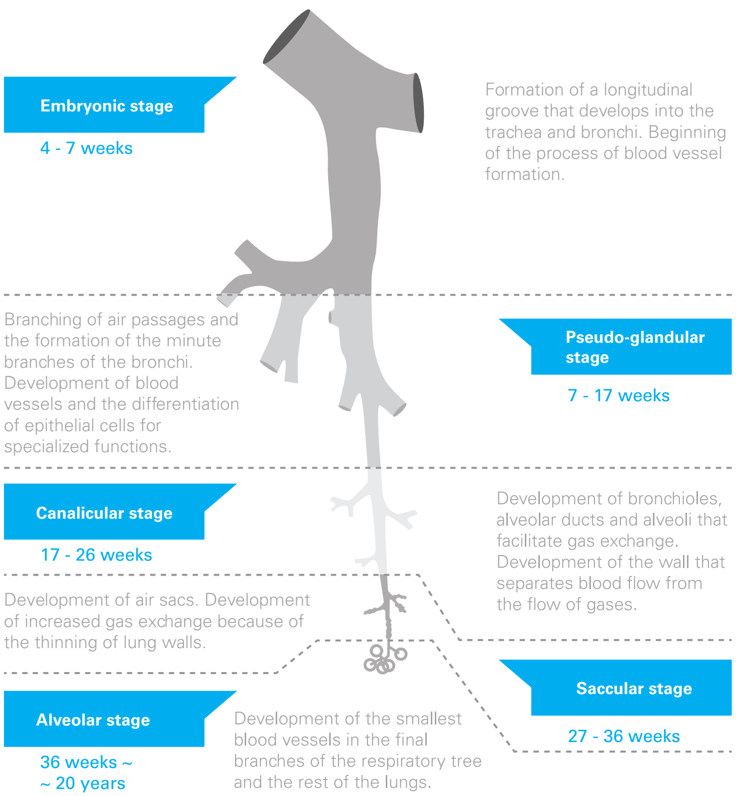
Fig. 14: Air pollution effects on the developing respiratory system.

"The developing heart, lung, brain, hormone system and immunity can all be harmed by air pollution" – Royal College of Physicians, UK, 2016[11]

Source: http://www.environment.ucla.edu/reportcard/article1700.html prevent a child's immune system from fighting infections.[7] Even short-term exposure to ozone can affect the movement of gases and liquids between lungs and bloodstream, facilitating allergic sensitization.[8]

A child's lungs are in essential stages of development the first few years of their life.

Fig. 15: Principal stages of lung development in humans.



Source: Adapted from: Kajekar R. Environmental factors and development outcomes in the lung. Pharmacol Ther 2007; 114: 129-45.

Indoor air pollution can be especially harmful due to the incredibly high concentration of pollutants. Widely cited studies report a three-fold increase in risk of acute respiratory infections in children with exposure to smoke from biomass fuel, and an 80 per cent increase in risk of developing pneumonia.[9,10]

> **"The developing heart, lung, brain, hormone system and immunity can all be harmed by pollution." – Royal College of Physicians, UK, 2016[11]**

Exposure levels

Children are also more physically exposed to air pollution than adults. Children breathe faster than adults – and more per unit of body weight. They also, therefore, breathe a higher amount of contaminants – per unit of body weight. Higher rates of mouth-breathing compared to nose-breathing among children also increase the amount of pollution inhaled.[12] Mouth breathing bypasses some of the preliminary filtration that occurs in nasal passages.

Children spend more hours per day outdoors than adults, and studies have also shown that they tend to be more active outdoors than adults as well.[13,14] Furthermore, young children tend to play closer to the ground, where particulate matter (PM), such as dust and other pollutants, is found in higher concentrations.[15]

Children under age 5 spend more time in cooking areas because of their reliance on their mothers.[16] Children, especially girls, continue to be highly exposed to indoor air pollution as they are often with their mothers and participate in household cooking and heating-related activities.

Children with pre-existing health conditions

Children with underlying health conditions can be especially vulnerable to air pollution. Air pollution not only causes but can often worsens underlying conditions such as asthma, diabetes, bronchitis and COPD. Children with chronic heart and lung disease, and immunocompromised and malnourished children are at particular risk.[17]

Asthma is most common in children under 10 years old.[18] Studies have shown that when air pollution levels are high, children with asthma visit the emergency room more frequently and use more medicine than at other times.[19] In one study, children with asthma were 18 per cent more at risk of an asthma episode during a day with increased particulate matter (especially from diesel vehicles).[20,21]

People with pre-existing respiratory diseases such as pneumonia, chronic bronchitis and COPD are at higher risk of negative effects from air pollution. Ozone can cause coughing, painful breathing, lung and throat irritation and wheezing, all of which most severely affect people with pre-existing respiratory diseases.[22] Several European studies have concluded that daily mortality increases by 0.3 per cent with every 10 µg/m3 increase in ozone exposure, and it increases by 0.4 per cent for people who have heart disease.[23]

People with cardiovascular diseases, including heart disease and high blood pressure, are more susceptible to air pollution. This is especially the case among older populations. Long-term exposure is linked with stroke and ischaemic heart disease.[24] One study showed a 0.6 per cent increase in mortality from cardiovascular disease per 20 µg/m3 increase in PM10. Another study indicated a 1.5 per cent increase in cardiovascular mortality and hospitalization rates for heart failure and irregular heart rhythm per 20 µg/m3 increase in PM10.[25] Pollution from wildfires has also been shown to worsen chronic heart diseases.[26]

People with diabetes are at increased risk from air pollution, especially particulate matter. PM2.5 interferes with proper cell and blood function.[27] One study demonstrated that in communities with high proportions of people with diabetes, hospital admissions doubled during periods of high levels of air pollution.[28]

Monitoring air pollution in India

To support action to limit citizen's exposure to air pollution, including that of children, the Government of India has expanded air quality monitoring and research. It now provides location-specific near real-time air quality data and forecasts for its largest cities. UNICEF is supporting programme partners in Jaipur in measuring the impact of pollution on the breathing capacity of children and advises citizens on the risks of air pollution and how to limit exposure and its adverse effects.[29] A mobile van and app help reach citizens with the new service.[30]

Gender-based vulnerabilities

A growing body of literature highlights gender disparities on vulnerability to indoor and outdoor air pollution. Physiological factors, including a woman's reproductive cycle, as well as socially constructed norms related to behaviour and occupation factor into potential disparities. Maternal health can be at considerable risk due to the effects of air pollution. Risks include foetal loss and preterm delivery (for more on prenatal effects, see next section).

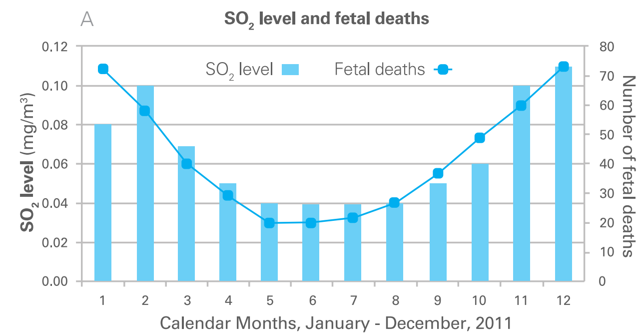
Where biomass is used in cooking and heating homes, and where women are more involved in cooking and heating in those homes, they are acutely vulnerable to household smoke that it generates. This is especially the case in homes where ventilation is poor, and where cooking takes place throughout the day. In most cases, women are also more affected in terms of time lost due to fuel collection.[31]

One study on Bangladesh found that children under age 5, regardless of gender, spend an hour a day in cooking areas because of their reliance on their mothers. From age 5 to 60, women's hours in cooking areas steadily rise from 1 hour a day to 3.8 hours a day, while men's hours in cooking areas decline from 1 hour a day to 0.2 hours a day. After age 60, women's hours in cooking areas rapidly fall, averaging at 1.5 hours a day. However, women's time in cooking areas beyond the age of 60 still remains higher than men's (averaging at 0.2 hours per day).[32]

Prenatal risks

Air pollution can affect the foetus considerably. Studies have shown stark associations between high levels of PM and foetal loss, preterm delivery and lower birthweight and fertility.[33,34,35,36] In Mongolia, for example, PM is higher during the winter when families burn coal to keep warm. This coincides with levels of foetal deaths up to three times greater during those months.[37]

Fig. 16: Calendar monthly averages of ambient air pollutant levels correlated with hours of darkness in Ulaanbaatar, Mongolia. (A) SO_2. (B) CO. (C) NO_2. (D) PM10. (E) PM2.5. Monthly average air pollutant levels are shown as light blue bars; seasonal hours of darkness during the annual solar cycle of 2011 are shown as blue dots and a connecting line.



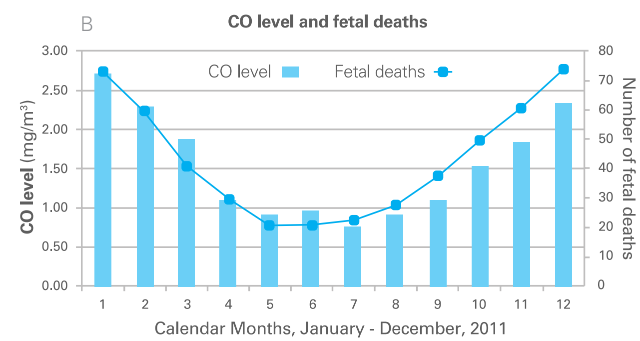
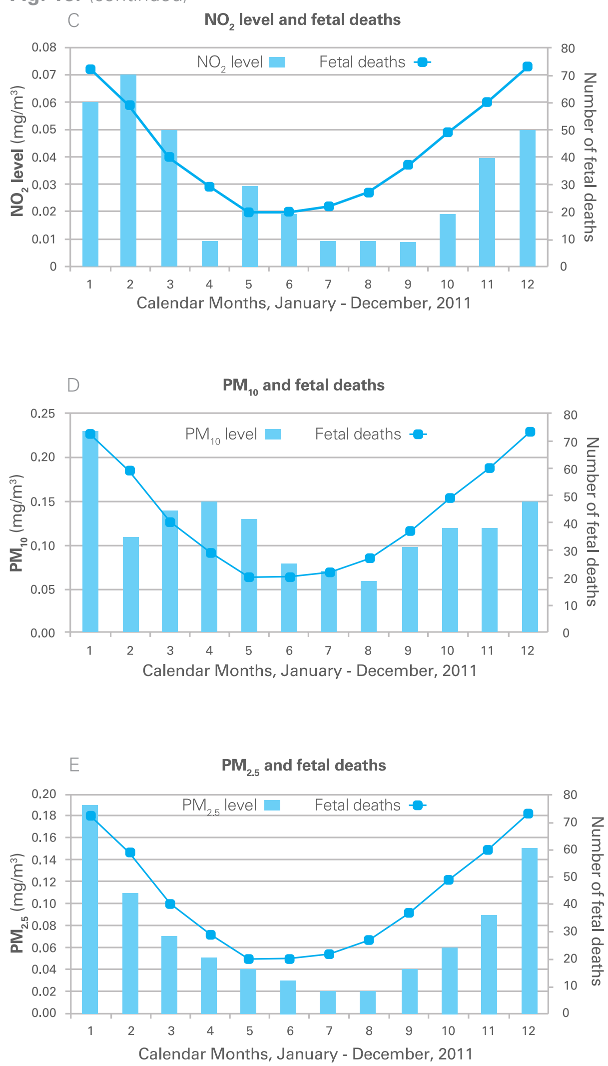


Fig. 16: (continued)



Source: Enkhmaa et al. BMC Pregnancy and Childbirth 2014, 14:146

Prenatal development is a critical time for the formation and maturation of important body systems. There is no other stage in life where such rapid changes occur. Organ damage that happens during these times can be irreversible. Some of the harmful effects from maternal exposure to air pollution are due to a reduced exchange of oxygen, resulting in foetal growth impairment. Moreover, air pollution and other toxic chemicals can interfere with critical stages of organ development, affecting further development in other stages. The brain and nervous system are particularly sensitive during this time period.[38]

The foetus's health is intrinsically connected to the mother's health. Although the mother's placenta filters out many harmful substances, very fine particles such as PM2.5 and heavy metals, such as lead, can still reach the foetus.[39]

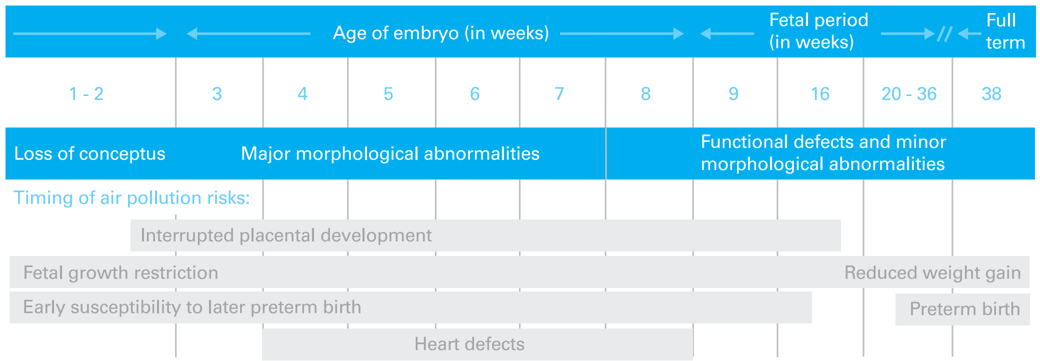
Furthermore, many of the effects might not even be visible in early life, and might only become apparent during the ageing process later in life.[40] Organ development continues for several years.

Studies have found that high levels of exposure to air pollution among pregnant mothers increases the child's likelihood of developing asthma before the age of 6,[41] as well as higher rates of childhood obesity.[42] Studies have also found that exposure can lead to height deficits among children.[43]

Research suggests that prenatal exposure to high levels of air pollution affects childhood mental health. This can increase the risk of such conditions as Attention Deficit Hyperactivity Disorder

Air pollution poses significant risks to pregnant mothers and prenatal development.

Fig. 17: Critical periods of risk from air pollution during fetal development.



Source: Ritz B, Willhelm M. Air pollution impacts on infants and children. UCLA Institute of the Environment: Southern California Environmental Report Card – Fall 2008, Los Angeles, CA: 2008.

(ADHD), symptoms of anxiety, depression and inattention, and behavioural disorders. Studies show these conditions inhibit the development of a child's self- regulating behaviours and social competency.[44]

The poorest children

Air pollution affects the poorest children most. Across both developed and developing countries, studies show that poorer families live in areas where pollution levels are higher. Air pollution combines with other aspects of the social, physical and geographical environment to create a disproportional disease burden on poorer communities.[45,46]

In the United States, studies show that air pollution is higher in non-white and low-income neighbourhoods, and lower in predominantly white neighbourhoods.[47,48] Disparities exist in areas such as the South Bronx in New York City, where studies have shown that asthma rates are four times the national average.[49] In Canada, studies show that more socially disadvantaged communities tend to experience highest levels of traffic-related air pollution.[50] In Ho Chi Minh City, Viet Nam, exposure to particulate matter and NO2 were found to be higher among poor neighbourhoods – and use of air conditioning and better quality ventilation systems in homes were higher among those not living in poverty.[51] Similarly, studies show that poorer cities are at risk for higher levels of outdoor air pollution due to traffic and industry.[52] In China, factories emitting large amounts of pollution are moving to suburbs where costs are lower and where migrant workers congregate.[53,54,55,56,57]

Economic development is one of the factors that determines the use of solid fuels for household energy needs.[58] Poorer families are more likely to use biomass and wood in regular household cooking and for heating, increasing the risk of pneumonia and respiratory tract infections.[59]

Lower-income households tend to have poor ventilation systems, and these ventilation systems can worsen indoor air pollution.[60] One study found that indoor smoke from cooking can be 20 times higher than international limits.[61] A study in Andhra Pradesh, India, found that solid fuel use created a mean 24-hour average concentration of particulate matter that ranged from 73 to 732 μg/m^3.[62] Guidelines from the WHO indicate that it should not exceed 10 μg/m^3.

Even at national levels, there is a relationship between wealth and the use of solid fuels for household energy needs. For example, Thailand – with a per capita income of US$5,816 – uses biomass to meet 23 per cent of household energy needs, while the United Republic of Tanzania – with a per capita income of US$864 – uses biomass to meet 95 per cent of household energy needs.[63]

Household construction and ventilation can make a big difference to indoor pollution levels

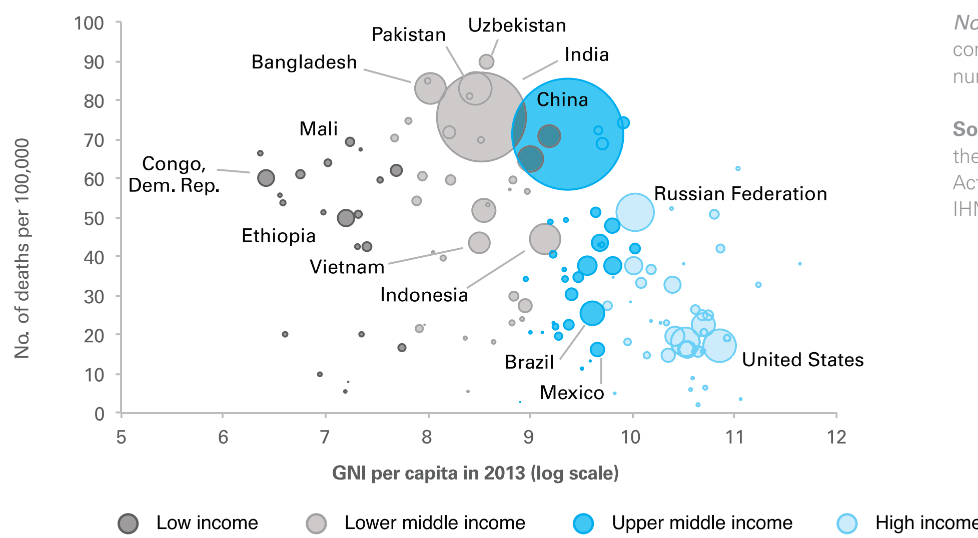
A study of 600 rural, peri-urban and urban households in Bangladesh found that ventilation influences the variation of PM in a household. The level of PM concentration in a household differed according to whether the kitchen had mud walls and its location. For households with inside cooking and non–mud wall construction, the average PM level was 223 μg/m^3 for all fuels and 250 μg/m^3 for firewood. For households with inside cooking and mud wall construction, the average PM level was 515 μg/m^3 for all fuels and 498 μg/m^3 for firewood. Mud wall construction increased the concentration of indoor PM concentration because the walls are frequently recoated with mud, which acts as a seal against ventilation. The study also found that indoor PM10 concentration increased by 253 μg/m^3 when the kitchen was located indoors and reduced by 158 μg/m^3 when the kitchen was located outdoors. When the kitchen was located outdoors, mud walls acted as a seal against the entry of PM gases inside.[64]

At a global scale, air pollution is concentrated in low- and middle-income countries. In fact, almost 90 per cent of deaths from outdoor air pollution occur in low- and middle-income countries,[65] and more than 99 per cent of deaths from indoor air pollution occur in low- and middle-income countries.[66]

According to the Global Burden of Disease, children under the age of 5 in low- and middle-income countries are 60 times more likely to die from exposure to air pollution compared with children in high-income countries.[67,68] For every 100,000 people, 31.5 die from air pollution in low- and middle-income countries, compared with 0.5 in high-income countries.[69]

Indoor air pollution is highest in Africa, where the proportion of the population using solid fuels can, in many countries, exceed 95 per cent.[70] Outdoor air pollution is highest in both Asia and Africa.[71] As industrial production continues to move to lower-cost production, low- and middle-income countries are likely to witness increasing levels of outdoor air pollution.[72] These countries will then share not only the highest rates of mortality due to indoor air pollution, as they currently do, but also an increasing share of the mortality burden of outdoor air pollution.[73]

Fig. 18: Outdoor PM2.5 death rate versus income per capita, 2013

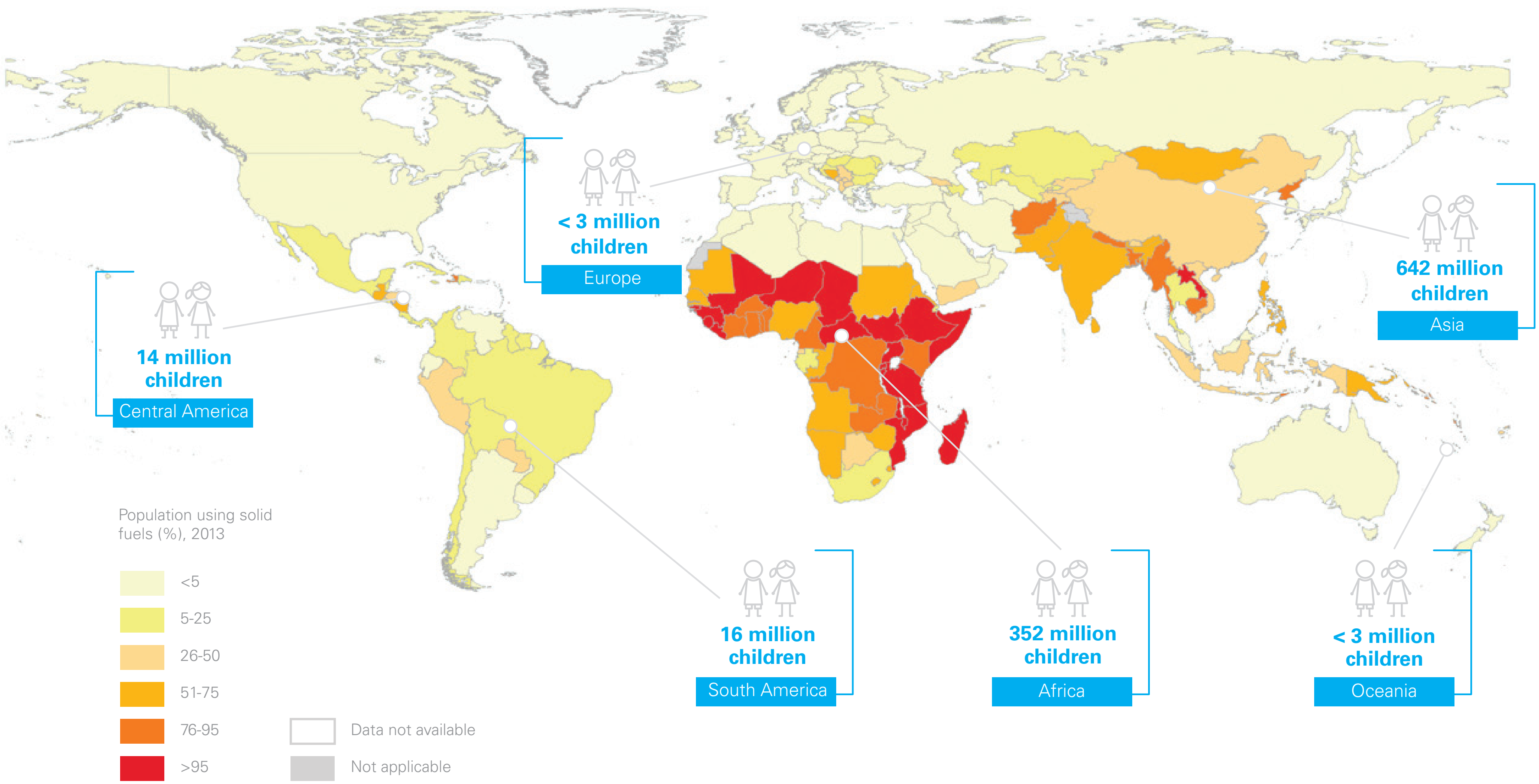


Note: Size of bubble corresponds to total number of deaths

Source: "Strengthening the Economic Case for Action" World Bank and IHME, 2016.

Over 1 billion children live in homes where solid fuels are used in cooking and heating.

Fig. 19: Population using solid fuels (%), 2013



These are only rough estimates for illustrative purposes. No age disaggregated data are available for population in households using solid fuels and therefore it is difficult to estimate the number of children in homes using solid fuels. These numbers were estimated by assuming that the proportion of children in a country using solid fuels is the same as the proportion for the total population. They are generated by taking the proportion of the population using solid fuels in every country and multiplying it by the number of children in the country from the United Nations Population Division. The number of children in households is likely to vary, which can bias the estimates. Solid fuels in rural areas tends to be higher and so too are the numbers of children per household, which is likely to result in an overall underestimate. Furthermore, countries where the proportion of the population using solid fuels is less than 5 per cent are not included, as a precise figure could not be obtained; and in countries where the proportion is greater than 95 per cent, 95 per cent is used. Furthermore, because women and children, especially young children, tend to spend more time near or around the kitchen than male adults, these numbers are likely to be underestimates of actual exposure levels of women and children.

Data Source: World Health Organization Global Health Observatory Data Repository

Map Production: Health Statistics and Information Systems (HSI),Global Health Observatory 2014

Intergenerational equity

Intergenerational equity is the principle of fairness between generations. It underlines the ethical standard that we cannot discount the cost of harm when it falls on future generations – those not yet born. The principle tells us that we have a responsibility to future generations to leave them with a planet that is liveable, a place where the natural environment is not more degraded than when we received it. The principle aims to prevent the effects of decisions that are unjust and to prevent harm and degradation from being passed on to future generations.

As this report shows, reducing global air quality has a detrimental impact on children – including before birth. It also affects poor children the most. Furthermore, unless air quality is improved, the direct and indirect effects of air pollution will be passed on to generations not yet born. The lifetime effects of air pollution can lower future incomes and reduce the capacity of future adults to care for their children. All these effects can create and perpetuate intergenerational inequity.

Moreover, air pollution, which includes several short-lived greenhouse gases, is also linked to the principle of intergenerational equity through the Conference of Parties (COP) Paris Agreement. The Agreement acknowledges in the Preamble *"that climate change is a common concern of humankind,"* and signatories agree to *"respect, promote and consider their respective obligations on . . . intergenerational equity."*[74]

Forest fires and air pollution

In 2015, the El Niño weather phenomenon led to drought in many places and rendered forests and peatlands to tinderboxes, and fires out of control.[75] Peat fires emit more carbon and methane than regular fires of a similar extent, thereby doing more damage to the global climate, and creating more toxic smog.[76,77] The smog from the fires raging in Indonesia led to closed schools, disabled airports and the country's declaring a state of emergency in six provinces. In total, 40 million Indonesians were exposed to hazardous levels of air pollution and approximately 5 million students experienced school closures due to the 2015 fires.[78,79,80] The smog not only spread across Indonesia, but also to neighbouring Malaysia, Singapore, Thailand and the Philippines. Overall, the haze led to more than 500,000 cases of respiratory illnesses in Southeast Asia.[81,82] It is projected that climate change may lead to even more powerful El Niño weather phenomena, which will make droughts even more intense and forest fires even more likely.[83,84]

Indoor air pollution with country examples

Indoor air pollution is caused in large part by cooking with inefficient cooking methods, such as cooking with solid fuels over open fires, and by burning biomass in ovens in unventilated homes. In 2012, 534,000 deaths of children under 5 were attributed to indoor air pollution, with the majority of these deaths caused by acute lower respiratory infections (ALRI).[85] There is also evidence linking indoor air pollution to low birthweight, tuberculosis, ischemic heart disease, cataracts, asthma and nasopharyngeal and laryngeal cancers.[86]

Women and girls are exposed to high levels of PM and carbon monoxide exposure as a consequence of disproportionately long periods of time spent at home near the family's stove.[87] Young children and babies are often kept close to the stove as their caregivers are preparing meals. Investments in clean cooking and awareness of the issue can thus substantially benefit child survival and development and public health outcomes. Substituting wood and other solid fuels that are traditionally collected by women and girls would bring additional co-benefits for their safety, education and equality as well as for the environment.

Bangladesh

Bangladesh has one of the largest burdens of child mortality associated with indoor air pollution. More than 8,500 children per year die from diseases caused by household air pollution (HAP) and 89 per cent of households use solid fuels – mostly wood, agricultural waste and cow dung – for cooking and space heating.[88]

The reasons for relatively limited uptake of improved cookstoves to date include a lack of awareness of health risks associated with HAP, higher costs compared to traditional cookstoves and competing development priorities.[89] Seeking to overcome these barriers, the Bangladesh Country Action Plan for Clean Cookstoves is a governmental strategy to achieve the goal of 100 per cent clean cooking solutions by 2030. The target is to disseminate improved cookstoves to more than 30 million households by 2030.[90] If this goal is reached, it will significantly reduce the direct and indirect health effects of children's exposure to air pollutants. It will also have a positive impact on women's health and time spent in the kitchen as Bangladeshi women, on average, spend four to five hours a day on cooking, and six to eight hours a day in the kitchen.[91]

Zimbabwe

Indoor air pollution from solid fuels is the leading risk factor contributing to the disease burden in Zimbabwe. In 2010, more than 3,000 child deaths from 0–4 years were caused by acute lower respiratory infections (ALRI). Research also shows that children in Zimbabwean households using wood, dung or straw for cooking were more than twice as likely to have suffered from ALRI than children from households using Liquefied Petroleum Gas (LPG), natural gas or electricity.[92]

To address this issue, UNICEF Zimbabwe partnered with the government to implement an improved cookstove programme in 2015 and 2016 in Hurungwe and Nuanetsi. Through these projects, women learned to construct the stoves themselves, as well as train other women to do the same. The resources to make the stoves are free and locally available. The pilot programmes reached 3,480 households (comprising approximately 17,400 indirect beneficiaries). The stoves have reduced specific fuel consumption by as much as 39 per cent.[93,94]

The projects not only helped reduce indoor air pollution and improve children's health, but also contributed to local forest conservation, reduced time spent collecting firewood and making positive impacts on local economies. Furthermore, more children were able to go to school on time because they spent less time preparing food and heating bath water.[95]

Awareness-raising and training are central components of UNICEF's cookstove project in Zimbabwe. Families are informed about the health risks of indoor air pollution, and how cooking in environments with fewer emissions and more ventilation (for example, outdoors) can significantly benefit health outcomes. Men and women learn about proper kitchen ventilation, how to reduce pollution during fire ignition and how using appropriately dried firewood can significantly reduce pollution levels.[96]

Mongolia

In Ulaanbaatar, Mongolia, air pollution is at its worst during the harsh and prolonged winters, with temperatures reaching as low as –40°C. Coal, wood and other solid fuels are then used by 70 per cent of the country's population for heating purposes.[97,98] These fuels contribute to both outdoor and indoor pollution levels and are further aggravated by a weather phenomenon in the winter that traps air pollutants near the ground.[99] This concentrates pollutants and makes Ulaanbaatar, a city of only 1.2 million, one of the cities with the worst air quality in the world, at times worse than Beijing and Delhi.[100,101] Pollution levels are worst in informal settlements whose inhabitants, typically living in circular tents (*gers*), rely on raw coal for heating and cooking.[102]

Evidence shows alarmingly strong statistical correlations between seasonal levels of air pollution and pregnancy loss in Ulaanbaatar. In the winter, when air pollution levels are higher due to coal burning for domestic heating, the number of miscarriages increases more than threefold – from 23 foetal deaths per 1,000 live births in May, to 73 per 1,000 live births in December.[103]

UNICEF Mongolia prepared a study and advocated for urgent action on air pollution in the country. A consultation with international and national experts on the issue helped to formulate initial responses and policy recommendations. These include measures to stop and replace coal combustion in residential areas as well as specific child health–related actions.[104] UNICEF Mongolia is engaging innovators and adolescents on monitoring pollution levels, and working with partners on the issue.[105]

300 million children live in areas where the outdoor air is toxic – exceeding six times international limits.

Chapter 4: Number of children living in areas with high levels of outdoor air pollution

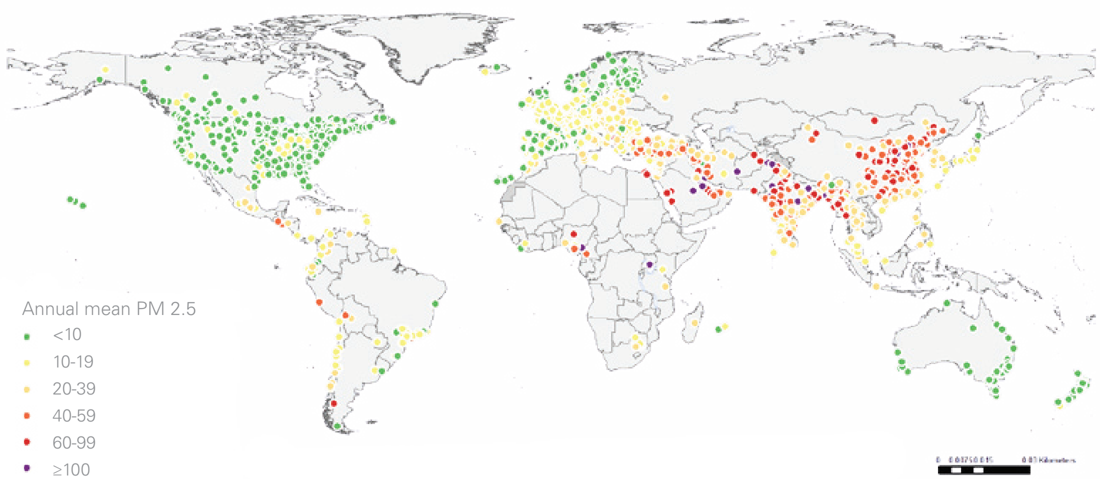
As air pollution has significant negative health implications for children, this report attempts to gauge the number of children who are exposed to highly polluted air.

Ground-level air sensors, which provide localized indication of PM2.5, are the most accurate measure of air quality.[1,2] The map below includes the results of ground-level monitoring of PM2.5 in 3,000 cities around the world. Air pollution levels tend to be highest in East Asia, South Asia and the Middle East and North African regions. They tend to be lower in North America, Europe and parts of the Western Pacific region.

80 per cent of people living in the urban areas presented in *Figure 20* are exposed to air quality levels that exceed WHO limits. Approximately 98 per cent of cities in low and middle income countries on the map do not meet WHO guideline limits for PM2.5 (<10 $\mu g/m^3$). In high-income countries, however, 56 per cent of cities do not meet WHO guideline limits.[3] According to the most recent update (2016), between 2008 and 2013, there has been an 8 per cent increase in global levels of urban air pollution. Improvements, however, were seen in some regions.

There are, however, fewer ground-level sensors in Africa compared to North America, Europe and Asia. As a result, global estimates of numbers of children exposed to poor air quality cannot be produced using ground-level monitoring systems.

Fig. 20: Concentration of particulate matter with an aerodynamic diameter of 2.5 μ or less (PM2.5) in nearly 3000 urban areas*, 2008-2015



The boundaries and names shown and the designations used on this map do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities or concerning the delimitation of its frontiers or boundaries. Dotted and dashed lines on maps represent approximate border lines for which there may not yet be full agreement.

Data Source: World Health Organization

Map Production: Information and Evidence Research (IER) World Health Organization

*The mean annual concentration of fine suspended particles of less than 2.5 microns in diameters is a common measure of air pollution. The mean is an urban population – weighted average from cities with available air pollution measures.

Recent ground-level monitoring estimates in urban areas reveal striking findings

Recent urban estimates point to striking findings, including the inclusion of several Nigerian cities among the top ten most polluted by PM10 standards. Moreover, many of the most polluted places in the world are no longer megacities and capitals – but rather medium-sized cities, suburban and manufacturing centres.

Fig. 21: Cities by PM2.5 pollution

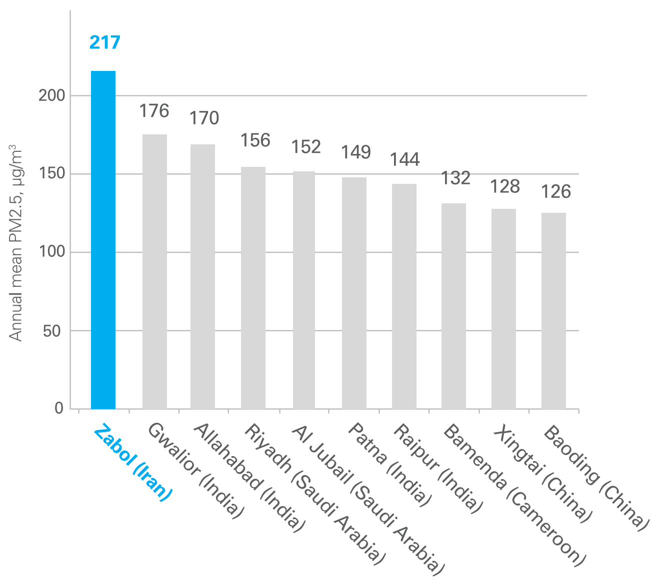
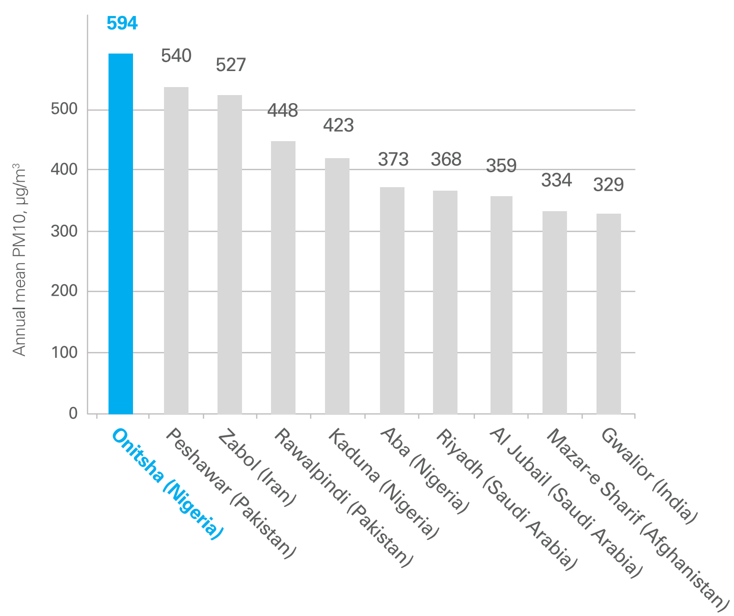


Fig. 22: Cities by PM10 pollution



Source: WHO Global Urban Ambient Air Pollution Database (2016)

Satellite imagery offers an alternative for global estimates.

Methodology

Population Data

The Gridded Population of the World version 4 (GPWv4) data set used as the basis for this analysis was derived from best available administrative boundary population counts for 2010 by the Center for International Earth Science Information Network (CIESIN) at Columbia University. GPWv4 is constructed from national or subnational input areal units of varying resolutions, which will show differences in the visual display of information depending on the resolution of the input boundaries, and represents the best available global population data. The GPWv4 data was then augmented by incorporating best available, higher-resolution data from WorldPop for South America, Africa and Asia. WorldPop uses census, survey, satellite, social media, cell phone and other spatial data sets, integrated into peer-reviewed statistical methods to produce open, fully documented and consistent gridded maps of population distributions. WorldPop works with statistics agencies, ministries of health and other organizations to construct databases of the most spatially detailed and recent population census data available.

The new hybrid gridded population data was calibrated to United Nations World Population Prospects projections for 2015, so that the national population totals equalled those from the United Nations. The percentage of the population under 18 years of age was then calculated on a national level, and enhanced with subnational boundaries and percentages for 58 countries provided by ICF International through the DHS Programme. The percentages were then used to estimate the number and location of children under 18 years of age in 2015 around the world.

For future populations, gridded population data was augmented by United Nations population projection data for the year 2050, showing the total number of people per nation, as well as the percentage of children under 18 years of age. Those projections were used as a multiplier to derive the number and location of children under 18 years of age in 2050 globally based on the gridded population data.

Air Quality Data

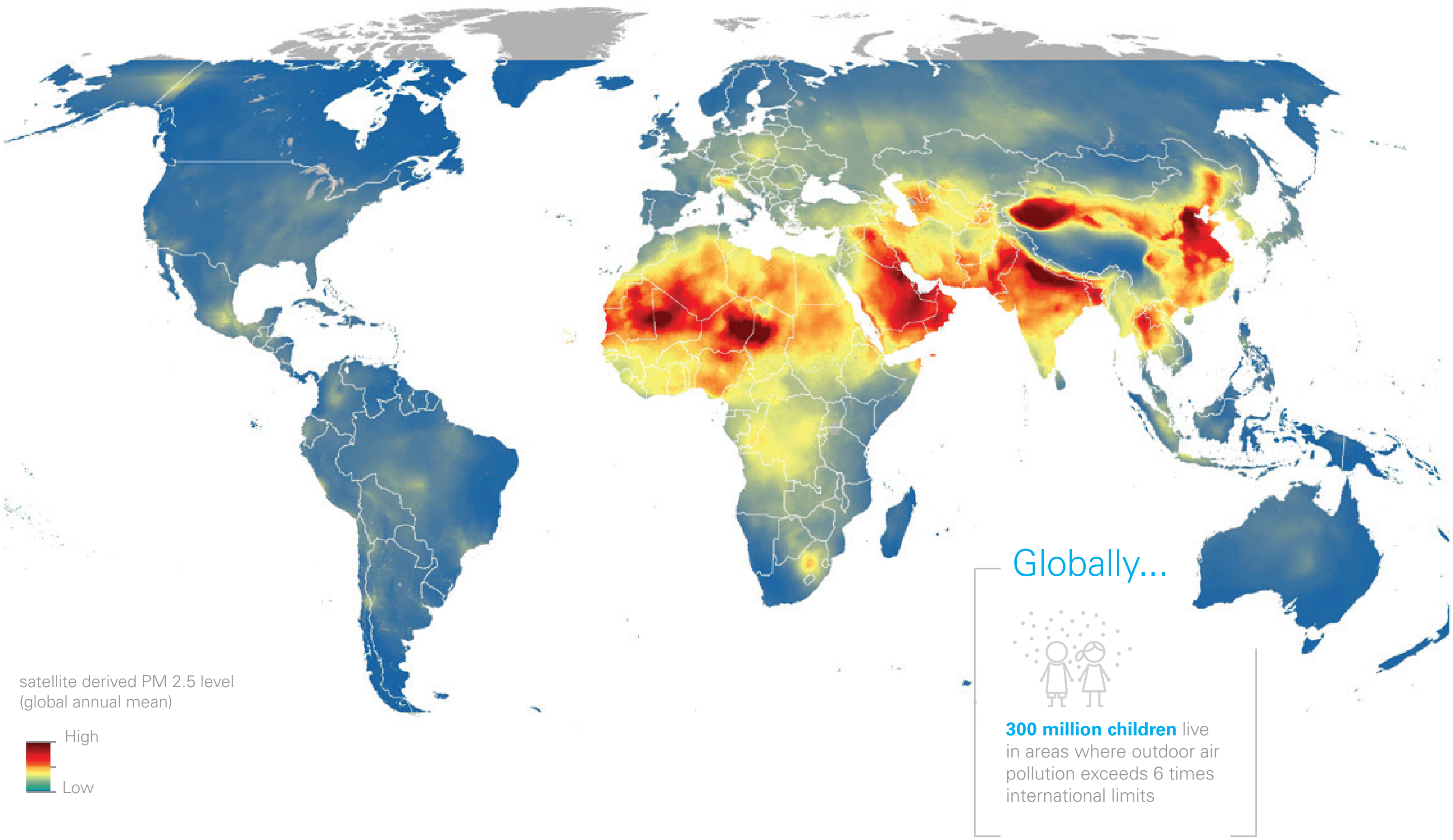
Ground-level fine particulate matter (PM2.5) was derived by the Atmospheric Composition Analysis Group at Dalhousie University, Canada. Their process combined Aerosol Optical Depth (AOD) retrievals from the NASA MODIS, MISR and SeaWIFS instruments with the GEOS-Chem chemical transport model, and subsequently calibrated them to global ground-based observations of PM2.5 using Geographically Weighted Regression (GWR). The best available data for the last three years (2012–2014) were averaged together as the basis for the current situation analysis.

The best available historic data for the first three years of global measurement (1998–2000) were averaged together as the basis for the historic trend analysis.

Overlaying the newly available high-resolution satellite imagery on PM2.5 with child population estimates for every square kilometre, based on CEISIN and WorldPop data calibrated using United Nations population estimates and DHS subnational demographic data, gives us the best global sense of the number of children living in high pollution zones.

Around 2 billion children live in areas where outdoor air pollution exceeds international limits.

Fig. 23: Satellite derived PM 2.5 level (global annual average), 2012-2014



This map is for illustrative purposes only. This map does not reflect a position by UNICEF on the legal status of any country or territory or the delimitation of any frontiers. The dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. The final boundary between the Sudan and South Sudan has not yet been determined. The final status of the Abyei area has not yet been determined.

Source of maps: van Donkelaar, A., R.V Martin, M.Brauer, N. C. Hsu, R. A. Kahn, R. C Levy, A. Lyapustin, A. M. Sayer, and D. M Winker, "Global Estimates of Fine Particulate Matter using a Combined Geophysical-Statistical Method with Information from Satellites, Models, and Monitors", Environ. Sci. Technol, doi: 10.1021/acs.est.5b05833, 2016.

Findings:

- **Around 2 billion children currently live in areas where outdoor air pollution (PM2.5) exceeds international limits.[5]**
- **Almost 300 million children live in areas where outdoor air pollution is toxic – exceeding six times international limits.**

It should be noted, however, that the satellite imagery picks up dust, as visible in the North Africa and Sahara region. Some modelling[6] is able to remove these effects. Windblown dust does, however, affect children and respiratory conditions, and is included as part of the WHO guidelines on thresholds for air pollution. Studies have also shown that it affects mortality and morbidity during episodes of high concentrations.[7,8,9,10] Therefore, because of its direct effect on children's health, we have included it in this analysis.

It should also be noted that these estimates can change based on seasonal and even daily fluctuations in outdoor air quality. For example, we know that air pollution is high during the winter in Ulaanbaatar, Mongolia, due to high amounts of solid fuel burning to keep warm, but the satellite images are unlikely to pick this up. Furthermore, the maps are not an indication of actual exposure, but rather indicate living in an area where outdoor air quality on a macro-level and over time has been determined to be poor. Exposure is based on many factors, which depend mostly on contextual locality and individual behaviour. For example, it depends on whether a child lives near roads with heavy traffic, where and when the child plays outdoors, whether significant waste-burning in the neighbourhood takes place, or whether children live in a home which uses biomass for cooking or heating.[11,12,13]

These figures do not include children living in high levels of indoor air pollution. Most children exposed to high levels of indoor air pollution live in rural areas, where ambient air pollution tends to be lower.

Furthermore, living in an area where air pollution levels are very high does not mean the child is exposed to air pollution all the time. As this report demonstrates, much can be done to protect children (see chapter 6).

In Africa...

520 million children live in areas where outdoor air pollution exceeds international limits

370 million children live in areas where outdoor air pollution exceeds 2 times international limits

60 million children live in areas where outdoor air pollution exceeds 4 times international limits

Less than a million children live in areas where outdoor air pollution exceeds 6 times international limits

Fig. 24 Satellite derived PM 2.5 level (global annual average), Africa, 2012-2014

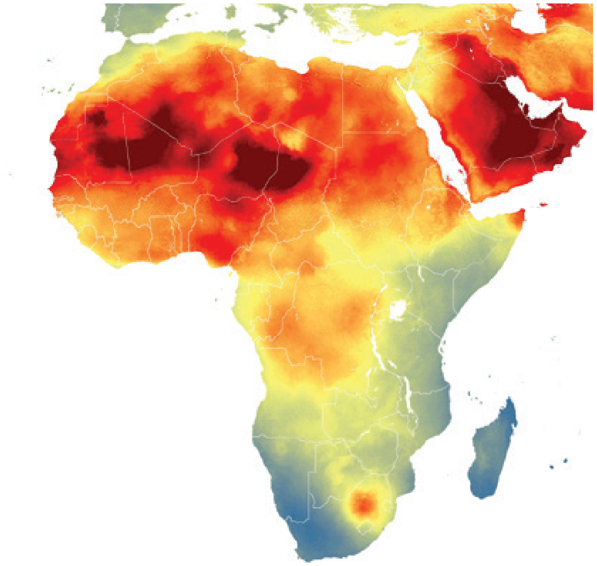
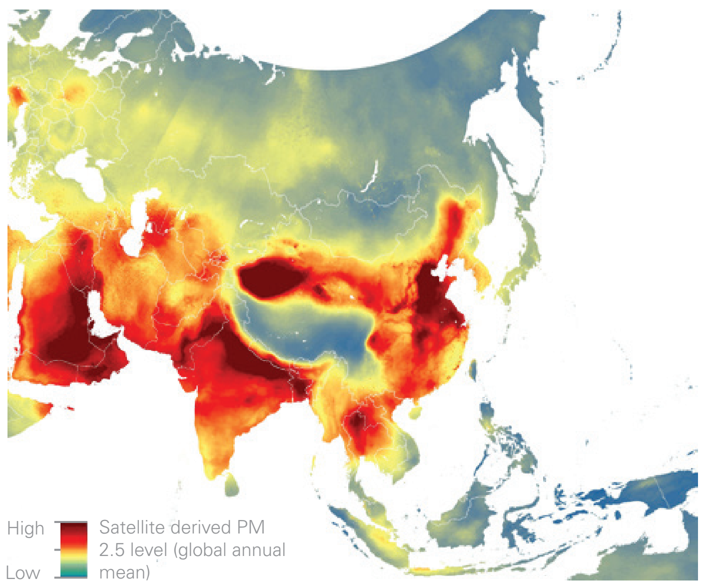


Fig. 25: Satellite derived PM 2.5 level (global annual average), Asia, 2012-2014



In Asia...

1.22 billion children live in areas where outdoor air pollution exceeds international limits

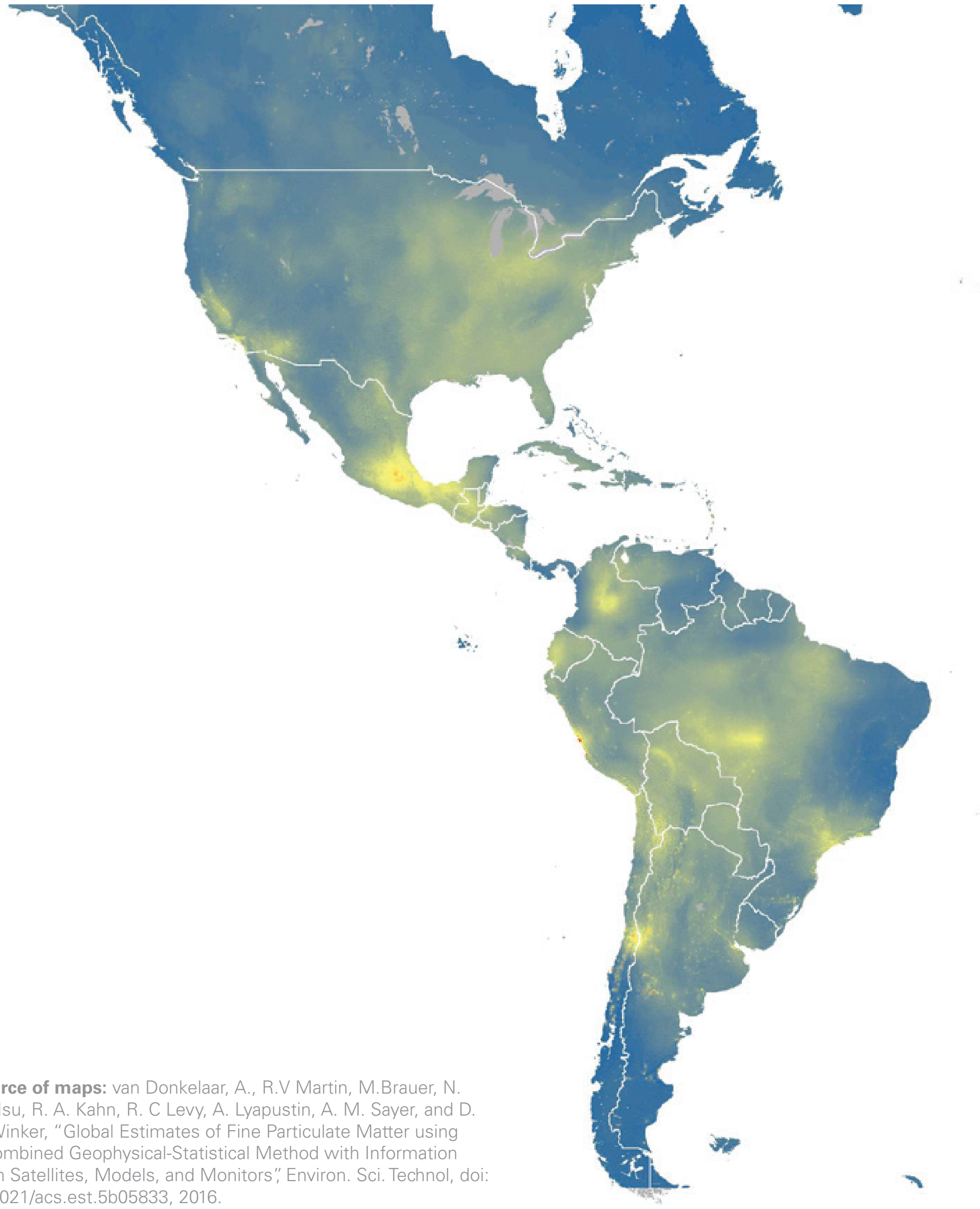
1.08 billion children live in areas where outdoor air pollution exceeds 2 times international limits

660 million children live in areas where outdoor air pollution exceeds 4 times international limits

300 million children live in areas where outdoor air pollution exceeds 6 times international limits

Source of maps: van Donkelaar, A., R.V Martin, M.Brauer, N. C. Hsu, R. A. Kahn, R. C Levy, A. Lyapustin, A. M. Sayer, and D. M Winker, "Global Estimates of Fine Particulate Matter using a Combined Geophysical-Statistical Method with Information from Satellites, Models, and Monitors", Environ. Sci. Technol, doi: 10.1021/acs.est.5b05833, 2016.

Fig. 26: Satellite derived PM 2.5 level (global annual average), Americas, 2012-2014



In The Americas...

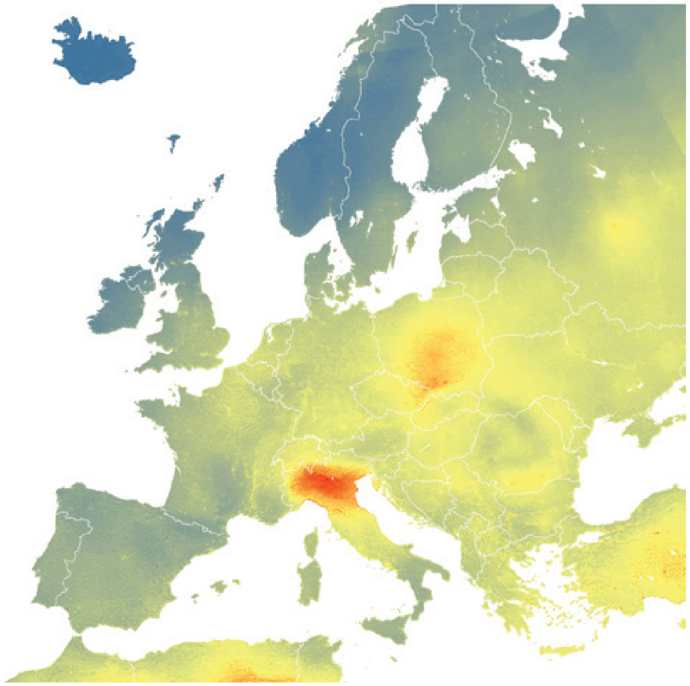
130 million children live in areas where outdoor air pollution exceeds international limits

20 million children live in areas where outdoor air pollution exceeds 2 times international limits

Over 1 million children live in areas where outdoor air pollution exceeds 4 times international limits

Source of maps: van Donkelaar, A., R.V Martin, M.Brauer, N. C. Hsu, R. A. Kahn, R. C Levy, A. Lyapustin, A. M. Sayer, and D. M Winker, "Global Estimates of Fine Particulate Matter using a Combined Geophysical-Statistical Method with Information from Satellites, Models, and Monitors", Environ. Sci. Technol, doi: 10.1021/acs.est.5b05833, 2016.

Fig. 27: Satellite derived PM 2.5 level (global annual average), Europe, 2012-2014



In Europe...

120 million children live in areas where outdoor air pollution exceeds international limits

20 million children live in areas where outdoor air pollution exceeds 2 times international limits

Source of maps: van Donkelaar, A., R.V Martin, M.Brauer, N. C. Hsu, R. A. Kahn, R. C Levy, A. Lyapustin, A. M. Sayer, and D. M Winker, "Global Estimates of Fine Particulate Matter using a Combined Geophysical-Statistical Method with Information from Satellites, Models, and Monitors", Environ. Sci. Technol, doi: 10.1021/acs.est.5b05833, 2016.

Number of children living in areas which exceed international limits, by UNICEF Region

UNICEF Region	$PM_{2.5}$ annual mean			
	>10 $\mu g/m^3$	>20 $\mu g/m^3$	>40 $\mu g/m^3$	>60 $\mu g/m^3$
CEE/CIS	100 million	40 million	2.3 million	
East Asia and the Pacific	450 million	360 million	190 million	70 million
Eastern and Southern Africa	200 million	70 million		
Latin America and the Caribbean	100 million	20 million	1.3 million	
Middle East and North Africa	170 million	140 million	30 million	10 million
South Asia	620 million	610 million	440 million	220 million
West and Central Africa	240 million	240 million	60 million	
Others	130 million	20 million		
Global	2 billion	1.5 billion	720 million	300 million

With actions to reduce air pollution, we can tackle threats to children’s health and climate change – at the same time.

Chapter 5: Wider benefits of reducing air pollution

As this report demonstrates there are significant links between air pollution and health. But, reducing air pollution also has wider benefits, including promoting economic growth, fighting climate change and achieving the SDGs.

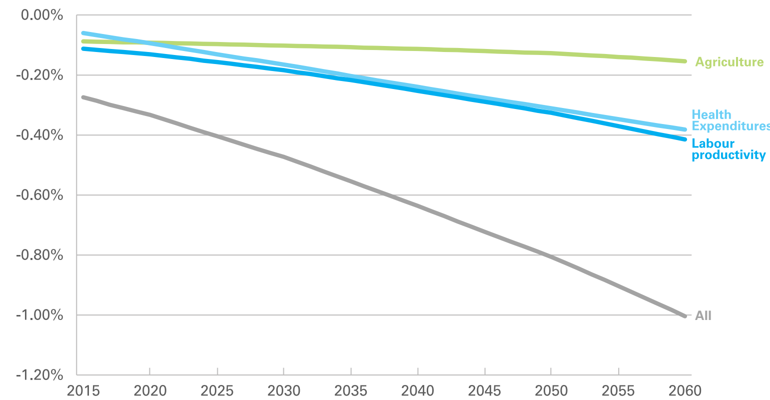
Promoting economic growth

The links between health and economic growth have been well established.[1] Air pollution affects a child's cognitive development, which in turn can affect school attendance and performance.[2,3] This, in turn, affects a child's future income potential, productivity and eventually impacts on economic growth. Illness to air pollution also raises a family's medical expenses – and prolonged exposure during childhood can cause complex and chronic health conditions that can be costly to manage to treat throughout a childhood and into adulthood.

It follows that by reducing air pollution, families and governments can save on medical expenses and improve the health of children as well as their future employment and well-being. This can have ripple effects for their employment, wages and for the economy as a whole.

Various studies demonstrate this connection. One study found that a 10 ppb decrease in ozone concentrations increases worker productivity by 4.2 per cent. Another study found that the closure of a factory in Mexico increased work hours (per week) among nearby residents by up to 1.3 hours, or 3.5 per cent. A US study on the effects of policy reform shows that the United States Clean Air Act Amendments could have an economic value of up to US$2 trillion by the year 2020 – offsetting initial implementation costs.[4]

Fig. 28: Change in global GDP from combined market impacts of air pollution



Source: The economic consequences of outdoor air pollution, OECD, 2016 ENV-linkages model

Air pollution also affects economic growth through its impact on crop yields and ecosystems.[5] High amounts of ozone can cause reduced growth and yield as well as premature plant death.[6,7] Furthermore, acidic and nitrogen compounds in the air can deposit onto the land, affecting overall water and soil quality, including biodiversity.[8] The impact of air pollution on agricultural productivity and crop yields is linked to families' incomes, local economic development and broader GDP growth.[9]

Biodiversity and ecosystems are also dependent on clean air – and their degradation can translate into significant economic consequences. The effects of air pollution on ecosystems also affect those families who rely on them to support their livelihoods. It can also affect aquatic ecosystems and livelihoods associated with them, including the loss of biota sensitive to increased acidity of surface waters, as well as increased phytoplankton and algal growth.[10,11,12]

Global studies have revealed the tremendous impact that air pollution has on the world economy. The OECD examined the potential economic costs of air pollution based on future projections of air quality around the world. The study evaluates market costs, including health expenditures, labour productivity and reductions in agricultural yields. Findings predict that the economic costs of air pollution will gradually increase from 0.3 per cent of global GDP to around 1 per cent of GDP by 2060.[13] Another recent study by the World Bank and the Institute for Health Metrics and Evaluation (IHME) indicates even greater economic costs of air pollution. The authors found that deaths from air pollution cost the global economy about US$225 billion in lost labour income and more than US$5 trillion in welfare losses in 2013.[14]

But the economic effect can also be felt at the individual and household level. Measures to reduce air pollution are highly cost-effective for families and communities. Clean cookstoves, for example, have been shown to provide significant household savings, mostly in terms of fuel, but also in terms of reduced expenses from illness.[15,16] The net cost for every individual who switches from biomass to LPG for cooking fuel is US$2.10, while the net benefit per person is US$14.40. The benefits of switching to a cleaner cookstove are even greater: the net cost for every individual who switches from a traditional cookstove to a cleaner one is US$5.50, while the net benefit per person is US$16.70. The net benefit is highly positive because the immediate savings on fuel offset the cost of the cleaner stove.[17] Because such interventions save more money than they cost, the same study found that making clean stoves available to those using biomass fuels and coal on traditional stoves would result in a negative intervention cost of US$34 billion and would generate an economic return of US$104 billion a year over a ten-year period. In other words, the present net annual value would be US$138 billion.[18]

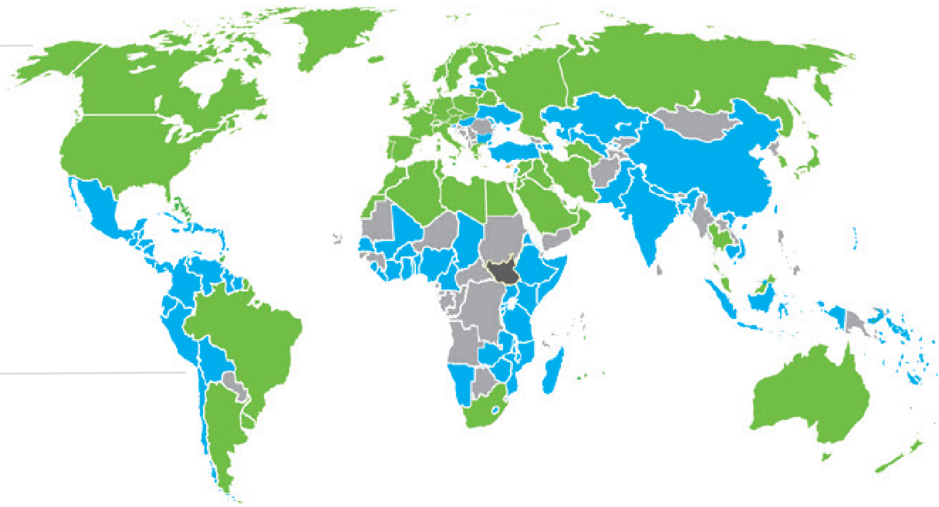
There are further economic effects of cleaner cookstoves. The reliance on wood as a household fuel can put pressure on forests, particularly in areas where fuel wood is scarce and the demand for wood outweighs natural regrowth. Unsustainable wood harvesting can lead to forest degradation, which may result in a loss of habitat and biodiversity.[19,20]

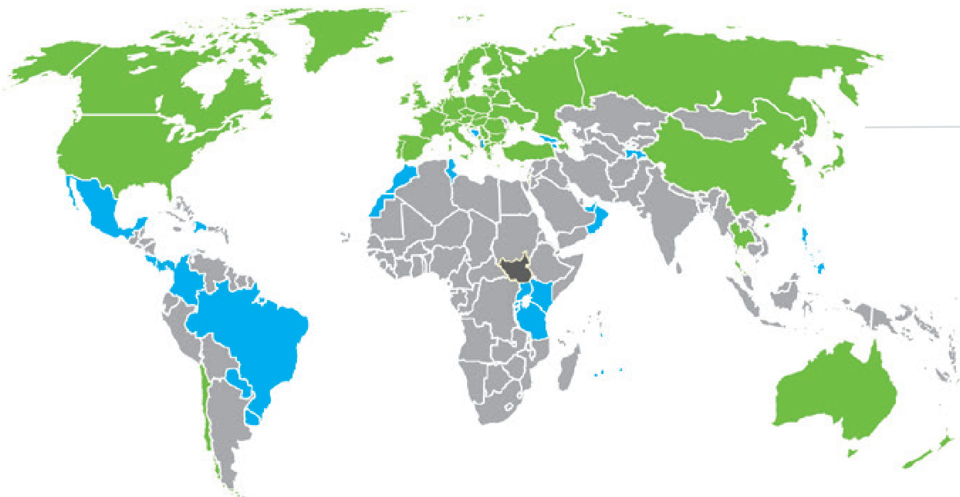
The opportunity cost of inefficient cookstoves can also be substantial. Households reliant on traditional biomass fuels often spend many hours a day on fuel collection and thus have less time available for other essential tasks.[21] This limits time available for income generation, schooling and other opportunities for economic development. Similarly, households with limited or no access to clean and reliable sources of lighting (e.g., electricity) can lose opportunities for educational and income-generating activities outside of daylight hours.[22]

But dependence on inefficient household fuels and appliances is often linked to poverty – and reinforces itself. Poor households frequently do not have the resources to obtain cleaner, more efficient fuels and appliances in the first place.

Indoor air pollution

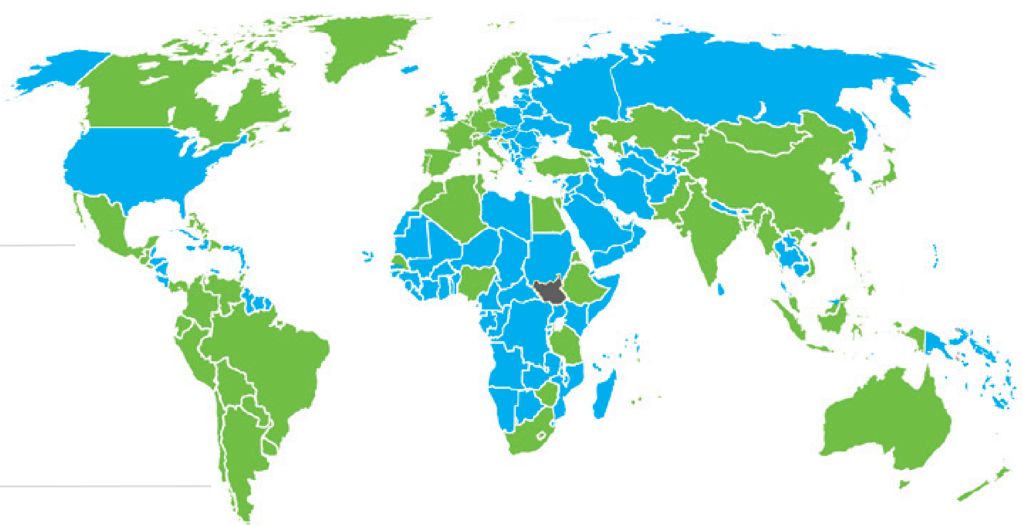
- Countries with good access to non-solid fuels and programmes to promote efficient cook/heating stoves
- Countries that lack either good access to non-solid fuels or programmes to promote efficient cook/heating stoves
- Countries that have no good access to non solid-fuels and do not have programmes to promote efficient cook/heating stoves
- No data





Fuels and vehicles

- Countries with low Sulphur fuels (50ppm) and advanced vehicle emission standards (Euro 4)
- Countries with either low Sulphur fuels (50ppm) or advanced vehicle emission standards (Euro 4)
- Countries with neither low Sulphur fuels (50ppm) nor advanced vehicle emission standards (Euro 4)
- No data



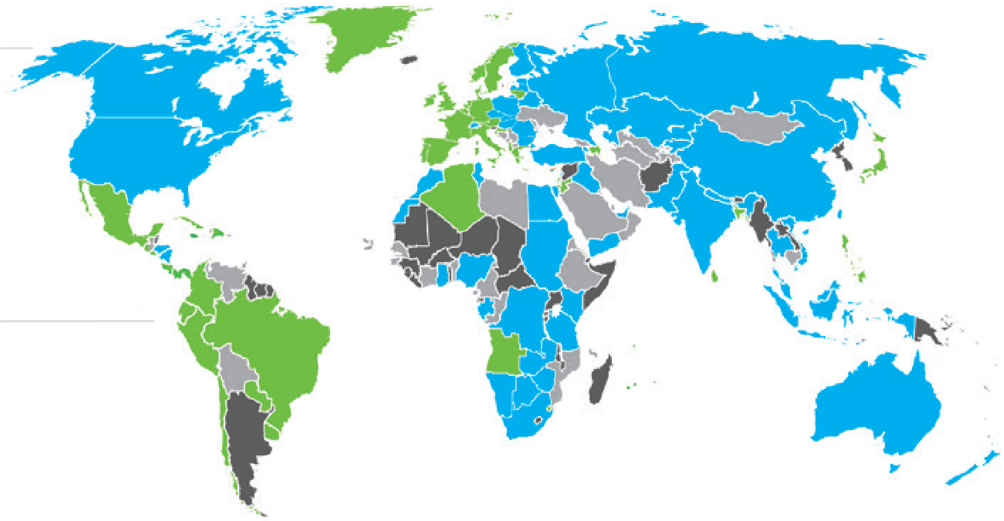
Public Transport

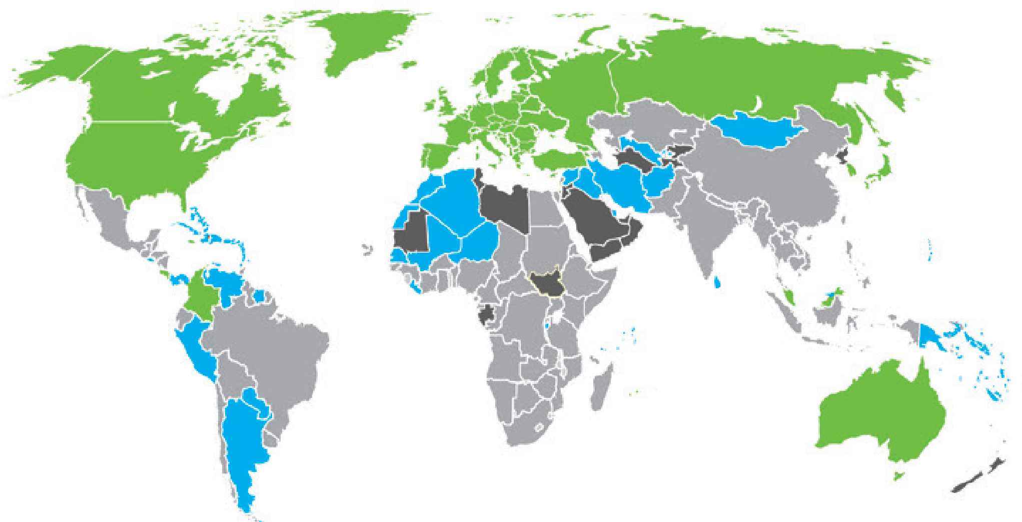
- Countries that have made major investments in public transport in the last 5 years
- Countries that have made some investments in public transport in the last 5 years
- No data

Source: Actions on Air Quality: Policies and Programmes for improving air quality around the world. United Nations Environment Programme (2016)

Industry

- Countries with incentives and high industrial energy efficiency
- Countries with incentives and low industrial energy efficiency or no incentives but have high industrial energy efficiency
- Countries with low industrial energy efficiency and no incentives
- No data



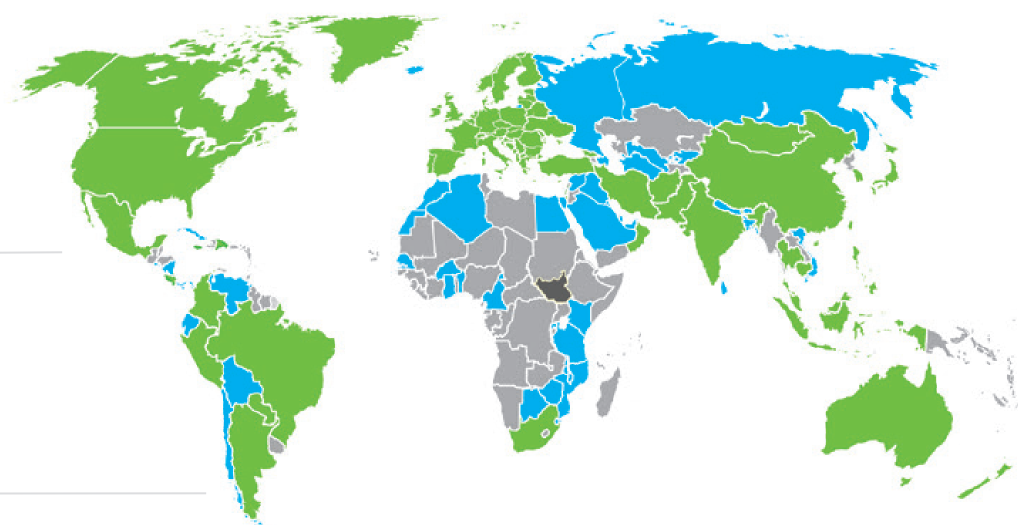


Burning waste

- Burning of both agricultural and municipal waste is strictly regulated
- Burning of either agricultural or municipal waste is regulated but still practised
- Burning of both agricultural and municipal waste is not regulated and is commonly practised
- No data

Air quality laws / Regulations

- Countries with AAQS and air quality laws & regulations
- Countries with either AAQS or air quality laws & regulations
- Countries without AAQS and air quality laws & regulations
- No data



Source: Actions on Air Quality: Policies and Programmes for improving air quality around the world. United Nations Environment Programme (2016)

Combatting climate change

Actions to reduce air pollution and greenhouse gas emissions go hand in hand. However, it should be noted that while there is some overlap, some of the pollutants that affect children's health are not the same as greenhouse gases. Particulate matter, is short-lived and stays in the atmosphere for only a matter of months, possibly a few years, whereas carbon dioxide (CO_2) stays in the atmosphere for many years, even decades.

Nonetheless, short-lived pollutants do play a role in climate change. Firstly, they are often produced by the same action as long-lived climate pollutants: fossil fuel combustion. Moreover, some of the pollutants do have warming effects. Studies have shown that actions to reduce short-lived climate pollutants could reduce global warming by as much as 0.5^{o}C by 2050*. Black carbon (a form of PM2.5) comes from incomplete combustion and significantly contributes to climate change. Black carbon absorbs sunlight, and when it is deposited on snow or ice, it facilitates melting. Black carbon is estimated to be responsible for approximately 15 per cent of the current excessive warming of global temperatures.[23]

Many mitigation actions have been found to have health co-benefits. The United Nations Environment Programme and the World Meteorological Organization conducted an extensive study that found that a small suite of mitigation actions among short-lived climate pollutants could prevent as many as 3.5–5 million premature deaths per year. These actions, listed in *Figure 31*, will also help towards achieving objectives outlined in each individual country's Nationally-Determined Contributions (INDCs) as part of the COP21 Climate Change Agreement.[24] Some of the key examples include: supporting active and rapid/mass transport; higher vehicle emissions efficiency standards; switching from fossil fuels to renewables for large-scale power production; promoting healthy diets low in red meat and processed meats and rich in plant-based foods; reducing food waste; using low-emission stoves and/or fuel switching to reduce solid fuel use; and passive building design principles; among others.

*UNEP & WMO (2011) Integrated Assessment of Black Carbon and Tropospheric Ozone, Nairobi, Kenya

Fig. 29: Policy map displaying air quality (AQ) and climate change (CC) interactions.

Negative for both air quality and climate change

- Fossil fuels combustion in stationary and mobile sources

Beneficial for both air quality and climate change

- Energy efficiency
- Wind, solar, tidal
- Hybrids, low emission vehicles
- Carbon capture and storage
- Reforestation

Source: Adapted from Defra (2010). *Air pollution: Action in a changing climate.*

Clean air, economic growth and carbon reduction in China

The metropolitan of Shenzhen is a pioneer for air quality management in China and a model for the *win-win-win* case of: clean air – low carbon – economic growth. As the first Chinese city with a population of over 10 million to successfully achieve the national air quality standard, the metropolitan region/city of Shenzhen is voluntarily aiming to further reduce PM2.5 levels and achieve the more stringent one proposed by the WHO by 2020. After having achieved the PM2.5 national standard, its GDP grew by 8.9 per cent versus China's national average of 6.9 per cent growth in 2015. The energy use per unit of GDP is only half of China's national average. Shenzhen is one of the cities supported jointly by the Children's Investment Fund Foundation and the Energy Foundation China. The partnership supported cities, and also successfully pushed for revision of China's Air Law and provided technical support regarding its implementation and enforcement in Shenzhen and other cities. The partnership successfully pushed for measures accelerating improved outcomes regarding air pollution and the reduction of greenhouse gases.

Provided by The Children's Investment Fund Foundation (CIFF)

Climate and health win-wins

Fig. 30: Potential magnitude of climate and health impacts of selected mitigation actions.

Sector and mitigation action	Certainty of major hort-lived climate pollutants-related climate benefit[1]	Aggregate level of potential health benefit[2]	Main health benefits (**blue** = direct benefits of reduced air pollution; **gray** = indirect benefits of reduced air pollution; **green** = ancillary health benefits)	Potential level of CO_2 reduction co-benefit
Transport				
Support active (and rapid mass) transport	High	High	Improved air quality Less crop damage and extreme weather Increased physical activity Reduced noise Fewer road traffic injuries[3]	High
Ultra-low sulfur diesel with diesel particle filters	Medium-high	Medium	Improved air quality Less crop damage and extreme weather	None
Higher vehicle emissions/efficiency standards	High[4]	Medium-high	Improved air quality Less crop damage and extreme weather	High[4]
Agriculture				
Alternate wet/dry rice irrigation	Medium-high[5]	Low-medium	Less crop damage and extreme weather Reduced vector-borne disease	Low[5]
Improved manure management	Low-medium	Low-medium	Reduced zoonotic disease Improved indoor air quality	Low
Reduced open burning of agricultural fields	Medium	Low-medium	Improved air quality Less crop damage and extreme weather	Low
Promoting healthy diets low in red meat and processed meats rich in plant-based foods[6]	High	High	Less crop damage and extreme weather Reduced obesity and diet-related non-communicable diseases	Medium-high[7]
Reducing food waste	Medium-high	Low-medium	Less crop damage and extreme weather Reduced food insecurity/undernutrition	Medium-high[7]
Household air pollution and building design				
Low emission stoves and/or fuel switching to reduce solid fuel use	Medium-high	High	Improved air quality Less crop damage and extreme weather Lower violence and injury risk during fuel collection Fewer burns	Medium[7]

Improved lighting to replace kerosene lamps	Medium	Medium	Improved air quality Less crop damage and extreme weather Fewer burns / Fewer poisonings	Low-medium
Passive design principles	Low-medium	Medium	Thermal regulation Improved indoor air quality	Medium
Energy supply/electricity				
Switch from fossil fuels to renewables for large scale power production[7]	Low	High (coal/oil) Low-medium (gas)	Improved air quality Less crop damage and extreme weather Fewer occupational injuries	High (coal/oil) Medium-high (gas)
Replacement or supplementation of small-scale diesel generators with renewables	Low-medium	Low-medium	Improved air quality Less crop damage and extreme weather Reduced noise	Low-medium
Control of fugitive emissions from the fossil fuel industry	High	Low	Improved air quality Less crop damage and extreme weather	Low-medium[8]
Industry				
Improved brick kilns	Low-medium	Medium	Improved air quality Less crop damage and extreme weather	Low-medium[7]
Improved coke ovens	Low-medium	Medium	Improved air quality Less crop damage and extreme weather	Low-medium[7]
Control of fugitive emissions from the fossil fuel industry	High	Low	Improved air quality Less crop damage and extreme weather	Low-medium
Waste management				
Landfill gas recovery	Medium	Low	Improved air quality Less crop damage and extreme weather	Low-medium[9]
Improved wastewater treatment (including sanitation provision)	Medium	Medium-high	Improved air quality Less crop damage and extreme weather Reduced infectious disease risk	Low-medium[9]

1. Incorporates both the potential for major emissions reductions as well as the certainty that those reductions will have the desired climate effect. For example, reducing BC emissions from BC-rich sources (e.g. diesel) will have less uncertainty than reducing BC from sources higher in co-emitted cooling agents (e.g. open burning). Near-term refers to anytime over the next few decades, though some climate benefits may occur almost immediately. 2. Assessed at the population level. 3. Assumes provision of safe infrastructure. 4. Increased efficiency may induce increased travel (a 'rebound') so should be combined with the complementary interventions (e.g. fuel taxes). 5. Note that potential climate benefit could potentially be offset by increases in nitrous oxide emissions, a long-lived greenhouse gas. 6. Avoid where there is a high risk of nutrient inadequacy. 7. Includes potential of CO2 uptake by reforested land or use for bioenergy crops. 8. Does not include fugitive emissions, which are considered separately. 9. Includes potential displacement of fossil fuels by utilizing captured gas.

Source: Climate and Clean Air Coalition, World Health Organization (2015) 'Reducing Global Health Risks Through Mitigation of Short-Lived Climate Pollutants. Scoping Report For Policy-makers.'

Making progress towards the SDGs

Air quality affects a range of rights and is connected to several international commitments, such as the 2030 Agenda for Sustainable Development.

Air quality is mentioned in four places in the SDGs:

Declaration

9. We envisage a world in which every country enjoys sustained, inclusive and sustainable economic growth and decent work for all. A world in which consumption and production patterns and use of all natural resources — from ***air*** *to land, from rivers, lakes and aquifers to oceans and seas — are sustainable. One in which democracy, good governance and the rule of law, as well as an enabling environment at the national and international levels, are essential for sustainable development, including sustained and inclusive economic growth, social development, environmental protection and the eradication of poverty and hunger. One in which development and the application of technology are climate-sensitive, respect biodiversity and are resilient. One in which humanity lives in harmony with nature and in which wildlife and other living species are protected.*[25]

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

3.9 By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and ***air****, water and soil* ***pollution*** *and contamination.*[26]

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

11.6 By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to ***air quality*** *and municipal and other waste management.*[27]

Goal 12. Ensure sustainable consumption and production patterns

12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to ***air****, water and soil in order to minimize their adverse impacts on human health and the environment.*[28]

Air pollution is also indirectly related to Goals 1, 2, 6, 7, 9, 13 and 15. Reducing air pollution can help reduce poverty both by enhancing health and productivity, as well as by saving money through reduced medical expenses. It is directly related to improving child and adult health – a key goal in the SDGs. Reduction of many air pollutants can also help improve the environment, reduce acid rain and protect ecosystems – which affects both water quality as well as food security. Reducing air pollution is also a co-benefit of many of the goals, including providing affordable and clean energy, responsible production and consumption, better urban planning and infrastructure, climate action and several others.

Sustainable Development Goals that are closely related to reducing air pollution

1 NO POVERTY

Reducing air pollution can help families become healthier, save on medical expenses, and improve productivity.

2 ZERO HUNGER

Air pollution can cause crop damage and affect food quality and security.

3 GOOD HEALTH AND WELL-BEING

Air pollution poses a major threat to human health. It is linked to respiratory infection and cardiovascular disease. It causes increases in population morbidity and mortality.

6 CLEAN WATER AND SANITATION

Pollutants such as sulfur dioxide (SO_2) and nitrogen oxide (NO_X) from open fires and the combustion of fossil fuels mix with precipitation causing harmful acid rain that can compromise water quality.

7 AFFORDABLE AND CLEAN ENERGY

Electricity from renewable energy rather than fossil fuels offers significant public health benefits through a reduction in air pollution.

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Power generation, industry and transportation are large contributors to air pollution. A new focus on decreasing energy consumption and on improving sustainable and public transportation could progressively reduce pollution.

11 SUSTAINABLE CITIES AND COMMUNITIES

Urban areas significantly contribute to air pollution. Making cities sustainable could progressively improve the air quality.

12 RESPONSIBLE CONSUMPTION AND PRODUCTION

Chemicals released into the air increase air pollution and contribute to harmful effects on human health. Responsible production and consumption could help to reduce these harmful chemicals.

13 CLIMATE ACTION

Combustion of fossil fuels plays a key role in the process of climate change, which places food, air and water supplies at risk, and poses a major threat to human health.

15 LIFE ON LAND

Emissions from combustion of fossil fuels mixed with precipitation cause acid rains that pose a major threat to forests and ecosystems.

Selected examples of policy initiatives aimed at reducing air pollution

Fig. 31

USA: The Clean Air Act requires the establishment of national ambient air quality standards and the regulation of toxic emissions, the violation of which can be penalized.[1]

Mexico: High density population centres have shifted to using ultra-low sulphur diesel in Mexico.[1]

Mexico City implemented policies such as removing lead from gasoline and expanding bus and underground transportation - including shuttle buses for schools and companies - to reduce levels of lead, carbon monoxide and sulphur dioxide in the air.[10]

Costa Rica: The use of clean energy is promoted by tax benefits and subsidies for LPG, in addition to the provision of solar panels for houses not connected to the grid.[1]

Bolivia: Bolivia is reducing emissions from transport by connecting buses to remote neighbourhoods and supporting the switch to buses.[1]

Chile: The Ministry of Environment exchanges old cookstoves with new and clean cookstoves to minimize pollution from residential wood burning.

Brazil: Sao Paulo uses thermoelectric power plants to convert methane from solid waste to electricity for 700,000 people.[9]

Brazil enforces national emission standards to old industrial facilities and requires electricity producers to invest in energy efficient projects.[1]

Curitiba has established high density development next to high capacity transportation systems, encouraging bus trips and reducing auto trips.[1]

In Brazil, farmers practicing conservation agriculture leave crop residue on the fields instead of burning it, thereby also improving soil quality.[1]

Norway: Norway is successfully promoting the sale of electric vehicles through financial incentives such as exemptions from purchase tax, road toll or VAT. In 2015, electric cars comprised 25% of all sales of new vehicles.[1]

United Kingdom: Standards and implementation of fuel quality were initiated by The Quality Assured Fuel Scheme. A national information campaign encouraged the uptake of clean stoves.[1]

France: The Environmental and Energy Management Agency of France plans to build 600 biogas plants every year for electricity and heat generation.[1]

European Union: Twenty eight European Union member states shifted to ultra-low sulphur fuel for petrol and diesel. Vehicle emission standards were also tightened.[1]

Namibia: A public education campaign for forest conservation and fire management was launched in 1996 in East Caprivi, decreasing fire incidences by 70 per cent.

South Africa: The Air Quality Act establishes air quality management measures with a particular focus on low air quality areas.

South Africa has encouraged investments in renewable energy production through various funds, tax allowances and deductions.

1. Actions on Air Quality: United Nations Environment Programme, 2014.
2. Country Action Plan for Clean Cookstoves: Power Division, Government of the People's Republic of Bangladesh, 2013.
3. Graham-Harrison, Emma and Vidhi Doshi, "Rajshahi: The City that Took on Air Pollution - and Won," The Guardian, 2016.
4. UNICEF Annual Report 2015 - Mongolia: UNICEF, 2015. UNICEF Annual Report 2015 - Zimbabwe: UNICEF, 2015.
5. "Mongolia - Comprehensive Tobacco Control Legislation Revised," WHO Framework Convention on Tobacco Control, http://www.who.int/fctc/implementation/news/news_mon/en/
6. "Air Quality Policies: India," UNEP. http://www.unep.org/Transport/airquality/pdf/India.pdf (accessed 07/14, 2016).
7. Clavel, Emilie, "Think You can't Live without Plastic Bags - Consider this, Rwanda did it!" The Guardian,2014.

Sweden: Sweden charges a sulphur tax for sulphur containing fuels and takes into account air pollution impacts when granting industrial permits.[1]

Denmark: The mandatory use of the best available industrial technology contributes to an improvement in energy and efficiency of consumer companies.[1]

Caterina, Italy: Caterina has initiated waste prevention policies such as "pay as you throw" and waste separation at source, increasing its recycling rate from 35% to 80%.[1]

Israel: The Clean Air Law of 2008 has set limits for emissions upon major industrial polluters, in addition to spot checks and penalties for violation of the standards.[1]

China: China has been tackling hazardous air pollution levels by focusing on the most polluting industries and implementing rigorous emission standards. Shenzhen in China was the first city of over 10 million inhabitants to achieve the national air quality standard while simultaneously growing its GDP.

Mongolia: UNICEF Mongolia advocated for child health related actions including reducing air pollution from coal combustion in residential areas through public and private partnerships.[4]

Mongolia banned smoking in all public areas in addition to banning second hand smoking in schools, parks and playgrounds.[5]

Japan: Japan has established an extensive railway and Non-Motorized Transport network that is both time and cost efficient.[1]

Bangladesh: Rajshahi achieved a 67.2 per cent decrease in PM10 concentrations by upgrading the city's brick kilns as well as greening and paving public spaces.[3]

The Bangladesh Country Action Plan for Clean Cookstoves aims to distribute improved cookstoves to 30 million households by 2030 in order to improve women and children's health.[2]

East African Community: East African member states have moved to low sulphur fuels through the efforts by the East African Community Secretariat.[1]

Rwanda: Rwanda banned non-biodegradable plastic bags, reducing the amount of burnt plastic and encouraging the use of environmentally friendly bags.[7]

Thailand: The Pollution Control Department adopted Euro 4 light-duty vehicle emission standards and low sulphur fuel, decreasing air pollution in Bangkok.[1]

Indonesia: Indonesia initiated TransJakarta, the world's longest Bus Rapid Transit (BRT) system, with subsidized tickets and dedicated bus lanes.[1]

Mozambique: The city council of Mozambique hired small-scale waste collection companies to collect waste in low-income areas, servicing 900,000 people who previously did not have access to this service.[8]

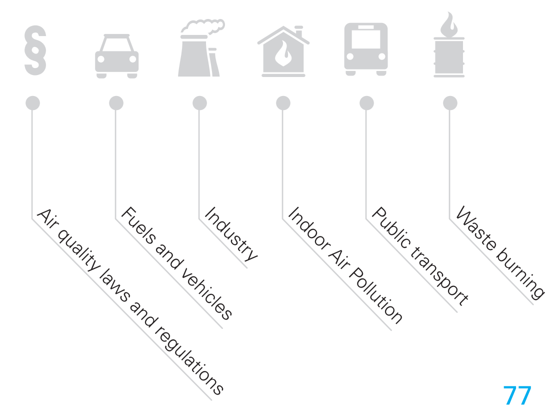
Zimbabwe: UNICEF Zimbabwe trained women from 3480 households to construct cleaner cookstoves, reducing fuel consumption by 39%.

India: The Ministry of New and Renewable energy invested in producing state of the art, clean and culturally appropriate cookstoves, distributing more than 2.7 million cookstoves in the country.[1]

New Delhi alternately banned cars with odd and even license plate numbers to reduce traffic related air pollution.[6]

Singapore: Singapore has established a strong non-motorized transport system, including a network of walking and biking paths, buses and trains. Singapore plans to substantially expand the network by 2030.[1]

Singapore provides tax incentives to encourage the switch to clean energy equipment and install pollution control and monitoring devices such as industrial CCTV systems.[1]



8. Global Waste Management Outlook: United Nations Environment Programme, 2015.
9. "Sao Paulo's Landfills Project, Brazil," Global Infrastructure Basel, http://www.gib-foundation.org/projects/sao-paulos-landfills-project/ (accessed 07/14, 2016).
10. O'Connor, Anne Marie, "Mexico City Drastically Reduced Air Pollutants since 1990s," Washington Post, 2010.

Air Pollution Action Agenda:

- Reduce air pollution
- Minimize exposure
- Improve child health
- Monitor air pollution

Chapter 6: Protecting children from air pollution

The science is clear: reducing air pollution levels saves and improves the quality of children's lives. It can help to reduce the incidence of acute and chronic respiratory infections such as pneumonia and asthma among children. Reducing air pollution would reduce complications during pregnancy and childbirth, as well as improve can improve children's development, helping them to lead longer and more productive lives, and benefit sustainable development and climate change mitigation.

As a broad framework, protecting children from air pollution requires a four-pronged approach:

1 **Greater efforts to reduce air pollution.** Air pollution is linked to diseases which kill many children. It is also a threat to their health and development. Reducing it will translate to millions of saved lives, and better healthier lives for all children and their children. Reducing air pollution will require a multitude of actions at various levels, from government to households and local communities – including actions to reduce fossil fuel combustion, investments in sustainable energy and low-carbon development policies.

Within households, it will require supporting the emerging clean cooking sector and ensuring that high-quality cookstoves and fuels are accessible and adopted by millions of households, as well as cleaner heating and cooling systems. It might also include provision of solar panels and other alternatives to diesel generators.

Within communities, it will require better management of community resources, including waste disposal, better public transportation options, and information and knowledge on reducing pollution. Nationally and internationally, technology and legislation that reduces harmful pollutants from vehicle emissions, and actions to reduce transport emissions in general, can make a big difference in mitigating outdoor air pollution.

2 **Minimize children's exposure to air pollution.** Children should be kept away from anything that harms them. Even though the toxic cocktail of chemicals in air pollution is invisible to the naked eye, these elements are deadly and affect children's health and well-being. Minimizing exposure includes better waste management systems, and improved ventilation. It can mean better ventilation and design-construction in homes to minimize exposure to both indoor and outdoor pollutants. This, in turn, will necessitate child sensitive urban planning so that polluting sources are kept away from places where children spend time, such as schools.[1]

3 **Improve children's overall health, so that when they are exposed to air pollution the risks of further health complications are reduced.** The pre-existing health of a child can greatly affect the degree to which air pollution affects their health. Providing all children with access to quality and affordable medical care, including vaccines and medicines that prevent infections that can lead to pneumonia, as well as exclusive breastfeeding, better nutrition, and maternal health care, helps build their resilience to many of the negative effects of air

pollution. Access to safe water and sanitation is also crucial in supporting children's health and risks associated with air pollution.

The children who are most vulnerable to air pollution are the ones who already suffer from poor health. Air pollution exacerbates inequity, as it further compromises their health, their future livelihood, and even their potential survival. Helping to improve the quality of the air breathed by the poorest children will be crucial in combatting inequity and preventing intergenerational cycles of poverty.

4 **Better monitoring of air pollution and its link with children's health.** Air quality can fluctuate rapidly in every environment. For example, cooking or heating with biomass in the home can cause a rapid, temporary spike in pollution. Also, urban ambient pollution tends to be highest during rush hour in most countries. Waste-burning is often worse at certain times of the day, too.

Monitoring devices and systems that help individuals, parents, families, communities and local and national governments adjust to immediately prevailing conditions will help minimize exposure and will educate the public and policymakers on key health risks. Better monitoring can also inspire greater action by a range of public and private stakeholders. It can lead to government standards, regulation and policies that work towards the realization of the World Health Organization air quality guidelines. Links between air pollution and child health should also be monitored, including through early diagnosis of illnesses and registration at health clinics, to help prevent the compounding negative impacts of air pollution on children's health. This may include better surveillance and early warning systems of child health and air pollution.

Action now needs to be taken across all levels of society – by parents, guardians, schoolteachers, medical professionals, local planning and city governments, as well as national governments, policymakers and the private sector. Parents, guardians and schoolteachers need to be empowered with accurate information about air pollution, and medical professionals should be trained so they can 'prescribe' emission-reduction tactics. This will require coordination and policy alignment.

No single sector can tackle air pollution alone – within government ministries it cuts across environment, health, social welfare, energy, finance and regulatory sectors. It also needs to be addressed across the public, private and civil society sectors and requires harmonized approaches to address the multitude of forces that cause air pollution – from consumer behaviour patterns to organizational and regulatory actions. This, in turn, will require more institutional capacity and coordination, as well as resources for programming. It will require working in a more integrated and effective manner – including across agencies and very much in line with the 2030 Agenda for Development. Air pollution affects about two billion of the world's children. It will require all of us to clear the air for them, and make it safe to breathe.

[1] United States Environmental Protection Agency, 'Best Practices for Reducing Near-Road Air Pollution Exposure at Schools', accessed 27 July 2016.

Examples of actions to be taken

Reduce air pollution

Support households to reduce indoor air pollution from cooking and heating with solid fuels.

Adopt cleaner cooking and heating fuels to reduce household air pollution.

Apply low-carbon development strategies in energy generation, housing and industry.

Install good quality filters on smokestacks.

Design traffic and urban spaces to avoid generating air pollution.

Switch from coal and polluting hydrocarbons to cleaner fuels and energy.

Make improvements and develop regulations for the open burning of waste.

Reduce exposure

Raise awareness of the harm pollutants cause children and pregnant women.

Restrict household air pollution around children as much as possible.

Install good quality air ventilation and/or filtration systems in homes and areas where children spend time.

Limit exposure of children to air pollution when levels are high.

Reduce children's exposure to second-hand tobacco smoke.

Improve air quality in children's environments through better urban planning, including green spaces.

Evacuation plans should rescue children who are threatened by the air pollution caused by forest fire, not only those who are in the immediate path of the fire.

Restrict highly polluting traffic around areas where children spend time such as schools, playgrounds, parks and residential areas.

Major sources of air pollution such as factories or heavy traffic should be kept at distance from schools and parks.

Raise awareness among those who care and provide services for children.

Improve child health

Provide children with access to good quality healthcare and WASH to improve their health and protect them from the negative effects of air pollution.

Encourage and support children and youth to participate in local environmental activities.

Increase understanding that child health, growth and development depends on both controlling root environmental causes of poor health, and clinical responses to disease.

Provide proper medical treatment to children with asthma, and other chronic respiratory conditions.

Increase the coverage of pneumococcal vaccines and treatment in community care centers.

Provide oxygen treatment innovations such as low cost oxygen concentrators.

O_2

Provide amoxicillin dispersible tablets as a first-line treatment.

Promote exclusive breastfeeding in the first 6 months to help prevent pneumonia.

Improve child nutrition to help fight air pollution related diseases.

Provide prenatal and postnatal healthcare for mothers and children.

Improve policy and monitoring

Develop and implement national laws and regulations for the detection of environmental diseases.

Develop and build consensus on children's environmental health indicators.

Monitor air quality systematically.

Fully recognize the important role of environmental protection in child survival, development and protection.

Utilize accurate and low-cost devices to easily diagnose pneumonia.

Give special policy attention to disadvantaged children who are closer and more vulnerable to environmental hazards.

Strengthen coordination and cooperation among government departments on air pollution.

Local governments should actively disseminate health warnings so that people can better protect themselves, and children, from air pollution.

Recognize the danger signs of pneumonia and seek care quickly.

Make sure that children's rights and their special vulnerabilities are systematically taken into account in discussions and negotiations on environmental agreements.

The science is clear: reducing air pollution levels can save children's lives.

References

EXECUTIVE SUMMARY AND KEY MESSAGES

1. World Health Organization, '7 Million Premature Deaths Annually Linked to Air Pollution', last modified 25 March 2014.
2. World Health Organization, 'Burden of Disease from Household Air Pollution for 2012: Summary of Results', 2012, accessed 20 July 2016.
3. Bates, D., 'The Effects of Air Pollution on Children, Environmental Health Perspectives, vol. 103, no. 6, 1995, pp. 49–53.
4. Calderon-Guarciduenas, Lilian, et al., 'Air Pollution and Detrimental Effects on Children's Brain: The need for a multi-disciplinary approach to the issue complexity and challenges', Frontiers in Human Neuroscience, vol. 8, no. 613, 2014.
5. World Health Organization, 'Air Pollution Levels Rising in Many of the World's Poorest Cities', 2016, accessed 11 July 2016.
6. Organisation for Economic Co-operation and Development, 'OECD Environmental Outlook to 2050: The consequences of inaction', OECD Publishing, 2012, 276.
7. Lelieveld, J., et al., 'The Contribution of Outdoor Air Pollution Sources to Premature Mortality on a Global Scale', Nature, vol. 525, no. 7569, 2015, pp. 367–71.
8. Schwartz, Joel, 'Air Pollution and Children's Health', Pediatrics, 2001, accessed 13 July 2016.
9. World Health Organization – Regional Office for Europe, 'What Are the Effects of Air Pollution on Children's Health and Development?', 2005, accessed 18 July 2016.
10. Ritz, Beate, and Michelle Wilhelm, 'Air Pollution Impacts on Infants and Children', UCLA Institute of the Environment and Sustainability, 2008.
11. Columbia University, 'Incidents Affecting Children', 2005, accessed 27 July 2016.
12. Agency for Toxic Substances and Disease Registry, 'Your Child's Environmental Health: How the body works – Differences between adults and children', 2002, accessed 11 July 2016.
13. Simon, Katharina, Georg Hollander, and Andrew McMichael, 'Evolution of the Immune System in Humans from Infancy to Old Age', Royal Society Publishing, vol. 282, no. 1821, 2015.
14. American Lung Association, 'State of the Air 2016', American Lung Association, 2016.
15. Stocks, Janet, and Samantha Sonappa, 'Early Life Influences on the Development of Chronic Obstructive Pulmonary Disease', Therapeutic Advances in Respiratory Disease, vol. 7, no. 3, 2013, pp, 161–173.
16. World Health Organization, 'Ambient (Outdoor) Air Quality and Health', 2014, accessed 11 July 2016.
17. World Health Organization, 'Global Health Observatory Visualizations', 2012, accessed 11 July 2016.
18. Ibid.
19. Bruckner, Markus, 'Economic Growth, Size of the Agricultural Sector, and Urbanization in Africa', Journal of Urban Economics, vol. 7, no. 1, 2012.
20. United Nations Economic Commission on Africa, 'Economic Report on Africa', 2016, accessed 14 July 2016.
21. Curnow, Robin, and Teo Kermeliotis, 'The Daily Grind of Commuting in Africa's Economic Hubs', 2012, CNN.
22. You, Danzhen, and David Anthony, 'Generation 2025 and Beyond: The critical importance of understanding demographic trends for children of the 21st century', United Nations Children's Fund, 2012.
23. Ritz, Beate, and Michelle Wilhelm, 'Air Pollution Impacts on Infants and Children', UCLA Institute of the Environment and Sustainability, 2008.
24. Kjellstrom, Tord, et al., 'Urban Environmental Health Hazards and Health Equity', Journal of Urban Health, vol. 84, no. 1, 2007, pp. 86–97.
25. World Bank, 'Solid Fuel Use: World Health Organization Global Health Observatory data repository', accessed 14 July 2016.
26. Ibid.
27. The Lancet, 'Household Air Pollution Puts More than 1 in 3 People at Risk of Ill Health and Early Death', ScienceDaily, 2014, last modified 2 September 2014.
28. Flynn, Elizabeth, et al., 'Indoor Air Pollutants Affecting Child Health', A Project of the American College of Medical Toxicology, Funded by a Cooperative Agreement with the U.S. Agency for Toxic Substances and Disease Registry, 2000.
29. Avol, E. L., et al., 'Respiratory Effects of Relocating to Areas of Differing Air Pollution Levels', US National Library of Medicine National Institutes of Health, vol. 1, no. 164, 2001, pp. 2067–2072.
30. Frye, Christian, et al., 'Association of Lung Function with Declining Ambient Air Pollution', Environmental Health Perspectives, vol. 111, no. 3, 2003, pp. 383–387.
31. Heinrich, Joachim, Bernd Hoelscher, and H. Wichmann, 'Decline of Ambient Air Pollution and Respiratory Symptoms in Children', American Journal of Respiratory and Critical Care Medicine, vol. 161, no. 6, 200, pp. 1930–1936.
32. Apte, Joshua, et al., 'Addressing Global Mortality from Ambient PM2.5', Environmental Science and Technology, vol. 49, 2015, p. 8062.
33. See chapter 5 for references.
34. Organisation for Economic Co-operation and Development, 'The Economic Consequences of Outdoor Air Pollution', OECD Publishing, 2016.
35. World Bank, 'The Cost of Air Pollution: Strengthening the economic case for action', 2016.

CHAPTER 1: AIR POLLUTION CAUSES AND TRENDS

1. Williams, Matt, 'What Causes Air Pollution?', Universe Today, 2016, accessed 12 July 2016.
2. World Wildlife Foundation, 'Palm Oil and Air Pollution', 2016, accessed 12 July 2016.
3. Stoiber, Richard, and Anders Jepsen, 'Sulphur Dioxide Contributions to the Atmosphere by Volcanoes', Science, vol. 182, no. 4112, 1973, pp. 577–578.
4. Thorsteinsson, Throstur, et al., 'Dust Storm Contributions to Airborne Particulate Matter in Reykjavík, Iceland', Atmospheric Environment, vol. 45, no. 32, 2011, pp. 5924–5933.
5. Samson, Perry, 'Atmospheric Transport and Dispersion of Air Pollutants Associated with Vehicular Emissions', National Academies Press, 1988.
6. World Health Organization, 'Air Pollution Levels Rising in Many of the World's Poorest Cities', 2016, accessed 11 July 2016.
7. United Nations Department of Economic and Social Affairs, 'Population Facts: Our urbanizing world', 2014.
8. Organisation for Economic Co-operation and Development, 'OECD Environmental Outlook to 2050: The consequences of inaction', OECD Publishing, 2012, p. 276.
9. European Environment Agency, 'Air Quality in Europe: 2014 report', 2014.
10. Environmental Integrity Project, 'America's Top Power Plant Toxic Air Polluters', 2011.
11. Greenpeace India, 'Clean Air Action Plan: The way forward', 2016, accessed 15 July 2016.
12. 'China Pollution Levels Hit 20 Times Safe Limit', The Guardian, 2014, accessed 11 August 2016.
13. Hove, Anders, Lauri Myllyvirta, and Calvin Quek, 'Beijing Blue Skies: Is this the new normal?', Paulson Institute, 2015.
14. World Health Organization, 'WHO Global Urban Ambient Air Pollution Database', 2016, accessed 11 August 2016.
15. Alternative Fuels Data Center, 'Emissions from Hybrid and Plug-in Electric Vehicles', 2016, last modified 13 June 2016.
16. World Health Organization, 'Household Air Pollution and Health', 2016, accessed 12 July 2016.
17. United States Environmental Protection Agency, 'Biological Pollutants Impact on Indoor Air Quality', 2015, accessed 2 August 2016.
18. Bluepoint Environmental,. 'Air Quality Pollution Sources', 2012, accessed 2 August 2016.
19. World Health Organization, 'Public Health and Environment (PHE): Household air pollution – Population using solid fuels (%), 2013', 2013, accessed 11 August 2016.
20. World Health Organization, 'Household Air Pollution: Burden of disease by country', 2012, accessed 18 July 2016.
21. World Health Organization, 'Household Air Pollution and Health', 2016, accessed 12 July 2016.
22. California Environmental Protection Agency, 'Air Pollution: Particulate matter brochure', 2009, accessed 12 July 2016.
23. World Health Organization, 'Ambient (Outdoor) Air Quality and Health', accessed 2 August 2016.
24. United States Environmental Protection Agency, 'Fine Particle (PM2.5) Designations', 2016, accessed 12 July 2016.
25. United States Environmental Protection Agency, 'Ozone Pollution', 2016, accessed 12 July 2016.
26. The National Institute of Environmental Health Sciences: National Institutes of Health, 'Ozone Alerts', accessed 12 July 2016.
27. United States Environmental Protection Agency, 'Health Effects of Ozone in Patients with Asthma and Other Chronic Respiratory Disease', 2016, accessed 3 August 2016.
28. Lelieveld, J., et al., 'The Contribution of Outdoor Air Pollution Sources to Premature Mortality on a Global Scale', Nature, vol. 525, no. 7569, 2015, pp. 367–371.
29. Hamilton County Department of Environmental Sciences, 'Nitrogen Oxides', accessed 2 August 2016.
30. Agency for Toxic Substances and Disease Registry, 'Polycyclic Aromatic Hydrocarbons (PAHs)', 1995, accessed 12 July 2016.
31. Miguel, Antonio, et al., 'On Road Emissions of Particulate Polycyclic Aromatic Hydrocarbons and Black Carbon from Gasoline and Diesel Vehicles', Environmental Science and Technology, vol. 32, no. 4, 1998, pp. 450–455.
32. Jedrychowski, W., et al., 'Prenatal Ambient Air Exposure to Polycyclic Aromatic Hydrocarbons and the Occurrence of Respiratory Symptoms over the First Year of Life', European Journal of Epidemiology, vol. 20, no. 9, 2005, pp. 775–782.
33. Perera F. P., et al., 'Effect of Prenatal Exposure to Airborne Polycyclic Aromatic Hydrocarbons on Neurodevelopment in the First 3 years of Life among Inner-city Children', Environmental Health Perspectives, 2006.
34. Department of the Environment and Heritage, Government of Australia, 'Sulfur Dioxide (SO2)', 2005, accessed 14 July 2016.
35. Queensland Government, 'Sulphur Dioxide', Hamilton County Department of Environmental Sciences, 2013, accessed 3 August 2016.
36. Ibid.
37. Johnke, Bernt, 'Emission from Waste Incineration',' Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, accessed 3 August 2016.
38. Halley, Geoff, 'Boiler/Burner Combustion Air Supply Requirements and Maintenance', The National Board of Boiler and Pressure Vessel Inspectors, 1998, accessed 3 August 2016.
39. World Health Organization, 'Health Effects of Exposure to Carbon Monoxide, CO', 1999, accessed 3 August 2016.
40. Medline Plus, 'Carbon Monoxide Poisoning', accessed 12 July 2016.

41. Nalbandian, Hermine, 'Trace Element Emissions from Coal', IEA Clean Coal Center, 2012.
42. Government of Saskatchewan, 'Health and Environmental Effects of Open Burning of Refuse and Other Solid Wastes', 2016, accessed 2 August 2016.
43. World Health Organization, 'Ambient (Outdoor) Air Quality and Health', accessed 11 July 2016.
44. According to the WHO guidelines, "given that there is substantial inter-individual variability in exposure and in the response in a given exposure, it is unlikely that any standard or guideline value will lead to complete protection for every individual against all possible adverse health effects of particulate matter. Rather, the standard-setting process needs to aim at achieving the lowest concentrations possible in the context of local constraints, capabilities and public health priorities."
45. US Environmental Protection Agency. "Volatile Organic Compounds' Impact on Indoor Air Quality." Accessed Oct 21, 2016. <https://www.epa.gov/indoor-air-quality-iaq/volatile-organic-compounds-impact-indoor-air-quality>
46. US Environment Protection Agency. "Ammonia". Accessed Oct 21, 2016. <https://www3.epa.gov/caddis/ssr_amm_int.html>

CHAPTER 2: IMPACT OF AIR POLLUTION ON CHILDREN

1. World Health Organization, 'Burden of Disease from Household Air Pollution for 2012: Summary of results', 2014, accessed 20 July 2016.
2. World Health Organization, 'Global Health Observatory (GHO) data', accessed 20 July 2016.
3. Darrow, Lyndsey, et al., 'Air Pollution and Acute Respiratory Infections among Children 0–4 Years of Age: An 18-year time-series study', American Journal of Epidemiology, vol. 180, no. 10, 2014, pp. 968–977.
4. World Health Organization, 'Burden of Disease from Household Air Pollution for 2012', 2014, accessed 18 July 2016.
5. World Health Organization, 'Ambient (Outdoor) Air Quality and Health', accessed 18 July 2016.
6. Bell, Michelle, Antonella Zanobetti, and Francesca Dominici, 'Evidence on Vulnerability and Susceptibility to Health Risks Associated with Short-Term Exposure to Particulate Matter: A systematic review and meta-analysis', American Journal of Epidemiology, 2013.
7. Thurston, G. D., et al., 'Ambient Particulate Matter Air Pollution Exposure and Mortality in the NIH-AARP Diet and Health Cohort', Environmental Health Perspectives, vol. 124, 2016, pp. 484–490.
8. World Helath Organization., 'Air Pollution Levels Rising in Many of the World's Poorest Cities', 2016.
9. Lelieveld, J., et al., 'The Contribution of Outdoor Air Pollution Sources to Premature Mortality on a Global Scale', Nature, vol. 525, no. 7569, 2015, pp. 367–71.
10. Organisation for Economic Co-operation and Development, 'Air Pollution to Cause 6–9 Million Premature Deaths and Cost 1% GDP by 2060', OECD, 2016, accessed 12 July 2016.
11. World Health Organization, 'Burden of Disease: Data by region', accessed 18 July 2016.
12. World Health Organization, 'Air Quality Guidelines: Global update 2005', 2005, accessed 18 July 2016.
13. Ibid.
14. MacIntyre, E., et al., 'Air Pollution and Respiratory Infections during Early Childhood: An analysis of 10 European birth cohorts within the ESCAPE Project', Environmental Health Perspectives, vol. 122, no. 1, 2014, pp. 107–113.
15. Ritz, Beate, and Michelle Wilhelm, 'Air Pollution Impacts on Infants and Children', UCLA Institute of the Environment and Sustainability, 2008.
16. Leischer N. L., et al., 'Outdoor Air Pollution, Preterm Birth, and Low Birth Weight: Analysis of the World Health Organization Global Survey on Maternal and Perinatal Health', Environmental Health Perspectives, vol. 122, 2014, pp. 425–430.
17. Hyunok, Choi, et al., 'Prenatal Exposure to Airborne Polycyclic Aromatic Hydrocarbons and Risk of Intrauterine Growth Restriction', Environmental Health Perspectives, vol. 116, no. 5, 2008, pp. 658–665.
18. Pedersen, Marie, et al. 'Ambient Air Pollution and Low Birthweight: A European cohort study (ESCAPE)"', The Lancet Respiratory Medicine, vol. 1, no. 9, 2013, pp. 695–704.
19. Guarnieri, Michael, et al., 'Outdoor Air Pollution and Asthma', The Lancet, vol. 383, no. 9928, 2014, pp. 1581–1592
20. Chen, Z., et al., 'Chronic Effects of Air Pollution on Respiratory Health in Southern California Children: Findings from the Southern California Children's Health Study', Journal of Thoracic Disease, vol. 7, no. 1, 2015, pp. 46–58.
21. Marks, Guy, et al., 'The Global Asthma Report 2014: Global burden of disease due to asthma', Global Asthma Network, accessed 2 August 2016.
22. World Health Organization, 'Bronchial Asthma', accessed 12 July 2016.
23. World Health Organization, 'Indoor Air Pollution: Health effects', accessed 2 August 2016.
24. Kelly, Frank, 'Oxidative Stress: Its role in air pollution and adverse health effects', Occupational and Environmental Medicine, vol. 60, no. 8, 2003, pp. 612–616.

25. Royal College of Physicians, 'Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
26. World Health Organization/United Nations Children's Fund, 'Ending Preventable Child Deaths from Pneumonia and Diarrhoea by 2025: The Integrated Global Action Plan for pneumonia and diarrhoea', 2013.
27. Simkhovich, B., M. Kleinman, and R. Kloner, 'Particulate Matter and Coronary Heart Disease', Current Opinion in Cardiology, vol. 24, no. 6, 2009, pp. 604–609.
28. Simon, Stacy, 'World Health Organization: Outdoor air pollution causes cancer', American Cancer Society, 2013.
29. Meo, S. A., et al., 'Effect of Environmental Air Pollution on Type 2 Diabetes Mellitus', European Review for Medical and Pharmacological Sciences, vol. 19, no. 1, 2015, pp. 123–128.
30. Rajagopalan, Sanjay, and Robert Brook, 'Air Pollution and Type 2 Diabetes', Diabetes, vol. 61, no. 12, 2012, pp. 3037–3045.
31. Suglia, S. Franco, et al., 'Association of Black Carbon with Cognition among Children in a Prospective Birth Cohort Study', American Journal of Epidemiology, vol. 167, no. 3, 2007, pp. 280–286.
32. Grandjean, P., and P. J. Landrigan, 'Developmental Neurotoxicity of Industrial Chemicals', The Lancet, vol. 368, no. 9553, 2006, pp. 2167–2178.
33. Brockmeyer, Sam, and Amedeo D'Angiulli, 'How Air Pollution Alters Brain Development: The role of neuroinflammation', Translational Neuroscience, vol. 7, no. 1, 2006, pp. 24–30.
34. Grandjean, P., and P. J. Landrigan, 'Developmental Neurotoxicity of Industrial Chemicals', The Lancet, vol. 368, no. 9553, 2006, pp. 2167–2178.
35. Weir, Kirsten, 'Smog in Our Brains: Researchers are identifying startling connections between air pollution and decreased cognition and well-being', American Psychological Association Monitor on Psychology, vol. 43, no. 7, 2012, p. 32.
36. Royal College of Physicians, 'Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
37. European Commission, 'Science for Environment Policy: Green spaces linked to improved cognitive development in schoolchildren', European Commission DG Environment News Alert Service, 2015.
38. Mohai, Paul, et al., 'Air Pollution around Schools Is Linked to Poorer Student Health and Academic Performance', Health Affairs, vol. 30, no. 5, 2011, pp. 252–262.
39. Power, Melinda C., et al., 'Traffic-Related Air Pollution and Cognitive Function in a Cohort of Older Men', Environmental Health Perspectives, vol. 119, no. 5, 2010, pp. 682–687.
40. Calderón-Garcidueñas, Lilian, et al., 'Air Pollution and Detrimental Effects on Children's Brain: The need for a multidisciplinary approach to the issue complexity and challenges', Frontiers in Human Neuroscience, vol. 8, 2014, p. 613.
41. Sunyer, Jordi, et al., 'Association between Traffic-Related Air Pollution in Schools and Cognitive Development in Primary School Children: A prospective cohort study', PLOS Medicine, 2015, accessed 24 August 2016.
42. Oudin, Anna, et al., ''Association between Neighbourhood Air Pollution Concentrations and Dispensed Medication for Psychiatric Disorders in a Large Longitudinal Cohort of Swedish Children and Adolescents', BMJ Open, vol. 6, no. 6, 2016.
43. Freire, Carmen, et al., 'Association of Traffic-Related Air Pollution with Cognitive Development in Children', Journal of Epidemiology and Community Health, vol. 64, no. 3, 2010, pp. 223–228.
44. Levesque, S., et al., 'Air Pollution and the Brain: Subchronic diesel exhaust exposure causes neuroinflammation and elevates early markers of neurodegenerative disease', Journal of Neuroinflammation, vol. 8, no. 5, 2011.
45. Campbell, A., et al., 'Human Brain Derived Cells Respond in a Type-Specific Manner after Exposure to Urban Particulate Matter (PM)', Toxicology in Vitro, vol. 28, no. 7, 2014, pp. 1290–1295.
46. Chen, J. C., et al., 'Ambient Air Pollution and Neurotoxicity on Brain Structure: Evidence from Women's Health Initiative Memory Study', Annals of Neurology, vol. 78, no. 3, 2015, pp. 466–476.
47. Marcotte, Dave E., 'Something in the Air? Pollution, allergens and children's cognitive functioning', American University School of Public Affairs, draft, 2015.
48. Dadvand, Payam, et al., 'Green Spaces and Cognitive Development in Primary Schoolchildren', Proceedings of the National Academy of Sciences of the United States of America, vol. 112, no. 26, 2015, pp. 7937–7942.
49. Datz, Todd, 'Green Office Environments Linked with Higher Cognitive Function Scores', Harvard School of Public Health Press Release, 2015.
50. Lavy, Victor, Avraham Ebenstein, and Sefi Roth, 'The Impact of Short Term Exposure to Ambient Air Pollution on Cognitive Performance and Human Capital Formation', The National Bureau of Economic Research, Working Paper Number 20648, 2014.
51. Wilker, Elissa H., et al., 'Long-Term Exposure to Fine Particulate Matter, Residential Proximity to Major Roads and Measures of Brain Structure', Stroke, 2014, accessed 24 August 2016; doi: 10.1161/STROKEAHA.114.008348.
52. Physicians for Social Responsibility, 'How Air Pollution Damages the Brain', 2009.
53. Ranft, Ulrich, et al., 'Long-Term Exposure to Traffic-Related Air Pollution and Mild Cognitive Impairment in the Elderly', Epidemiology 20, no. 6, 2009, p. 22.
54. Sunyer, Jordi, et al., 'Association between Traffic-Related Air Pollution in Schools and Cognitive Development in Primary School Children: A prospective cohort study', PLoS Medicine, 2005, accessed 15 July 2016; doi:10.1371/journal.pmed.1001792.

55. Payam Dadvand, Mark J., et al., 'Green Spaces and Cognitive Development in Primary Schoolchildren', Proceedings of the National Academy of Sciences, vol. 112, no. 26, 2015, pp. 7937–7942.
56. Liu, Jianghong, and Gary Lewis, 'Environmental Toxicity and Poor Cognitive Outcomes in Children and Adults', Journal of Environmental Health, vol. 76, no. 6, 2014, pp. 130–138.
57. Paul, Mohai, et al., 'Air Pollution around Schools Is Linked to Poorer Student Health and Academic Performance', Health Affairs, vol. 30, no. 5, 2011, pp. 852–862.
58. Science Daily, 'Air Pollution Linked to Children's Low Academic Achievement', 2015.
59. Miller, Sebastian, and Mauricio Vela, 'The Effects of Air Pollution on Educational Outcomes: Evidence from Chile', Inter-American Development Bank, 2013.
60. Zweig, Jacqueline S., John C. Ham, and Edward L. Avol, 'Air Pollution and Academic Performance: Evidence from California schools', College Park, University of Maryland, 2009.
61. Royal College of Physicians, 'Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
62. Peterson, B. S., et al., 'Effects of Prenatal Exposure to Air Pollutants (Polycyclic Aromatic Hydrocarbons) on the Development of Brain White Matter, Cognition, and Behavior in Later Childhood', JAMA Psychiatry, vol. 72, no. 6, 2015, pp. 531–540.
63. Perera, Frederica P., et al., 'Prenatal Polycyclic Aromatic Hydrocarbon (PAH) Exposure and Child Behavior at Age 6–7', Environmental Health Perspectives, 2012, accessed 11 July 2016.
64. Park, Alice, 'How Air Pollution Affects Babies in the Womb', Time Magazine, 2016.
65. Grandjean, Philippe, and Philip J. Landrigan, 'Neurobehavioural Effects of Developmental Toxicity', The Lancet Neurology, 2014.
66. Tang, G., et al., 'Loss of mTOR-dependent Macroautophagy Causes Autistic-like Synaptic Pruning Deficits', Neuron, vol. 83, no. 5, 2015, pp. 1131–1143.
67. Vishnevetsky, Julia, et al., 'Combined Effects of Prenatal Polycyclic Aromatic Hydrocarbons and Material Hardship on Child IQ', Neurotoxicology and Teratology, vol. 49, 2015, pp. 74–80.
68. McKenzie J., L. Bhatti, and E. Tursan d'Espaignet, 'WHO Tobacco Knowledge Summaries: Tobacco and dementia', World Health Organization, 2014.
69. Samet J. M, and S. Y. Yoon, eds., 'Gender, Women and the Tobacco Epidemic', World Health Organization, 2010.
70. World Health Organization, Fact Sheet: Lead poisoning and health, <www.who.int/mediacentre/factsheets/fs379/en>.
71. Ibid.
72. Ibid.
73. Ibid.
74. Ibid.
75. Ibid.
76. Ibid.
77. Tsai, P., and T. Hatfield, 'Global Benefits from the Phaseout of Leaded Fuel', Journal of Environmental Health, vol. 74, no. 5, December 2011.
78. Schwartz, Joel, 'Air Pollution and Children's Health', Pediatrics, vol. 113, no. 3, 2004, pp. 1037–1043.
79. Royal College of Physicians, 'Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
80. Peterson, B. S., et al., 'Effects of Prenatal Exposure to Air Pollutants (Polycyclic Aromatic Hydrocarbons) on the Development of Brain White Matter, Cognition, and Behavior in Later Childhood', JAMA Psychiatry, vol. 72, no. 6, 2015, pp. 531–540.
81. Royal College of Physicians, "Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
82. Koenig, Jane, 'Air Pollution and Asthma', Journal of Allergy and Clinical Immunology, vol. 104, no. 4, 1999, pp. 717–722.
83. Chen, Z., et al., 'Chronic Effects of Air Pollution on Respiratory Health in Southern California Children: Findings from the Southern California Children's Health Study', Journal of Thoracic Disease, vol. 7, no. 1, 2015, pp. 46–58.
84. World Health Organization – Regional Office for Europe, 'What Are the Effects of Air Pollution on Children's Health and Development?', accessed 18 July 2016.
85. Lee, Byeong-Jae, Bumseok Kim, and Kyuhong Lee, 'Air Pollution Exposure and Cardiovascular Disease', Toxicology Research, vol. 30, no. 2, 2014, pp. 71–75.
86. Tinuoye, O., J. Pell, and D. Mackay, 'Meta-analysis of the Association between Secondhand Smoke Exposure and Physician-Diagnosed Childhood Asthma', Nicotine and Tobacco Research, vol. 15, no. 9, 2013, pp. 1475–1483.
87. Ibid.
88. Mackay, D., et al., 'Smoke-free Legislation and Hospitalizations for Childhood Asthma', New England Journal of Medicine, vol. 16, no. 363, 2010, pp. 1139–1145.
89. Government of Saskatchewan, "Health and Environmental Effects of Open Burning of Refuse and Other Solid Wastes', 2016, accessed 2 August 2016.
90. NCAR Earth System Laboratory, 'Emissions of Particulates, Greenhouse Gases, and Air Pollutants from Open Waste Burning', 2014, accessed 2 August 2016.
91. United Nations Environment Programme, 'Actions on Air Quality', 2014.
92. United Nations Environment Programme, 'Waste Burning Graph', United Nations Environment Programme, accessed 13 July 2016.

93. Perkins, Devin, et al., 'E-Waste: A global hazard', Annals of Global Health, vol. 80, no. 4, 2014, pp. 286–295.
94. United Nations Habitat, 'State of the World's Cities 2010/2011: Cities for All – Bridging the urban divide', United Nations Habitat, 2008.
95. Greenpeace, 'Where Does E-Waste End Up?', 2009.
96. Center for International Environmental Law, 'Human Rights Impacts of E-Waste', 2015, accessed 13 July 2016.
97. Ibid.
98. World Bank, 'What a Waste: A global review of solid waste management', 2012, accessed 13 July 2016.
99. United Nations Environmental Programme, 'Global Waste Management Outlook', 2015.

Figure 9 (page 27):

I. WHO website http://www.who.int/indoorair/health_impacts/disease/en/
II. Chan SH, Van Hee VC, Bergen S, Szpiro AA, DeRoo LA, London SJ, Marshall JD, Kaufman JD, Sandler DP. 2015. Long-term air pollution exposure and blood pressure in the Sister Study. Environ Health Perspect 123:951–958; http://ehp.niehs.nih.gov/1408125/
III. WHO website http://www.who.int/mediacentre/factsheets/fs313/en/
IV. Centers for Disease Control and Prevention website: http://ephtracking.cdc.gov/showAirContaminants.action#ozone
V. Centers for Disease Control and Prevention website: http://ephtracking.cdc.gov/showAirContaminants.action#ozone
VI. WHO website http://www.who.int/mediacentre/factsheets/fs292/en/
VII. WHO website http://www.who.int/mediacentre/factsheets/fs313/en/
VIII. WHO website http://www.who.int/mediacentre/factsheets/fs313/en/
IX. WHO website http://www.who.int/mediacentre/factsheets/fs292/en/
X. Paulin L and Hansel N. Particulate air pollution and impaired lung function [version 1; referees: 3 approved]. F1000Research 2016, 5(F1000 Faculty Rev):201 https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4765726/
XI. IARC website https://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf, WHO website http://www.who.int/mediacentre/factsheets/fs292/en/
XII. See pg 29 to 30, including:

Suglia, S. Franco, et al., 'Association of Black Carbon with Cognition among Children in a Prospective Birth Cohort Study', American Journal of Epidemiology, vol. 167, no. 3, 2007, pp. 280–286.
Grandjean, P., and P. J. Landrigan, 'Developmental Neurotoxicity of Industrial Chemicals', The Lancet, vol. 368, no. 9553, 2006, pp. 2167–2178.
Brockmeyer, Sam, and Amedeo D'Angiulli, 'How Air Pollution Alters Brain Development: The role of neuroinflammation', Translational Neuroscience, vol. 7, no. 1, 2006, pp. 24–30.
Grandjean, P., and P. J. Landrigan, 'Developmental Neurotoxicity of Industrial Chemicals', The Lancet, vol. 368, no. 9553, 2006, pp. 2167–2178.
Weir, Kirsten, 'Smog in Our Brains: Researchers are identifying startling connections between air pollution and decreased cognition and well-being', American Psychological Association Monitor on Psychology, vol. 43, no. 7, 2012, p. 32.
Royal College of Physicians, 'Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
European Commission, 'Science for Environment Policy: Green spaces linked to improved cognitive development in schoolchildren', European Commission DG Environment News Alert Service, 2015.
Mohai, Paul, et al., 'Air Pollution around Schools Is Linked to Poorer Student Health and Academic Performance', Health Affairs, vol. 30, no. 5, 2011, pp. 252–262.
Power, Melinda C., et al., 'Traffic-Related Air Pollution and Cognitive Function in a Cohort of Older Men', Environmental Health Perspectives, vol. 119, no. 5, 2010, pp. 682–687.
Calderón-Garcidueñas, Lilian, et al., 'Air Pollution and Detrimental Effects on Children's Brain: The need for a multidisciplinary approach to the issue complexity and challenges', Frontiers in Human Neuroscience, vol. 8, 2014, p. 613.
Sunyer, Jordi, et al., 'Association between Traffic-Related Air Pollution in Schools and Cognitive Development in Primary School Children: A prospective cohort study', PLOS Medicine, 2015, accessed 24 August 2016.
Oudin, Anna, et al., ''Association between Neighbourhood Air Pollution Concentrations and Dispensed Medication for Psychiatric Disorders in a Large Longitudinal Cohort of Swedish Children and Adolescents', BMJ Open, vol. 6, no. 6, 2016.
Freire, Carmen, et al., 'Association of Traffic-Related Air Pollution with Cognitive Development in Children', Journal of Epidemiology and Community Health, vol. 64, no. 3, 2010, pp. 223–228.
Levesque, S., et al., 'Air Pollution and the Brain: Subchronic diesel exhaust exposure causes neuroinflammation and elevates early markers of neurodegenerative disease', Jour- nal of Neuroinflammation, vol. 8, no. 5, 2011.
Campbell, A., et al., 'Human Brain Derived Cells Respond in a Type-Specific Manner after Exposure to Urban Particulate Matter (PM)', Toxicology in Vitro, vol. 28, no. 7, 2014, pp. 1290–1295.
Chen, J. C., et al., 'Ambient Air Pollution and Neurotoxicity on Brain Structure: Evidence from Women's Health Initiative Memory Study', Annals of Neurology, vol. 78, no. 3,

2015, pp. 466–476.
Marcotte, Dave E., 'Something in the Air? Pollution, allergens and children's cognitive functioning', American University School of Public Affairs, draft, 2015.
Dadvand, Payam, et al., 'Green Spaces and Cognitive Development in Primary Schoolchildren', Proceedings of the National Academy of Sciences of the United States of Ameri- ca, vol. 112, no. 26, 2015, pp. 7937–7942.
Datz, Todd, 'Green Office Environments Linked with Higher Cognitive Function Scores', Harvard School of Public Health Press Release, 2015.
Lavy, Victor, Avraham Ebenstein, and Sefi Roth, 'The Impact of Short Term Exposure to Ambient Air Pollution on Cognitive Performance and Human Capital Formation', The National Bureau of Economic Research, Working Paper Number 20648, 2014.
Wilker, Elissa H., et al., 'Long-Term Exposure to Fine Particulate Matter, Residential Proximity to Major Roads and Measures of Brain Structure', Stroke, 2014, accessed 24 August 2016; doi: 10.1161/STROKEAHA.114.008348.
Physicians for Social Responsibility, 'How Air Pollution Damages the Brain', 2009.
Ranft, Ulrich, et al., 'Long-Term Exposure to Traffic-Related Air Pollution and Mild Cognitive Impairment in the Elderly', Epidemiology 20, no. 6, 2009, p. 22.
Sunyer, Jordi, et al., 'Association between Traffic-Related Air Pollution in Schools and Cognitive Development in Primary School Children: A prospective cohort study', PLoS Medi- cine, 2005, accessed 15 July 2016; doi:10.1371/journal.pmed.1001792.
Payam Dadvand, Mark J., et al., 'Green Spaces and Cognitive Development in Primary Schoolchildren', Proceedings of the National Academy of Sciences, vol. 112, no. 26, 2015, pp. 7937–7942.
Liu, Jianghong, and Gary Lewis, 'Environmental Toxicity and Poor Cognitive Outcomes in Children and Adults', Journal of Environmental Health, vol. 76, no. 6, 2014, pp. 130–138.
Paul, Mohai, et al., 'Air Pollution around Schools Is Linked to Poorer Student Health and Academic Performance', Health Affairs, vol. 30, no. 5, 2011, pp. 852–862.
Science Daily, 'Air Pollution Linked to Children's Low Academic Achievement', 2015.
Miller, Sebastian, and Mauricio Vela, 'The Effects of Air Pollution on Educational Outcomes: Evidence from Chile', Inter-American Development Bank, 2013.
Zweig, Jacqueline S., John C. Ham, and Edward L. Avol, 'Air Pollution and Academic Performance: Evidence from California schools', College Park, University of Maryland, 2009.
Royal College of Physicians, 'Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
Peterson, B. S., et al., 'Effects of Prenatal Exposure to Air Pollutants (Polycyclic Aromatic Hydrocarbons) on the Development of Brain White Matter, Cognition, and Behavior in Later Childhood', JAMA Psychiatry, vol. 72, no. 6, 2015, pp. 531–540.
Perera, Frederica P., et al., 'Prenatal Polycyclic Aromatic Hydrocarbon (PAH) Exposure and Child Behavior at Age 6–7', Environmental Health Perspectives, 2012, accessed 11 July 2016.
Grandjean, Philippe, and Philip J. Landrigan, 'Neurobehavioural Effects of Developmental Toxicity', The Lancet Neurology, 2014.
Tang, G., et al., 'Loss of mTOR-dependent Macroautophagy Causes Autistic-like Synaptic Pruning Deficits', Neuron, vol. 83, no. 5, 2015, pp. 1131–1143.
Vishnevetsky, Julia, et al., 'Combined Effects of Prenatal Polycyclic Aromatic Hydrocarbons and Material Hardship on Child IQ', Neurotoxicology and Teratology, vol. 49, 2015, pp. 74–80.

XIII. Ambient air pollution and low birthweight: a European cohort study (ESCAPE) Pedersen, Marie et al. The Lancet Respiratory Medicine , Volume 1 , Issue 9 , 695 - 704
XIV. Fleischer NL, Merialdi M, van Donkelaar A, Vadillo-Ortega F, Martin RV, Betran AP, Souza JP, O'Neill MS. 2014. Outdoor air pollution, preterm birth, and low birth weight: analysis of the World Health Organization Global Survey on Maternal and Perinatal Health. Environ Health Perspect 122:425–430; http://dx.doi.org/10.1289/ehp.1306837
XV. WHO website http://www.who.int/indoorair/health_impacts/disease/en/

Figure 12 (page 33):

I. Ambient air pollution and low birthweight: a European cohort study (ESCAPE) Pedersen, Marie et al. The Lancet Respiratory Medicine , Volume 1 , Issue 9 , 695 - 704
II. Fleischer NL, Merialdi M, van Donkelaar A, Vadillo-Ortega F, Martin RV, Betran AP, Souza JP, O'Neill MS. 2014. Outdoor air pollution, preterm birth, and low birth weight: analysis of the World Health Organization Global Survey on Maternal and Perinatal Health. Environ Health Perspect 122:425–430; http://dx.doi.org/10.1289/ehp.1306837
III. WHO website http://www.who.int/indoorair/health_impacts/disease/en/
IV. WHO website http://www.who.int/mediacentre/factsheets/fs313/en/
V. Centers for Disease Control and Prevention website: http://ephtracking.cdc.gov/showAirContaminants.action#ozone
VI. Centers for Disease Control and Prevention website: http://ephtracking.cdc.gov/showAirContaminants.action#ozone
VII. WHO website http://www.who.int/mediacentre/factsheets/fs313/en/
VIII. WHO website http://www.who.int/mediacentre/factsheets/fs313/en/
IX. WHO website http://www.who.int/mediacentre/factsheets/fs292/en/

X. IARC website https://www.iarc.fr/en/media-centre/pr/2012/pdfs/pr213_E.pdf
XI. Park, Alice. "How Air Pollution Affects Babies in the Womb." Time Publication Date: March 25, 2015 website http://time.com/3757864/air-pollution-babies/
XII. WHO website http://www.who.int/indoorair/health_impacts/disease/en/
XIII. Chan SH, Van Hee VC, Bergen S, Szpiro AA, DeRoo LA, London SJ, Marshall JD, Kaufman JD, Sandler DP. 2015. Long-term air pollution exposure and blood pressure in the Sister Study. Environ Health Perspect 123:951–958; http://ehp.niehs.nih.gov/1408125/
XIV. Meo SA, Memon AN, Sheikh SA, Rouq FA, Usmani AM, Hassan A, Arian SA. Effect of environmental air pollution on type 2 diabetes mellitus. Eur Rev Med Pharmacol Sci. 2015 Jan;19(1):123-8.
XV. WHO website http://www.who.int/mediacentre/factsheets/fs292/en/

CHAPTER 3: UNIQUE VULNERABILITIES OF CHILDREN

1. Schwartz, Joel, 'Air Pollution and Children's Health', Pediatrics, vol. 113, no. 3, 2004, pp. 1037–1043.
2. Columbia University School of Nursing, 'Incidents Affecting Children', accessed 13 July 2016.
3. World Health Organization, 'Pneumonia', accessed 13 July 2016.
4. WebMD, 'Asthma Health Center', accessed 13 July 2016.
5. American Lung Association, 'Air Pollution and Children's Health', 2003, accessed 13 July 2016.
6. Gearhart, J., and R. Schlesinger, 'Response of the Tracheobronchial Mucociliary Clearance System to Repeated Irritant Exposure: Effect of sulfuric acid mist on function and structure', Experimental Lung Research, vol. 14, no. 5, 1988, pp. 587–605.
7. American Lung Association, 'Children and Air Pollution', accessed 13 July 2016.
8. National Aeronautics and Space Administration, 'Earth Observatory: The ozone we breathe', accessed 13 July 2016.
9. Wonodi, Chizoba B., et al., and the Pneumonia Methods Working Group and PERCH Site Investigators, 'Evaluation of Risk Factors for Severe Pneumonia in Children: The pneumonia etiology research for child health study', Clinical Infectious Diseases, vol. 54, pp. 124–131.
10. Po, J. Y., J. M. FitzGerald, and C. Carlsten, 'Respiratory Disease Associated with Solid Biomass Fuel Exposure in Rural Women and Children: Systematic review and meta-analysis', Thorax, vol. 66, 2011, pp. 232–239.
11. Royal College of Physicians, 'Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
12. Bergeson, P., and J. Shaw, "Are Infants Really Obligatory Nasal Breathers?," Clinical Pediatrics, vol. 40, 2001, pp. 567–569.
13. Schwartz, Joel, 'Air Pollution and Children's Health', Pediatrics, vol. 113, no. 3, 2004, pp. 1037–1043.
14. Wiley, David, and Amy Cory, 'Encyclopedia of School Health', Sage Publications, 2013, p. 222.
15. Columbia University School of Nursing, 'Incidents Affecting Children', accessed 13 July 2016.
16. Dasgupta, Susmita, et al., 'Who Suffers from Indoor Air Pollution? Evidence from Bangladesh', Oxford University Press, 2006.
17. British Columbia Air Quality, 'How Air Quality Affects Health', accessed 18 July 2016.
18. O'Neill, M., et al., 'Air Pollution and Health: Emerging information on susceptible populations', Air Quality Atmosphere and Health, vol. 5, no. 2, 2012, pp. 189–201.
19. United States Environmental Protection Agency, 'Ozone and Your Patient's Health', accessed 13 July 2016.
20. O'Neill, M., et al., 'Air Pollution and Health: Emerging information on susceptible populations', Air Quality Atmosphere and Health, vol. 5, no. 2, 2012, pp. 189–201.
21. Brandt, E., et al., 'Diesel Exhaust Particle Induction of IL-17A Contributes to Severe Asthma', Journal of Allergy and Clinical Immunology, vol. 132, no. 5, 2013, pp. 1194–1204.
22. Centers for Disease Control and Prevention, 'Ozone and Your Health', 2014.
23. World Health Organization, 'Ambient (Outdoor) Air Quality and Health', 2014, accessed 11 July 2016.
24. World Health Organization, 'Indoor Air Pollution', 2014, accessed 12 July 2016.
25. O'Neill, Marie S., et al., 'Air Pollution and Health: Emerging information on susceptible population', Air Quality, Atmosphere and Health, vol. 5, no. 2, 2012, pp. 189–201.
26. Centers for Disease Control and Prevention, 'Prescribed Fires and Air Quality', 2016.
27. Rajagopalan, Sanjay, and Robert Brook, 'Air Pollution and Type 2 Diabetes', Diabetes, vol. 61, no. 12, 2012, pp. 3037–3045.
28. O'Neill, Marie S., et al., 2012, 'Air Pollution and Health: Emerging information on susceptible populations', Air Quality, Atmosphere and Health, vol. 5, no. 2, 2012, pp. 189–201.
29. UNICEF, internal source.
30. City of Jaipur, 'Pollution Check and Control in the City of Jaipur', <www.cityofjaipur.com>, accessed 2 June 2016.
31. World Health Organization, 'Indoor Air Pollution', 2014, accessed 12 July 2016.

32. Dasgupta, Susmita, et al., 'Who Suffers from Indoor Air Pollution? Evidence from Bangladesh', Oxford University Press, 2006, p. 447.
33. Frutos, Victor, et al., 'Impact of Air Pollution on Fertility: A systematic review', Gynecological Endocrinology, vol. 31, no. 1, 2014, pp. 1–7.
34. Schwartz, Joel, 'Air Pollution and Children's Health', Pediatrics, vol. 113, no. 3, 2004, pp. 1037–1043, accessed 13 July 2016.
35. Ibid.
36. Goldizen, Fiona C., Peter D. Sly, and Luke D. Knibbs, 'Respiratory Effects of Air Pollution on Children', Pediatric Pulmonology, vol. 51, 2016, p. 99.
37. Enkhmaa, Davaasambuu, et al., 'Seasonal Ambient Air Pollution Correlates Strongly with Spontaneous Abortion in Mongolia', BMC Pregnancy and Childbirth, vol. 14, 2014, p. 146.
38. Harrison, Elizabeth, Jenelle Partelow, and Holly Grason, 'Environmental Toxicants and Maternal and Child Health: An emerging public health challenge', Johns Hopkins Bloomberg School of Public Health: Women's and Children's Health Policy Center, Baltimore, 2009.
39. Royal College of Physicians, 'Every Breath We Take: The lifelong impact of air pollution', Royal College of Physicians, 2016.
40. United Nations Children's Fund, 'Early Childhood Development: The Key to a Full and Productive Life', 2011.
41. Sbihi, Hind, et al., 'Perinatal Air Pollution Exposure and Development of Asthma from Birth to Age 10 Years', European Respiratory Journal, vol. 48, no. 1, 2016.
42. Rundle, Andrew, et al., 'Association of Childhood Obesity with Maternal Exposure to Ambient Air Polycyclic Aromatic Hydrocarbons during Pregnancy', American Journal of Epidemiology, vol. 175, no. 11, 2012, pp. 1163–1172.
43. Body Growth Rate in Preadolescent Children and Outdoor Air Quality', Environmental Research, vol. 90, no. 1, 2002, pp. 12–20.
44. Margolis, Amy E., et al., 'Longitudinal Effects of Prenatal Exposure to Air Pollutants on Self-regulatory Capacities and Social Competence', Journal of Child Psychology and Psychiatry, 2016; doi:10.1111/jcpp.12548.
45. World Health Organization, 'The Environment and Health for Children and Their Mothers', accessed 11 July 2016.
46. World Health Organization, 'Frequently Asked Questions: Ambient and household air pollution and health', 2014, accessed 11 July 2016.
47. Clark, Lara P., Dylan B. Milet, and Julian D. Marshall, 'National Patterns in Environmental Injustice and Inequality: Outdoor NO2 air pollution in the United States', PLoS One, 2014, accessed 11 July 2016.
48. Miranda, Marie Lynn, et al., 'Making the Environmental Justice Grade: The relative burden of air pollution exposure in the United States', International Journal of Environmental Research and Public Health, vol. 8, 2011, pp. 1755–1771.
49. Katz, Cheryl, 'Minorities, Poor Breathe Worse Air Pollution, Study Finds', Environmental Health News, 2012.
50. Sider, Timothy, et al., 'Smog and Socio-Economics: An evaluation of equity in traffic-related air pollution generation and exposure', University of Central Florida, Orlando, 2015.
51. Mehta, Sumi, et al., 'Effect of Poverty on the Relationship between Personal Exposures and Ambient Concentrations of Air Pollutants in Ho Chi Minh City', Atmospheric Environment, vol. 95, 2014, pp. 571–580.
52. United Nations Sustainable Development Goals, 'UN Health Agency Warns of Rise in Urban Air Pollution, with Poorest Cities Most at Risk', 2016, accessed 5 August 2016.
53. Ma, Chunbo, and Ethan Schoolman, 'Corrigendum to "Who Bears the Environmental Burden in China—An Analysis of the Distribution of Industrial Pollution Sources?" [Ecological Economics 69 (2010) 1869–1876]', Ecological Economics, vol. 70, 2011, p. 569
54. Schoolman, Ethan, and Chunbo Ma, 'Migration, Class, and Environmental Inequality: Exposure to pollution in China's Jiangsu Province', Ecological Economics, vol. 75, 2012, pp. 140–151.
55. Zhao, Xiaoli, Sufang Zhang, and Chunyang Fan, 'Environmental Externality and Inequality in China: Current status and future choices', Environmental Pollution, vol. 190, 2014, pp. 176–79.
56. Zheng, Siqi, et al., 'Real Estate Valuation and Cross-Boundary Air Pollution Externalities: Evidence from Chinese cities', Journal of Real Estate Finance and Economics, vol. 48, 2014, pp. 398–414.
57. Zheng, Siqi, et al., 'The Evolving Geography of China's Industrial Production: Implications for pollution dynamics and urban quality of life', Journal of Economic Surveys, vol. 28, no. 4, 2014, pp. 709–24.
58. International Energy Agency, 'World Energy Outlook 2006', 2006.
59. Smith, K. R., et al., 'Indoor Air Pollution in Developing Countries and Acute Lower Respiratory Infections in Children', Thorax, vol. 55, no. 6, 2000, pp. 518–532.
60. World Health Organization, 'Indoor Air Pollution: Health effects', accessed 11 July 2016.
61. World Bank, 'One Goal, Two Paths: Achieving universal access to modern energy in East Asia and Pacific', World Bank Publications, 2011.
62. Balakrishnana, Kalpana, et al., 'Exposure Assessment for Respirable Particulates Associated with Household Fuel Use in Rural Districts of Andhra Pradesh, India', Journal of Exposure Analysis and Environmental Epidemiology, vol. 14, 2004.
63. World Bank, "Solid Fuel Use: World Health Organization Global Health Observatory data repository; GDP per capita."
64. World Bank, 'Indoor Air Quality for Poor Families: New evidence from Bangladesh', 2004.
65. World Health Organization, 'Ambient (Outdoor) Air Quality and Health', accessed 11 July 2016.

66. World Health Organization, 'Ambient Air Pollution Attributable Deaths, by Region, 2012', 2012, accessed 11 July 2016.
67. GBD 2013 Collaborators, 'Global, Regional, and National Comparative Risk Assessment of 79 Behavioural, Environmental and Occupational, and Metabolic Risks or Clusters of Risks in 188 Countries, 1990–2013: A systematic analysis for the Global Burden of Disease Study 2013', The Lancet, vol. 396, no. 10010, 2015, pp. 2287–2323.
68. World Bank, 'The Cost of Air Pollution: Strengthening the Economic Case for Action', 2016.
69. GBD 2013 Collaborators, 'Global, Regional, and National Comparative Risk Assessment of 79 Behavioural, Environmental and Occupational, and Metabolic Risks or Clusters of Risks in 188 Countries, 1990–2013: A systematic analysis for the Global Burden of Disease Study 2013', The Lancet, vol. 396, no. 10010, 2015, pp. 2287–2323.
70. World Health Organization, 'Public Health and Environment (PHE): Household air pollution – Population using solid fuels (%), 2013', 2013, accessed 12 July 2016.
71. World Health Organization, 'Ambient Air Pollution Database', 2014, accessed 11 July 2016.
72. Castleman, B., 'The Export of Hazardous Factories to Developing Nations', International Journal of Health Services, vol. 9, no. 4, 1979, pp. 569–606.
73. World Health Organization, 'Ambient Air Pollution Attrirubtable Deaths, by Region, 2012', 2012, accessed 11 July 2016.
74. United Nations Framework Convention on Climate Change, Twenty-first Session, 'Adoption of the Paris Agreement', 2015.
75. Harris, Nancy, et al., 'With Latest Fire Crisis, Indonesia Surpasses Russia as World's Fourth-Largest Emitter', World Resources Institute, 2015.
76. University of Leicester, 'Peat fires: A legacy of carbon up in smoke', University of Leicester Press Release, 2015, accessed 12 October 2016.
77. Chisholm, Ryan, and Lahiru Wijedasa, 'The Need for Long-term Remedies for Indonesia's Forest Fires', Conservation Biology, vol. 30, 2016, pp. 5–6.
78. Ibid.
79. World Bank,'Indonesia's Fire and Haze Crisis', World Bank Press Release, 2015.
80. Lamb, Kate, 'Indonesia's Fires Labelled a 'Crime against Humanity' as 500,000 Suffer', The Guardian, 2015.
81. Ibid.
82. Chisholm, Ryan, and Lahiru Wijedasa, 'The Need for Long-term Remedies for Indonesia's Forest Fires', Conservation Biology, vol. 30, 2016, pp. 5–6.
83. World Bank, 'The Cost of Fire: An economic analysis of Indonesia's 2015 fire crisis', 2016.
84. Cai, Wendu, et al., 'Increasing Frequency of Extreme El Niño Events due to Greenhouse Warming', Nature Climate Change, 2014.
85. World Health Organization, 'Burden of Disease from Household Air Pollution for 2012: Summary of results', 2014, accessed 28 July 2016.
86. World Health Organization, 'Household Air Pollution and Health', accessed 28 July 2016.
87. Ibid.
88. Global Alliance for Clean Cookstoves, 'Country Profile: Bangladesh', accessed 3 October 2016.
89. Mobarak, Ahmed Mushfiq, et al., 'Low Demand for Nontraditional Cookstove Technologies', Proceedings of the National Academy of Sciences of the United States of America, vol. 109, no. 27, 2012, pp. 10815–10820.
90. Power Division, Ministry of Power, Energy & Mineral Resources, 'Country Action Plan for Clean Cookstoves: Dhaka, Bangladesh', Government of the People's Republic of Bangladesh, 2013.
91. Ibid.
92. Mishra, Vinod, 'Indoor Air Pollution from Biomass Combustion and Acute Respiratory Illness in Preschool Age Children in Zimbabwe', International Journal of Epidemiology, vol. 32, no. 5, 2003, pp. 847–853.
93. United Nations Children's Fund, 'UNICEF Annual Report 2015 Zimbabwe', 2015.
94. Email communication with UNICEF Country Office.
95. United Nations Children's Fund, 'UNICEF Annual Report 2014 Zimbabwe', 2014.
96. United Nations Children's Fund, 'UNICEF Annual Report 2014 Zimbabwe', 2014; United Nations Children's Fund, 'UNICEF Annual Report 2015 Zimbabwe', 2015.
97. World Bank, 'Air Quality Analysis of Ulaanbaatar: Improving air quality to reduce health impacts', 2011.
98. Global Alliance for Clean Cookstoves, 'Country Profile: Mongolia', accessed 3 October 2016.
99. Amarsaikhan, D., et al., 'A Study on Air Pollution in Ulaanbaatar City, Mongolia', Journal of Geoscience and Environment Protection, vol. 2, 2014, pp. 123–128.
100. World Bank, 'Curbing Air Pollution in Mongolia's Capital', 2012, accessed 11 July 2016.
101. Awe, Y., et al., 'Clean Air and Health Lung Enhancing the World Bank's Approach to Air Quality Management', Environment and Natural Resources Global Practice Discussion Paper 03, World Bank Group Report, ACS9035, 2015.
102. Ibid.
103. Enkhmaa, Davaasambuu, et al., 'Seasonal Ambient Air Pollution Correlates Strongly with Spontaneous Abortion in Mongolia', BMC Pregnancy and Childbirth, vol. 14, 2014, p. 146.
104. Altangerel, Enkhzul, 'Air Pollution Is Endangering Children's Health in Mongolia', United Nations Children's Fund.
105. UNICEF internal source.

CHAPTER 4: NUMBER OF CHILDREN LIVING IN AREAS WITH HIGH LEVELS OF OUTDOOR AIR POLLUTION

1. *Tian, Jie, and Dongmei Chen, 'A Semi-Empirical Model for Predicting Hourly Ground-Level Fine Particulate Matter (PM2.5) Concentration in Southern Ontario from Satellite Remote Sensing and Ground-Based Meteorological Measurements', Remote Sensing of Environment, vol. 114, no. 2, 2010.*
2. *World Health Organization, 'Health Aspects of Air Pollution with Particulate Matter, Ozone and Nitrogen Dioxide', 2003.*
3. *World Health Organization, 'Air Pollution Levels Rising in Many of the World's Poorest Cities', WHO Media Centre, 2016.*
4. *van Donkelaar, A., et al., 'Global Estimates of Fine Particulate Matter Using a Combined Geophysical-Statistical Method with Information from Satellites, Models, and Monitors', Environmental Science and Technology, vol. 50, no. 7, 2016, pp. 3762–3772.*
5. *According to the WHO guidelines, "given that there is substantial inter-individual variability in exposure and in the response in a given exposure, it is unlikely that any standard or guideline value will lead to complete protection for every individual against all possible adverse health effects of particulate matter. Rather, the standard-setting process needs to aim at achieving the lowest concentrations possible in the context of local constraints, capabilities and public health priorities."*
6. *van Donkelaar, A., et al., 'Global Estimates of Fine Particulate Matter Using a Combined Geophysical-Statistical Method with Information from Satellites, Models, and Monitors', Environmental Science and Technology, vol. 50, no. 7, 2016, pp. 3762–3772.*
7. *Chen, J., et al., 'Funciontal Analysis of Genetic Variation in Catechol-O-methyltransferase (COMT): Effects on mRNA, protein, and enzyme activity in postmortem human brain', American Journal of Human Genetics, vol. 75, no. 5, November 2004, pp. 807–821.*
8. *Bell, M. L., J. K. Levy, and Z. Lin, 'The Effect of Sandstorms and Air Pollution on Cause-Specific Hospital Admissions in Taipei, Taiwan', Occupational and Environmental Medicine, vol. 65, no. 2, February 2008, pp. 104–111.*
9. *Thalib, L., and A. Al-Taiar, 'Dust Storms and the Risk of Asthma Admissions to Hospitals in Kuwait', Science of the Total Environment, vol. 433, 2012, pp. 347–351. DOI: 10.1016/j.scitotenv.2012.06.082.*
10. *Vodonos, Alina, et al., 'The Impact of Desert Dust Exposures on Hospitalizations due to Exacerbation of Chronic Obstructive Pulmonary Disease', Air Quality, Atmosphere & Health, vol. 7, no. 4, 2014.*
11. *Fullerton, Duncan G., Nigel Bruce, and Stephen B. Gordon, 'Indoor Air Pollution from Biomass Fuel Smoke Is a Major Health Concern in the Developing World', Transactions of the Royal Society of Tropical Medicine and Hygiene, vol. 102, no. 9, 2008, pp. 843–851.*
12. *United States Environmental Protection Agency, 'Near Roadway Air Pollution and Health', accessed 14 July 2016.*
13. *Thompson, Andrea, 'Burning Trash Bad for Humans and Global Warming', Scientific American, 2014.*

CHAPTER 5: WIDER BENEFITS OF REDUCING AIR POLLUTION

1. See for example: Bloom, D. and Canning, D. The Health and Wealth of Nations. Science, 287: 1207-9. 2000; Davis, K., Colins, S., Doty, M., Ho, A. and Holmgren, A.. 'Health and productivity among U.S. workers'. Commonwealth Fund pub. #856, 2005; Liu, G., Dow, W., Fu, A., Akin, J. and Lance, P. 'Income productivity in China: On the role of health'. Journal of Health Economics 27, 2008, pp. 27-44; Mitchell, R. and Bates, P. Measuring health-related productivity loss. Popul. Health. Manag.14 (2), 2011, pp. 93-98; Savedoff, W. D, and Schultz T, P. 'Wealth from Health. Linking Social Investments to Earnings in Latin America'. Inter-American Development Bank, Washington DC. 2000; Savedoff, W.D. and Schultz, P.T. 'Earnings and the Elusive Dividends of Health'. RES Working Papers 3108, Inter-American Development Bank, Research Department. 2000; Schultz, T.P. and Tansel, 'A. Measurement of Returns to Adult Health: Morbidity Effects on Wage Rates in Cote d'Ivoire and Ghana'. Papers 663, Yale - Economic Growth Center. 1992; Strauss, J. and Thomas, D. 'Health, Nutrition and Economic Development'. Journal of Economic Literature. 36, pp. 766-817. 1998; Tompa, E. The Impact of Health on Productivity: Empirical Evidence and Policy Implications. The Review of Economic Performance and Social Progress. pp. 181-202. 2002
2. Porta, D., et al., 'Air Pollution and Cognitive Development at Age 7 in a Prospective Italian Birth Cohort', Epidemiology, vol. 27, no. 2, 2016, pp. 228–236.
3. Sunyer, Jordi, et al., 'Association between Traffic-Related Air Pollution in Schools and Cognitive Development in Primary School Children: A prospective cohort study', PLoS Medicine, 2015, accessed 15 July 2016; doi:10.1371/journal.pmed.1001792.
4. United States Environmental Protection Agency, 'Highlights from the Clean Air Act 40th Anniversary Celebration', 2010.
5. See for example: McCool, Patrick M., et al., "Determining Crop Yield Losses from Air Pollutants', California Agriculture, 1986, pp. 9–10; Lovett, Gary M., et al., 'Effects of Air Pollution on Ecosystems and Biological Diversity in the Eastern United States', Annals of the New York Academy of Sciences, vol. 1162, 2009, pp. 99–135; McCool, Patrick M., et al., 'Determining Crop Yield Losses from Air Pollutants', California Agriculture, 1986, pp. 9–10; Greaver, Tara, et al., 'Ecological Effects of Nitrogen and Sulfur Air Pollution in the US: What do we know?', Frontiers in Ecology and the Environment, vol. 10, 2012, pp. 365–72; Chen, Dima, et al., 'Evidence That Acidification Induced Declines in Plant Diversity and Productivity Are Mediated by Changes in Below-Ground Communities and Soil Properties in a Semi-Arid Steppe', Journal of Ecology, vol. 101, 2013, pp. 1322–1334; Ghorayshi,

Azeen, 'India Air Pollution "Cutting Crop Yields by Almost Half."', The Guardian, 2014; Duprè, Cecilia, et al., 'Changes in Species Richness and Composition in European Acidic Grasslands Over the Past 70 Years: The contribution of cumulative atmospheric nitrogen deposition', Global Change Biology, vol. 16, 2010, pp. 344–57.

6. United States Department of Agriculture, 'Effects of Ozone Air Pollution on Plants', accessed 12 July 2016.
7. United States Department of Agriculture Forest Service, 'Ozone: Its formation and impacts on people and plants', 2013, accessed 12 July 2016.
8. Marris, Emma, 'Nitrogen Pollution Stomps on Biodiversity', Nature, 2008, accessed 15 July 2016; doi:doi:10.1038/news.2008.561.
9. Organisation for Economic Co-operation and Development, 'Air Pollution to Cause 6–9 Million Premature Deaths and Cost 1% GDP by 2060', 2016, accessed 12 July 2016.
10. Greaver, Tara, et al., 'Ecological Effects of Nitrogen and Sulfur Air Pollution in the US: What do we know?', Frontiers in Ecology and the Environment, vol. 10, 2012, pp. 365–372.
11. Chen, Dima, et al., 'Evidence That Acidification Induced Declines in Plant Diversity and Productivity Are Mediated by Changes in Below-Ground Communities and Soil Properties in a Semi-Arid Steppe', Journal of Ecology, vol. 101, 2013, pp. 1322–1334.
12. Duprè, Cecilia, et al., 'Changes in Species Richness and Composition in European Acidic Grasslands Over the Past 70 Years: The contribution of cumulative atmospheric nitrogen deposition', Global Change Biology, vol. 16, 2010, pp. 344–357.
13. Organisation for Economic Co-operation and Development, 'The Economic Consequences of Outdoor Air Pollution', OECD Publishing, 2016.
14. World Bank, 'The Cost of Air Pollution: Strengthening the economic case for action', 2016.
15. Hammitt, James K., 'Air Pollution and Medical Care', Health Affairs, vol. 22, no. 1, 2003, pp. 277–278.
16. United States Environmental Protection Agency, 'The Clean Air Act and the Economy', accessed 12 July 2016.
17. Jeuland, Marc, and Jie-Sheng Tan Soo, 'Analyzing the Costs and Benefits of Clean and Improved Cooking Solutions', Global Alliance for Clean Cookstoves, 2016.
18. Rehfuess, Eva, 'Fuel for Life: Household energy and health', World Health Organization, 2006.
19. Brook, Barry W., Navjot S. Sodhi, and Peter K. L. Ng, 'Catastrophic Extinctions Follow Deforestation in Singapore', Nature, vol. 424, 2003, pp. 420–426.
20. Pandit, M. K., et al., 'Unreported yet Massive Deforestation Driving Loss of Endemic Biodiversity in Indian Himalaya', Biodiversity and Conservation, vol. 16, no. 1, 2007, pp. 153–163.
21. International Energy Agency, 'World Energy Outlook 2006', 2006.
22. Barnes, Douglas F., 'Electric Power for Rural Growth: How electricity affects rural life in developing countries', Energy for Development, Second ed., 2014, p. 119.
23. United States Environmental Protection Agency, 'Climate Change and Air Quality', Our Nation's Air, 2011, accessed 12 July 2016.
24. D'Amato, Gennaro, et al., 'Climate Change, Air Pollution and Extreme Events Leading to Increasing Prevalence of Allergic Respiratory Diseases', Multidisciplinary Respiratory Medicine, vol. 8, no. 12, 2013.
25. United Nations, 'Transforming Our World: The 2030 Agenda for Sustainable Development', United Nations Sustainable Development Knowledge Platform, accessed 12 July 2016.
26. United Nations, 'UN Sustainable Development Goal 3: Ensure Healthy Lives and Promote Well-being for All at All Ages', United Nations Sustainable Development Goals, accessed 12 July 2016.
27. United Nations, 'UN Sustainable Development Goal 11: Make Cities Inclusive, Safe, Resilient and Sustainable', United Nations Sustainable Development Goals, accessed 12 July 2016.
28. United Nations, 'UN Sustainable Development Goal 12: Ensure Sustainable Consumption and Production Patterns', United Nations Sustainable Development Goals, accessed 12 July 2016.

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