AMBIENT AIR POLLUTION
TRAINING FOR HEALTH CARE PROVIDERS

Children’s Health and the Environment
WHO Training Package for the Health Sector
World Health Organization
www.who.int/ceh

WHO/CED/PHE/EPE/19.12.14

Notes:
• Please add details of the date, time, place and sponsorship of the meeting for which you are using this presentation in the space indicated.
• This is a large set of slides from which the presenter should select the most relevant ones to use in a specific presentation. These slides cover many facets of the problem. A number of slides refer to the specific issues related to ambient air pollution in developing countries, as these regions bear the burden of disease in children. Present only those slides that apply most directly to the local situation in the region.
Learning objectives

- Describe the main sources of ambient air pollution
- Discuss major ambient air pollutants
- Review their major health effects (short-term and long-term)
- Promote preventive measures for children
- Understand strategies to reduce ambient air pollution

There are four objectives for this training module. At the end of the presentation, the individual will be able to:

1. Describe the main sources of ambient air pollution
2. Discuss the major ambient air pollutants
3. Review their major health effects (short-term and long-term)
5. List some strategies to reduce ambient air pollution.

It is very important to recognize that air pollution is variable and that each community has unique problems based on its geography, climate, industries, traffic, and a variety of other factors.

Figure:
- © WHO/Sergey Volkov
Note: When selecting the slides to include in your presentation, please choose only those of relevance to the region and/or interests of your audience.

We begin by addressing the scope of the problem of ambient air pollution.

The contaminants addressed in this module include:

**Classical pollutants**
- Particulate matter
- Sulfur dioxide
- Nitrogen oxides
- Ozone

**Organic pollutants**
- VOCs
- Carbon monoxide
- PAHs
- Benzene
- Vinyl chloride

**Inorganic pollutants**
- Lead
- Fluoride
- Arsenic
- Chromium VI
- Nickel
SCOPE OF THE PROBLEM & CHILDREN’S UNIQUE VULNERABILITY

Figure:
• © WHO/Anna Kari
Why does this matter? In 2016, 253,000 children under five years of age died due to ambient (outdoor) air pollution. Children are uniquely vulnerable to environmental factors, with 26% of all under five deaths attributable to the environment. Consequently, environmental action presents an opportunity to reduce child mortality and illness. Attention to ambient air pollution and interventions to improve air quality can prevent disease in children.

The International Agency for Research on Cancer classifies both outdoor air pollution and particulate matter, a major component of ambient air pollution, as Group 1 carcinogens, causing cancer in humans. Worldwide and across all age groups, 4.2 million deaths in 2016 were attributable to ambient air pollution, with 90% of this burden borne by low and middle income countries.

One problem is that these estimates of the health impact of outdoor air pollution are based largely on the results of research conducted in Europe and North America, which went through some of the same experiences with heavy coal-using industries and vehicular traffic that Asia is currently experiencing. Results from developed countries, where air pollution has been dealt with for at least 100 years and especially the last 50-60 years, are extrapolated to developing countries. Such extrapolation raises considerable uncertainties because developing countries differ from Europe and North American in the nature of their air pollution, the conditions and magnitude of exposures to that pollution, and the health status of the population. Thus, conducting and evaluating epidemiological studies in developing countries is a priority.

References:

Figure:
A common proxy indicator for air pollution is particulate matter (PM), which is a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. Air quality is typically measured in terms of hourly, daily or annual mean concentrations in µg/m³ of PM₁₀ and PM₂.₅, particles with a diameter of 10 microns or less and 2.5 microns or less respectively. PM₁₀ is small enough to enter the respiratory tract, and PM₂.₅ is further able to cross the lung barrier into the bloodstream.

This map displays the annual concentration of PM₂.₅ in µg/m³.

An interactive map of annual mean ambient PM₂.₅ is available online at: https://maps.who.int/airpollution/.

Reference:

Figure:
Children are uniquely vulnerable to the effects of air pollution due to both physiological and behavioural differences from adults.

In terms of physiological differences, children are still developing, so their immune, respiratory and central nervous systems are immature and highly sensitive to environmental stimuli, including air pollution. The inside lining of the respiratory tract is permeable in young children, making them especially vulnerable to irritants in the airways.

At birth, an infant has only about 30-50% of the alveoli that will be present in adulthood. Alveolar development occurs most rapidly during the first two years of life, though it may continue for many years. During this period, children experience a higher ratio of lung surface area to lung volume than do adults, as well as a larger lung surface area to body weight ratio relative to adults. Both of these factors facilitate absorption of particles from air pollution.

Children breathe more air per kilogram of body weight than do adults. An infant breathes at a rate about five times that of an adult, while children three to five years of age breathe at a rate 60% higher than that of adults. Thus, environmental toxicants in the air are delivered to children at higher internal doses relative to adults. Children have high rates of mouth-breathing, bypassing nasal filtration, which can also expose them to higher levels of air pollution.

Airway passages in children are smaller than those in adults, so inflammation resulting from air pollution irritants causes proportionately greater airway obstruction. Irritation caused by air pollution that would produce only a slight response in an adult can result in potentially significant obstruction in the airways of a young child.

References:

Figure:
In addition to physiological differences, children also exhibit a number of behavioural differences that put them at greater risk from air pollution exposure.

Young children do not know to stay away from sources of air pollution, and the youngest children lack agency to move away at all. Children with their small statures spend time close to the ground, where some ambient air pollutants are found in highest concentration, as well as outside. They also tend to be more physically active than adults, increasing their breathing rate and exposure to ambient air pollution.

Time spent outside is influenced by many factors, including geographical region, climate, seasons and weather. Whether an area is urban or rural can affect outdoor time, as can the economic development of the region. Social and cultural aspects also may influence outside activity.

Finally, because children have longer life expectancies than do adults, the effects of air pollution have time to manifest for diseases with long latency. Environmental insults to children early in life will impact them for years to come.

References:
MAIN SOURCES OF AMBIENT AIR POLLUTION

Figure:
- © WHO/Sergey Volkov
Ambient air pollution sources differ between regions, urban and rural areas, as explored in the following slides. However, crossover effects link all types of air pollution. Urban air pollution can spread to downwind rural areas and vice versa; household air pollution is a major contributor to ambient air pollution, and air quality outdoors can also affect air quality indoors. Please see module on household air pollution for specific details on household air pollution and its sources. Improving air quality requires collaboration at all levels.

Note:
This is an opportunity to mention that the source of ambient air pollution depends on where you are. This information should be customized to meet the needs of the community and region in which the talk is being presented.

References:

Figure:
In urban settings, fossil fuel combustion and waste management are the main contributors. Fossil fuel combustion occurs in transport, industrial energy supply and household energy supply, including for cooking, heating and lighting. It releases carbon monoxide, sulfur dioxide, particulate matter, nitrogen oxides, hydrocarbons and other pollutants. The characteristics of emissions and solid waste disposal may vary for each specific industry (e.g. smelting, paper production, refining and others) and even site.

Open burning of waste is an issue in both urban and rural areas of many developing countries. Municipal or agricultural waste is burned in almost 170 countries, emitting pollutants that can spread regionally.

References:

Figure:
• © WHO / WPRO / Chau Doan
In rural settings, household energy, agricultural practices and natural processes are major sources. Polluting fuels such as kerosene, biomass and coal are common in rural areas, and agricultural practices including waste burning, deforestation and excessive use of fertilizers and pesticides affect air quality as well. Natural phenomena including forest fires, fog and dust storms also contribute to air pollution.

References:

Image:
• © WHO / SEARO / Joao Soares Gusmao
Air pollution levels are tightly linked to climate and topography.

Air pollution episodes can be particularly troublesome if the affected city is located in a valley surrounded by mountains.

Surfaces such as roads (gravel, dirt, asphalt) can generate air pollution when cars drive on them.

In arid regions, windblown soil and dust caused by dust storms can significantly increase particulate matter concentrations, with effects on morbidity and mortality.

References:
For this module, we will divide the major pollutants into three categories:

- Classical pollutants
  - Particulate matter
  - Sulfur dioxide
  - Nitrogen oxides
  - Ozone
- Organic pollutants
  - Carbon monoxide
  - PAHs
  - VOCs
    - Benzene
    - Vinyl chloride
- Inorganic pollutants
  - Lead
  - Arsenic
  - Chromium VI
  - Nickel

Select references are provided for the health effects of each pollutant. For a full list of references, please consult:

There are four classical pollutants: particulate matter, sulfur dioxide, nitrogen oxides and ozone. In some countries, these pollutants are routinely measured, and governments sometimes set standards for them. For example, in the USA there are National Ambient Air Quality Standards (NAAQS) for these pollutants. All four classical pollutants were included in the most recent WHO air quality guidelines (discussed in intervention section).

References:
Particulate matter has many sources dependent on the region of interest. Much of PM arises from anthropogenic sources. This includes use of fossil fuels for industry in electrical utilities as well as personal vehicle use. Biomass burning also contributes to PM generation through domestic energy generation and agricultural burning. Geologic sources of PM can include significant quantities of dust arising in arid regions or from roadways and construction.

Particulate matter poses a threat to child health due to the small size of particles, which can enter airways and even cross into the bloodstream. This leads to inflammation and oxidative stress in the respiratory tract as well as decreased gas exchange. Particulate matter has also been shown to change gene expression and hormone production.

IARC classifies particulate matter as a Group 1 carcinogen, causing cancer in humans. Children exposed to PM\textsubscript{10} may be at increased risk of developing leukaemia, especially those living in close proximity to highways with their traffic-related air pollution.

Exposure to PM in ambient air pollution has also been linked to many adverse birth outcomes, including low birth weight, stillbirth, preterm birth, congenital anomalies of the heart and small for gestational age. Perinatal circumstances due to PM furthermore contribute to infant mortality, as do PM-related diseases such as acute lower respiratory infections (ALRI) and pneumonia. Particulate matter is associated with the development and exacerbation of asthma, as well as impaired lung function.

There is some evidence that PM plays a role in neurodevelopmental issues, including with cognitive function, behaviour and Autism Spectrum Disorder. Also of note, exposure to PM has been linked to ear infections, insulin resistance and high blood pressure, which may lead to cardiovascular disease in adults.

References:

Sulfur dioxide arises from the combustion of sulfur-containing fossil fuels, such as coal and oil. In urban areas, use of these fuels for domestic heating, power generation and motor vehicles is most significant. Environmental sulfur dioxide also comes from natural sources, such as volcanoes.

Exposure to sulfur dioxide in children has been shown to cause bronchial inflammation and oxidative damage. Likely through these mechanisms, SO₂ has been associated with ALRI and pneumonia, as well as asthma development and exacerbation. Prenatal SO₂ exposures have consistently been linked to preterm birth, and may also contribute to stillbirth, low birth weight and congenital anomalies such as coarctation of the aorta and tetralogy of Fallot. Infant mortality associated with the nervous and circulatory system may also be linked to sulfur dioxide exposure.

References:


Nitrogen oxides have both anthropogenic and natural sources. Anthropogenic sources are mainly combustion in heating, power generation, vehicles and ships. Natural sources include volcanoes, lightning and bacteria.

Most frequently, nitric oxide is emitted and quickly converted to nitrogen dioxide. Nitrogen dioxide is the species of most interest with respect to human health effects. It also plays a key role in formation of ozone, another classical pollutant.

Nitrogen dioxide has been linked to a wide variety to health effects in children. Stillbirth, congenital anomalies, including coarctation of the aorta and tetralogy of Fallot, small for gestational age and sudden infant death syndrome have all been associated with NO\textsubscript{2} exposure.

Inflammation and oxidative damage due to NO\textsubscript{2} can damage the respiratory tract. Exposure to NO\textsubscript{2} has been linked to abnormal lung function, lung function deficits, ALRI and asthma.

Neurodevelopmental issues, such as cognitive development and motor development have been associated with NO\textsubscript{2} exposure. Prenatal exposures have furthermore been linked to development of leukaemia and bilateral retinoblastoma in children, as well as elevated leptin and adiponectin levels, potentially contributing to increased BMI. Children may further face increased risk of ear infections (otitis media) and insulin resistance due to NO\textsubscript{2}.

References:

Ozone is not directly emitted by primary sources; it is formed in the atmosphere through complex reactions involving nitrogen dioxide and VOCs. When nitrogen dioxide absorbs energy from solar radiation ($h\nu$, where $h$ is Planck's constant and $\nu$ is the frequency of light, $\nu \leq 430\text{nm}$), it dissociates to form nitric oxide and atomic oxygen. Atomic oxygen then reacts with molecular oxygen to form ozone.

<table>
<thead>
<tr>
<th>Sources</th>
<th>Associated health effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{NO}_2 + h\nu \rightarrow \text{NO} + \text{O}$</td>
<td>• ALRI</td>
</tr>
<tr>
<td>$\text{O} + \text{O}_2 \rightarrow \text{O}_3$</td>
<td>• Otitis media</td>
</tr>
<tr>
<td>Dependent on concentrations of $\text{NO}_2$ and VOCs, sunshine intensity, atmospheric convection</td>
<td>• Asthma exacerbation</td>
</tr>
<tr>
<td></td>
<td>• Stillbirth</td>
</tr>
<tr>
<td></td>
<td>• Small for gestational age (SGA)</td>
</tr>
<tr>
<td></td>
<td>• Autism Spectrum Disorder (ASD)</td>
</tr>
</tbody>
</table>

VOCs also affect ozone formation as their reactions in the atmosphere affect the equilibrium of nitric oxide. Thus, ozone concentration is dependent on concentrations of $\text{NO}_2$ and VOCs, sunshine intensity and atmospheric convection, which carries atmospheric ozone with prevailing wind currents.

While atmospheric ozone shields us from UV rays, ground-level ozone is a pollutant and respiratory irritant. Exposure to ozone may lead to increased risk of ALRI, pneumonia and otitis media and can exacerbate asthma for children. Prenatal exposures to ozone have also been linked to stillbirth, small for gestational age (SGA) and Autism Spectrum Disorders (ASD).

**References:**
- Hehua Z, Qing C, Shanyan G, Qijun W, Yuhong Z (2017). The impact of prenatal exposure to air pollution on


Persistent organic pollutants (POPs) are organic compounds of anthropogenic origin that resist degradation and accumulate in the food chain. They include pesticides, such as aldrin and DDT, and industrial chemicals such as polychlorinated biphenyls (PCBs) and by-products, for example polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDD/PCDF). POPs are characterized by low water solubility and high lipid solubility, which gives them high potential for bioaccumulation in fatty tissues of living organisms. POPs are part of the group of pollutants that is responsible for large-scale transboundary air pollution.

Reference:
Sources of carbon dioxide can be anthropogenic or natural. Anthropogenic sources include combustion of fossil fuels, such as by vehicles or industry, forest clearing, savanna burning, wood fires or oxidation of methane and other hydrocarbons produced by humans. Natural sources can be from forest fires, plants, oceans and oxidation of naturally occurring hydrocarbons.

Carbon monoxide is lethal and dangerous to human health. Exposure to CO in ambient air pollution has been linked to many adverse health effects in children including: stillbirth, SGA, ASD, asthma, otitis media and infant mortality due to respiratory causes. Carbon monoxide is able to cross the placenta, making prenatal exposures of particular concern.

References:
Polycyclic aromatic hydrocarbons (PAHs) come mainly from the incomplete combustion of fossil fuels, including coal and oil for electricity and industrial use and in motor vehicles. PAHs are capable of crossing the placenta, and prenatal exposures have been linked to increased BMI, obesity and medulloblastoma in children. IARC has classified benzo[a]pyrene, a PAH, as a Group 1 carcinogen, causing cancer in humans. Exposure to PAHs has also been shown to cause epigenetic modifications to DNA that damage the lung.

Volatile organic compounds (VOCs) are hydrocarbons, oxygenates, halogenates and other carbon compounds that are present in the atmosphere as vapours. They mainly come from pressurized system leakage, like with methane or natural gas, or from evaporation of a liquid fuel, but can also arise from incineration or fossil fuel combustion, or paints and adhesives.

Benzene exposure in ambient air is common around the world. It comes from biomass burning and gasoline. Benzene is an IARC Group 2B carcinogen, possibly carcinogenic to humans. Exposure to benzene has been linked to leukaemia in children, including chronic lymphoid leukaemia, chronic myeloid leukaemia and acute myeloid leukaemia, as well as to other childhood cancers: non-Hodgkin lymphoma, multiple myeloma and lung cancer. Prenatal exposure to benzene may also lead to lung function deficits in children.

Vinyl chloride is a synthetic compound produced industrially, notably for polyvinyl chloride (PVC), a type of plastic. Atmospheric releases likely occur due to accidents in PVC plants or during transportation. However, vinyl chloride has also been detected in landfill gas as chlorinated hydrocarbons break down. Vinyl chloride is an IARC Group 1 carcinogen, causing cancer in humans.

References:


INORGANIC POLLUTANTS

- Lead
- Arsenic
- Chromium VI
- Nickel compounds
Lead has historically been used in petrol, and while it has been eliminated from gasoline in almost every country, it is often still used in aviation fuel leading to dangerous concentrations in ambient air. Lead can also be released into the air via burning of materials that contain lead, such as during mining, smelting and waste incineration or recycling. Manufacturing products such as lead-acid batteries also contributes to air pollution. Lead can be found in dust and in particulate matter, and current exposures may be caused by historic emissions.

No safe level of lead exposure exists. Exposure to lead in ambient air pollution can occur via inhalation directly or ingestion when lead contaminates soil, dust or food that children may eat. Lead poisoning results in reduced cognitive function, including lower IQ, poor academic performance and decreased executive function. Neurodevelopmental effects can follow children throughout their entire lives. Exposure also causes attention deficits, impulsivity and hyperactivity; furthermore, it likely causes conduct disorders and has been associated with criminal offenses in young adults who were exposed as children. In addition to these externalizing behaviours, internalizing behaviours may also arise due to lead exposure, such as depression and anxiety. Other likely health effects of lead include hearing loss, fine and gross motor function decrements, and asthma and allergy. Overall, lead causes harmful effects on blood cells and blood-producing organs.

References:
Carcinogens in air

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>System affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>→ Lung</td>
</tr>
<tr>
<td>Chromium (VI)</td>
<td>→ Lung</td>
</tr>
<tr>
<td>Nickel</td>
<td>→ Lung</td>
</tr>
</tbody>
</table>

The listed metal air pollutants are carcinogenic. Arsenic and chromium (VI) are IARC Group 1 carcinogens, causing cancer in humans. Nickel is an IARC Group 2A carcinogen, probably causing cancer in humans.

Arsenic occurs naturally in the earth’s crust. Although most exposures occur through food and water, air concentrations near emission sources, including nonferrous metal smelters and power plants burning arsenic-rich coal, can be significantly elevated.

Sources of chromium in air are mainly burning of fossil fuels and natural sources. Inhaled chromium VI can cause lung cancer and possibly respiratory irritation, and impaired lung and dermal function.

Nickel also is found naturally in the earth’s crust, but it is also released into air by burning residual and fuel oils, incinerating municipal waste, mining and refining. It is a component of particulate matter.

References:
HEALTH EFFECTS

Image:
• © WHO / Tom Pietrasik
Preterm birth complications are a leading cause of child mortality. In 2017, prematurity caused 964,000 under five deaths, making it the leading cause of child mortality. Congenital anomalies caused 474,000 under five deaths in 2017, making them the fourth leading cause of death in that age group. Many preterm birth complications, including prematurity and congenital anomalies, are linked to air pollution.

There is strong evidence of an association between exposure to ambient air pollution, especially particulate matter, and low birth weight. There is growing evidence that maternal exposure to ambient air pollution, especially fine particulate matter, increases the risk of preterm birth. Several studies have demonstrated a link between components of air pollution and stillbirth, though the strength varies by pollutant. Evidence is suggestive of a link between air pollution and small for gestational age. Studies on ambient air pollution and congenital anomalies have been inconsistent.

Several biological mechanisms that explain how ambient air pollution affects birth outcomes have been proposed. Oxidative stress may affect early embryonic development including through DNA damage. Air pollution may stimulate pulmonary, placental and maternal inflammation, and with weakened maternal immunity, infection may occur that restricts intrauterine growth and leads to preterm birth. Epigenetic changes have also been identified in umbilical cord blood and placental DNA in cases of preterm birth linked to air pollution; animal studies suggest that epigenetic changes may interfere with cerebral cortex development in the embryo.

References:
Ambient air pollution is associated with infant mortality, with greater exposure linked to increased mortality. Many studies address acute exposures, while more research is needed on cumulative effects. Particulate matter exposure has been linked to infant mortality due to adverse birth outcomes, which may affect cardiovascular function. Along with carbon monoxide, particulate matter has also been associated with infant mortality due to respiratory disease. It has been proposed that PM damages the immature lung, leading to inflammation, respiratory distress and hypoxaemia. CO poisoning is known to cause infant mortality. Nitrogen dioxide has been linked to sudden infant death syndrome. Finally, both PM$_{2.5}$ and PM$_{10}$ are linked with all cause infant mortality.

References:

Image:
• © WHO / Antonio Suarez Weise
It is clear that exposure to air pollution increases the incidence of acute lower respiratory infections, including pneumonia. This is a major area for concern, as acute respiratory infections were the second leading cause of child mortality in 2017, causing 809,000 under five deaths, or 15% of mortality. With respect to ambient air pollution, even short-term exposures to PM$_{2.5}$, SO$_2$, NO$_2$ and O$_3$ have been associated with ALRI. Long-term exposure to vehicle traffic is also of concern, as are prenatal exposures. Particulate matter and nitrogen dioxide may damage the respiratory tract, making it more prone to infection; PM has also been shown to interfere with alveolar macrophages, potentially reducing immune response to pathogens.

Ambient air pollution both causes and exacerbates asthma in children. Exposure to NO$_2$, PM$_{2.5}$, PM$_{10}$ and SO$_2$ prenatally and NO$_x$, PM$_{2.5}$, PM$_{10}$ and CO postnatally have been linked to development of asthma. Likewise, to NO$_2$, PM$_{2.5}$, PM$_{10}$, SO$_2$, CO and O$_3$ are all associated with asthma exacerbation, with a stronger effect seen in children under 15 years of age. PAHs and benzene may also play a role. Bronchial inflammation and epigenetic modifications to DNA leading to lung damage may mediate these effects.

There is robust evidence that exposure to ambient air pollution, particularly from traffic, damages children’s lung function and lung function growth. Decreased lung function has been linked to particulate matter, nitrogen dioxide, carbon monoxide and benzene. Particles in air pollution that reach the bronchioles and alveoli may irritate lung cells, resulting in oxidative stress and inflammation. Both prenatal and postnatal exposures can lead to reduced lung function and growth in children, and it is suspected that prenatal exposure to air pollution causes epigenetic changes affecting the lungs. This damage can persist as lasting deficits in lung function throughout life, as function may be determined early on in development. Reduced lung function early in life is also associated with other chronic conditions, including asthma and chronic obstructive pulmonary disease.

References:


Ambient air pollution as well as some of its components are carcinogenic. Outdoor air pollution, particulate matter and diesel exhaust are all classified as Group 1 carcinogens, causing cancer in humans, by the International Agency for Research on Cancer. Benzene and gasoline exhaust are IARC Group 2B carcinogens, possibly carcinogenic to humans.

Childhood leukaemia has been associated with traffic-related air pollution in numerous studies. Diesel and gasoline exhaust, PM₁₀ and benzene have all been implicated, as well as prenatal exposure to NOₓ. Children living near highways may be at increased risk due to greater exposure to these pollutants. There is some evidence that children born to father’s with pre-birth occupational exposure to diesel and petrol exhaust are at higher risk of leukaemia.

Prenatal exposures to traffic-related pollutants have also been linked with retinoblastoma, germ-cell tumours and embryonal tumours. Fetal exposure to AAP is associated with astrocytoma, and PAHs are associated with medulloblastoma.

The biological mechanisms through which air pollution causes cancer are unknown. Two possibilities are faulty immune response to infections and allergies and DNA damage caused by air pollutants.

References:

Air pollution can negatively affect neurodevelopment. There is strong evidence that exposure to ambient air pollution, especially from traffic, can impair mental and motor development. Nitrogen dioxide and particulate matter, including black carbon, have been linked to deficits in motor development.

Evidence of an association between ambient air pollution and Autism Spectrum Disorder is relatively consistent. Prenatal exposure to particulate matter is of particular interest. Some evidence connects prenatal exposure to air pollution with cognitive function, psychomotor function and behavioural problems, but findings are inconsistent. Potential effects include decreased general memory index, slower working memory, impulsivity, aggressiveness and problems of attention and inhibition.

Mechanisms by which air pollution may affect neurodevelopment include many alterations in the brain. Reduced white matter tied to prenatal PAH exposure and structural changes in the cerebral cortex have been observed with fetal exposures. Neuroinflammation and disruption of the blood-brain barrier, leading to particulate matter deposition, have been found with long-term exposures.

References:
Ambient air pollution is strongly linked to otitis media, or ear infections, though findings on individual pollutants are not consistent. Exposure to particulate matter has been shown to alter gene expression in epithelial cells of the middle ear. Increased mucin gene expression, which can contribute to chronic infection, has also been observed with exposure to diesel exhaust.

There is a potential link between ambient air pollution and overweight and obesity in children. Several pollutants, including NO\textsubscript{x} and PAHs, have been associated with increased BMI, obesity and insulin resistance, though findings are not consistent. Developmental exposures to chemical compounds in ambient air pollution may negatively affect metabolic outcomes.

Prenatal exposure to particulate matter has been linked to elevated blood pressure in children as well as carotid arterial stiffness in adults. These elements of cardiovascular disease due to air pollution may persist for a lifetime.

Reduced lung function and growth in childhood due to ambient air pollution can lead to chronic lung disease in adulthood, as developmental trajectory is determined early in life.

Early exposure to air pollutants has also been associated with development of anaemia much later in life.

Children exposed to environmental hazards must bear these burdens for years to come.

References:


Image:
• © WHO / SEARO / Sanjit Das
The infographic presents several interventions to reduce air pollution and its effect on child health.

**Figure:**
Prevention in environmental health can take place at multiple levels. Clinicians may be familiar with tertiary prevention, disease treatment, such as medication for patients presenting with illness like asthma. A level before tertiary prevention is secondary prevention, early detection of disease. Screening programs may detect nascent illnesses before they reach more critical stages, which may be tailored towards environmental health hazards. Primary prevention then is prevention of disease before it develops through reduction of personal exposure to risk factors. This can happen at the level of the individual or the family, for example, moving to an area with less air pollution. These interventions are dependent on a family’s resources.

In order to prevent disease in wider populations, interventions must focus on broad health determinants. This level is primordial prevention, actions that minimize future hazards to health and address broad health determinants. In the context of ambient air pollution, primordial prevention will seek to reduce contaminants in air that affect entire populations. Health professionals are at the optimal position to contribute to all levels of prevention, from seeing individual patients to advocating for public policy. The following slides will address interventions at multiple levels that the audience take action towards with regard to ambient air pollution.

Reference:
Health professionals should be informed of local air quality: sources of pollutants, patterns of exposure and monitoring tools. They should know about existing and emerging evidence on ambient air pollution’s effects on child health.

Seeing patients, health professionals can engage in both tertiary and secondary prevention by treating health conditions associated with air pollution and recognizing exposure through screening. They are well-trained to diagnose and treat disease, but they can also look hard for environmental causes of disease. WHO’s paediatric environmental history is a concise tool developed with field-testing in Argentina that assesses environmental exposures. Important questions to ask with regards to ambient air pollution include: whether families perceive sources of smoke, fog or dust near their homes; whether they live or spend time near busy roads; how frequently lorries pass by their street; and how many hours a day children play outside.

Much research remains to be done on air pollution and child health, from the causes, mechanisms and effects of exposure, to treatment, management and prevention options. Health professionals can contribute to this work, conducting and publishing research, reporting sentinel cases, designing pilot studies and recruiting patients for studies. They should build collaborations with the affected communities they work with and identify and evaluate interventions to protect child health.

With those families and communities, health professionals can prescribe solutions and provide education on air pollution (primary prevention). Exclusive breastfeeding should be promoted in the first six months to prevent pneumonia and respiratory symptoms, among other benefits. When possible, families should be encouraged and assisted in relocating from areas of high traffic. Patients may ask about wearing face masks to filter air; WHO is currently reviewing their use. In some specific cases masks can be recommended, but they are not generally recommended because they are expensive and do not represent a viable mid-term or long-term solution in polluted areas.

Educating colleagues and future health professionals can magnify the message of air pollution’s negative effects to children. Including information on children’s environmental health and air pollution in curricula of medical, nursing and midwifery schools will increase awareness and preparation to combat this environmental health hazard.

Finally, these community and network connections are vital to the role of advocacy. Health professionals have a powerful voice in advocating for policies that will reduce exposures to air pollution (primordial prevention). Emphasizing the importance of protecting children at risk, health professions can write letters, testify at hearings and approach policy-makers with education and recommendations. Advocacy may take place at the local level, the national level or the international level; recommendations for each area are discussed in the following slides.

References:
Health providers can ask clinical questions to determine risk of ambient air pollution to their patients.

Examples of potential sources of smoke, fog and dust include fires from burning waste, industry and agriculture. If ambient air pollution is identified, health providers should advocate for local monitoring and control. They may also discuss with parents whether to minimize children’s time outside while pollution is present.

Examples of areas with heavy traffic include roads with frequent blocked traffic, slower speeds and long queues. If traffic represents a health risk, advocate for local monitoring and control and discuss with parents how to minimize their child’s exposure, such as keeping windows closed and limited time outside during times of heavy traffic.

References:
WHO Air Quality Guidelines outline optimal achievable air quality levels to protect human health worldwide. The emphasis in the guidelines is placed on exposure, because this is the element that can be controlled to lessen dose and hence lessen the consequent health effect. Values for major ambient air pollutants are given in the table above, listed by average exposure over the listed time period. This table shows guidelines for short-term exposures.

Health professionals can use these guidelines in conjunction with local regulatory levels, which have been established in almost all major cities, to gauge risk to patients of real-time air pollution exposures. Air quality standards in different countries may vary due to local circumstances, such as technology available and economic feasibility. Interim targets may also be of use and are described in the references below.

Guidelines do not provide thresholds below which no health effects occur; they suggest the lowest levels possible given local constraints.

The WHO air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide were last updated in 2005. Carbon monoxide was evaluated in 2000; it was also evaluated in 2010 as an indoor pollutant. Much research has emerged since the publication of these guidelines and a review is currently ongoing for a future update. The values for particulate matter, ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide are expected to be updated, likely with lower concentrations.

### Long-term exposures:

<table>
<thead>
<tr>
<th>Substance</th>
<th>Mean concentration</th>
<th>Averaging time</th>
</tr>
</thead>
<tbody>
<tr>
<td>PM$_{10}$</td>
<td>20 μg/m$^3$</td>
<td>1 year</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>10 μg/m$^3$</td>
<td>1 year</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>40 μg/m$^3$</td>
<td>1 year</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>20 μg/m$^3$</td>
<td>24 hours</td>
</tr>
<tr>
<td>CO</td>
<td>60 mg/m$^3$</td>
<td>30 minutes</td>
</tr>
<tr>
<td></td>
<td>30 mg/m$^3$</td>
<td>1 hour</td>
</tr>
<tr>
<td></td>
<td>10 mg/m$^3$</td>
<td>8 hours</td>
</tr>
</tbody>
</table>

For carbon monoxide exposures of fewer than 8 hours, exposure should be for no longer than the listed times and should not be repeated within 8 hours.

In addition, the WHO AQG for lead over an averaging time of 1 year was established as 0.5 μg/m$^3$ in 2000. Also in
that year, WHO reviewed vinyl chloride, arsenic, chromium and nickel but found no safe levels for those pollutants. Fluoride was reviewed as well but no guideline value established. In 2010, WHO reviewed but found no safe levels of benzene and PAHs.

References:


Health care professionals should be aware that energy-efficient housing and use of clean fuels at home can reduce ambient air pollutants and better human health. Understanding that burning solid fuels releases harmful pollutants, health professionals can ask detailed questions of patients on their home energy sources. Shifting from wood, animal dung, charcoal, crop wastes, coal and kerosene to clean fuels such as biogas, ethanol, LPG, natural gas and electricity can even be “prescribed” to alleviate or prevent health effects in children. More efficient stoves, including advanced biomass stoves as an interim measure, should also be recommended. The health sector can also advocate for energy efficiency in buildings through design. Insulation prevents unwanted heat or mass transfer, saving energy. Natural ventilation can cool buildings but may not be beneficial in areas of high ambient air pollution. Greater natural lighting can reduce the need for household energy, preventing pollution. Furthermore, health care facilities have an imperative to utilize these design techniques to reduce their polluting impact and serve as an example for sustainable practices.

Health care professionals can also advocate for and inform city planning that improves air quality. Designing more compact cities that are space-efficient, maintaining walking and cycling networks and providing bus rapid transit or light rail to reduce personal vehicle usage can increase energy efficiency and, as a result, ambient air pollution. Urban design can also improve air quality through green spaces in parks, rooftops, “vertical” urban gardens, walking and cycling paths that break up heat islands, as well as open skyline designs that allow cooling winds into cities. Health professionals should also make note of waste management strategies and sites: open incineration of solid waste, common in developing regions, releases ambient air pollutants, and children who live near waste sites face elevated risk for health effects. Anaerobic digestion, an alternative to open incineration, allows for capture of methane, reducing emissions and providing a renewable energy source.

References:
Emission of ambient air pollutants due to waste management is an important issue inside and outside urban areas; it is estimated that 86% of countries practice open burning of waste. Alternatives to open incineration of solid waste include waste reduction, separation, processing, management and recycling, and can be promoted within the health sector and practiced by health care facilities. As mentioned in the context of cities, anaerobic digestion captures methane from waste and reduces pollution; outside of cities this can be further applied to livestock and manure waste. Health care professionals should support such alternatives to open burning; if open burning cannot be avoided, we must advocate for strict emissions controls.

The agricultural sector is a good example of waste management practices, as the largest anthropogenic source of methane emissions. Waste management technologies can be applied to produce biogas, and crop residues can be diverted from open burning, which creates air pollution. Eating a plants-based diet and reducing consumption of red meat reduces methane and nitrogen dioxide emissions; alternating wet and dry irrigation to avoid continuous flooding also lowers methane levels.

.Local-level case study:
Tianjin Eco-City was planned by collaboration between Singapore and China as a model for sustainable development to be environmentally-friendly and resource-efficient. The Eco-city is designed to be compact with residential, commercial and recreational space within walking distance from public transport. Priority in transportation infrastructure is given to pedestrians, non-motorized transport and public transport. Natural spaces connect a green lung at the core of the Eco-city with green relief corridors throughout the urban area, and water bodies are linked in a blue network as well. 36 eco-city standards have been developed, including that air quality should meet national standards for at least 75% of the year.

References:
Transport is a sector of major influence on ambient air quality that can be influenced by individual as well as policy action. Public transit reduces traffic emissions compared to private vehicles; investment and participation in mass public transit can significantly improve air quality. Rail is also a better option compared to car or plane for air quality. When private vehicles are necessary, the health sector should advocate for strict emissions and efficiency standards. Low-emissions vehicles such as lighter cars, hybrids and electric vehicles are preferred. Compressed natural gas is cleaner than diesel, while it is unclear whether biogas reduces pollution. Health care professionals can play a critical role in motivating political support for green transportation efforts.

**Local case study:**
Freiburg, Germany is a remarkable example of improvements in transportation. Despite strong economic growth, the city succeeded in levelling off motorization rates and reducing average CO₂ emissions from transport.

It is important to note that regional contexts are quite dissimilar in terms of public transport trip share, average non-motorized trip distances and other factors.

**References:**
Industry and power generation are major contributors to ambient air pollution. Billions of bricks are produced annually, often in kilns that release copious particulate matter; coke, a fuel made from coal that is used in iron smelting and steel production, is commonly produced in high emission ovens. Improved designs and newer technologies for kilns and ovens are available to reduce emissions, and the health sector can play a role in pushing for their uptake. Health professionals can also back regulations that reduce industry smokestack emissions.

Power generation from fossil fuels is a major cause of ambient air pollution. Coal and oil produce high levels of fine particulate matter, while diesel produces black carbon. Natural gas produces substantially less particulate matter and is preferred over coal and oil, along with nuclear energy and, most notably, renewables. Hydropower, wind, geothermal, solar and biomass energy sources are sustainable, renewable energy sources that can replace fossil fuels for electricity and, in doing so, reduce air pollution. The health sector can advocate for their adoption and lead the way by choosing green energy and rooftop solar generation when feasible. Co-generation of heat and power can also reduce energy demand.

National-level case study:
In Denmark, policy requires industry to use the best available technology. Due to quick adoption of improved methods, energy efficiency improved 26.3% and overall final-consumer efficiency improved by 20.2% from 1990 to 2010.

References:
The effects of industrialization became apparent in Los Angeles beginning around the turn of the 20th century. Due to the area’s mountains, relatively stagnant winds and atmospheric temperature inversions, the Los Angeles Basin was particularly prone to the worst ambient air quality in the country. By the Second World War, it was staring residents of Southern California right in the eye, with thick clouds of smog that caused stinging eyes, withering crops and deteriorating rubber. Cities and counties began a war on smog, researching its constituents and formation as well as health effects.

California established the first tailpipe emissions standards in the country in 1966; this led to the development of the catalytic converter that significantly reduced pollutants in exhaust. When the Clean Air Act was amended in 1970, it recognized the earlier efforts of California and its unique propensity for pollution; the Act made California the only state that can establish its own vehicle emissions standards to be stricter than federal standards. The state has continued to lead efforts to reduce air pollution with a Zero-Emission Vehicle program requiring auto manufacturers to develop cleaner cars; a carbon cap-and-trade program and the nation’s first greenhouse gas restrictions for cars.

This reduction in ambient air pollution in Southern California has also presented a natural experiment; the Children’s Health Study has collected two decades of respiratory data on children along with air quality monitoring data from 1993 to 2011. Over this time, total emissions of NO\textsubscript{x} decreased by 54%, PM\textsubscript{2.5} by 21% and PM\textsubscript{10} by 15%. Comparing earlier cohorts to later allows researchers to measure health outcomes under different levels of ambient air quality. Impressively, this improvement in air quality occurred while statewide gross domestic product (GDP) grew 2.7% annually and there was an overall 22% increase in population and 38% increase in motor vehicle use.

Lung development was examined in three cohorts of children who were followed for four years: the first cohort in 1994-1998, the second in 1997-2001 and the third in 2007-2011. Comparing the later cohorts of children with the earlier, it was found that lung function development improved with decreasing levels of NO\textsubscript{x}, PM\textsubscript{2.5} and PM\textsubscript{10}. Lung function was assessed by forced expiratory volume in one second (FEV\textsubscript{1}) and forced vital capacity (FVC) over four years for each participant, from age 11 to 15 years. The proportion of children at age 15 with clinically low FEV\textsubscript{1} declined significantly from 7.9% in the first cohort to 3.6% in the third cohort, with similar results for FVC values.

The Children’s Health Study also measured bronchitic symptoms in three Southern California cohorts from 1993 to 2001, from 1996 to 2004 and from 2003 to 2012. Symptoms including bronchitis, daily cough for three consecutive months and congestion or phlegm not accompanied by a cold decreased with lower levels of ambient NO\textsubscript{x}, O\textsubscript{3}, PM\textsubscript{2.5} and PM\textsubscript{10}. Prevalence of bronchitic symptoms in children with asthma decreased by 10.1% to 18.7% based on the individual pollutant reduction measured. The differences were much smaller among children without asthma, with
decreases of 1.8% to 2.3%. Overall bronchitic symptoms decreased most in communities with the most improvements in ambient air quality.

Understanding these lessons, it is clear that air pollution interventions are critical to child health. However, new and continued challenges persist with increasing population size, reliance on passenger vehicles and climate change. Climate change and rising temperatures lead to increased ambient air pollution, notably due to intensified wildfires in Southern California. Continued challenges must be met with continued efforts to improve air quality.

FEV₁: forced expiratory volume in one second  
FVC: forced vital capacity

References:
Prior to its phasedown, use of lead in gasoline resulted in significant exposures to lead through air; up to 90% of lead in air in urban environments was due to its use in gasoline in 1970s USA. In turn, this caused about half of lead in blood and contributed substantially to lead toxicity in children. The Clean Air Act of 1970 allowed the U.S. Environmental Protection Agency (EPA) to regulate fuel additives, and it began to phase lead out of gasoline in 1973.

The figure on the slide shows the remarkable declines in blood lead levels that followed. With decreased use of lead in gasoline over time, blood lead levels fell correspondingly. Seasonal variations can also be seen, with blood lead levels rising in the summer when more gas is used.

In 1980, mean concentration of lead in air was 1.95 µg/m³. Lead phaseout in gasoline was completed in 1995, with mean lead at 0.43 µg/m³. Continued efforts to reduce lead in other areas has further contributed to the reduction of lead in air to 0.015 µg/m³ in 2017. In children between one and five years of age, median blood lead level decreased from 15 µg/dL in 1976-1980 to 0.76 µg/dL in 2015-2016.

The Partnership for Clean Fuels and Vehicles was established in 1992, when 82 countries were still using lead in gasoline. Governments, international organizations, industry and nongovernmental organizations in the partnership contributed to a remarkable decline: only one country (Algeria) continued to use leaded petrol as of July 2018.

References:


Figure:
• Derived from information in:
BreatheLife is an initiative formed by WHO, UN Environment and Climate and Clean Air Coalition to address the effects of air pollution on human health and the planet. The global campaign provides a platform for cities to share best practices, including monitoring, solutions and education, with the goal of bringing air quality to safe levels by 2030. It also provides information tailored for the health sector as well as specific recommendations for individual action. As of 2019, the BreatheLife network includes 53 cities, regions and countries, which have supported 173 actions affecting a total of 146 million people.

Cities and regions that join the BreatheLife network identify short-lived climate pollutants and reduction measures to prioritize; measure progress in reducing air pollution; and share strategies with other cities in the network. BreatheLife is also rolling out regional workshops to provide guidance on monitoring air pollution, implementing solutions and building grassroots support. The campaign also provides tailored creative communication pieces.

Health care professionals can use BreatheLife’s resources for up-to-date data, policy recommendations and individual actions. Search your city on the platform to see whether your local government is “breathing life” into your region.

Unmask My City is an alliance of doctors, nurses, public health practitioners and healthcare professionals that aims to improve air quality in cities to improve public health. The alliance advocates for policies and programmes that will bring cities in line with WHO Air Quality Guidelines. As masks are a measure of last resort, Unmask My City argues that more sustainable and systemic interventions are needed to protect from health effects of air pollution. Health professionals joining the network can support and drive local clean air campaigns.

Reference:

Figures:
- © Unmask My City and © BreatheLife
The first international legally binding instrument to deal with air pollution on a broad regional level was the 1979 Convention on Long-range Transboundary Air Pollution, which created a framework for international cooperation in reducing air pollution and brought together research and policy.

The Stockholm Convention, established in 2001, requires parties to eliminate production of and restrict import and export of persistent organic pollutants. As of 2018, there were 182 parties to the Stockholm Convention.

In 2015, the Sixty-eighth World Health Assembly adopted a landmark resolution, “Health and the environment: addressing the health impact of air pollution”. Member States were urged to research, publicize and minimize the health effects of air pollution.

In 2016, the Director-General of the World Health Organization proposed a road map for an enhanced global response to the adverse health effects of air pollution, including a proposed monitoring and reporting framework with indicators and objectives to track progress.

In 2018, the First WHO Global Conference on Air Pollution and Health brought together representatives from countries, cities, UN organizations, intergovernmental organizations and civil society to discuss air pollution, its health effects and how to address them. Over 70 commitments to tackle air pollution were made to move the global community on a path towards cleaner air.

Many additional interventions not presented here focus on reducing emissions that lead to climate change, which has the joint effect of reducing air pollution.

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1979</td>
<td>Convention on Long-range Transboundary Air Pollution</td>
</tr>
<tr>
<td>2001</td>
<td>Stockholm Convention on Persistent Organic Pollutants</td>
</tr>
<tr>
<td>2015</td>
<td>World Health Assembly resolution on air pollution</td>
</tr>
<tr>
<td>2016</td>
<td>World Health Assembly road map for an enhanced global response to the adverse health effects of air pollution</td>
</tr>
<tr>
<td>2018</td>
<td>First WHO Global Conference on Air Pollution and Health</td>
</tr>
</tbody>
</table>

References:

Image:
- © WHO / SEARO / Sanjit Das
On September 25th 2015, countries adopted a set of Sustainable Development Goals (SDGs) to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda. Each goal has specific targets to be achieved over the next 15 years.

Many SDGs relate to ambient air pollution. As we have seen, there are many components to improving air quality, from energy and industry to urban design and waste management. Listed below are ambient air pollution-related SDGs – achieving each of these goals will reduce health effects of air pollution on children.

- **SDG 3**: Ensure healthy lives and promote well-being for all at all ages.
- **SDG 7**: Ensure access to affordable, reliable, sustainable and modern energy for all.
- **SDG 9**: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
- **SDG 11**: Make cities and human settlements inclusive, safe, resilient and sustainable.
- **SDG 12**: Ensure sustainable consumption and production patterns.
- **SDG 13**: Take urgent action to combat climate change and its impacts.

Several SDGs include targets and indicators that directly address air pollution, included below.

- **Target 3.9**: By 2030, substantially reduce the number of deaths and illnesses from hazardous chemicals and air, water and soil pollution and contamination.
- **Indicator 3.9.1**: Mortality rate attributed to household and ambient air pollution
- **Target 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

For the goals to be reached, everyone needs to do their part: governments, the private sector, civil society and people like you. Healthy environments for children are key to achieving the Sustainable Development Goals. Every SDG has the potential to impact the development of healthy environments for children.

**Reference:**

**Figure:**
To end this presentation, a reminder that achieving a clean environment can be fought on many fronts – and that health professionals are at the crux.

**Figure:**
Acknowledgements for current version

Reviewers: Pierpaolo Mudu (WHO), Irina Buka (Canada)
Initial edits by Ruth Etzel (EP A)
Final review, technical and copy-editing: Gloria Chen (WHO Consultant)
WHO CEH training project coordinator: Marie-Noëlle Bruné Drisse (WHO)

WHO is grateful to the ISDE for organizing the working meeting of the Training Package in 2016.

This publication was made possible with financial support from the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety, Germany.

Update: November 2019
Design by L’IV Com Sàrl, Villars-sous-Yens, Switzerland.
Acknowledgements from past versions

WHO is grateful to the US EPA Office of Children’s Health Protection for the financial support that made this project possible and for some of the data, graphics and text used in preparing these materials.

First draft prepared by Ruth A. Etzel (USA)

With the advice of the Working Group Members on the Training Package for the Health Sector: Cristina Alonso (Uruguay); Yona Amitai (Israel); Stephanie Boese-O’Reilly (Germany); Stephana Borgo (ISDE, Italy); Irena Buka (Canada); Ernesto Burgio (ISDE, Italy); Lilian Corra (Argentina); Ruth A. Etzel (WHO); Lilia Fruchtengarten (Brazil); Amalia Laborde (Uruguay); Leda Nemer (WHO/EURO); Jenny Pronczuk (WHO); Roberto Romizzi (ISDE, Italy); Christian Schweizer (WHO/EURO); Katherine M. Shea (USA).

Reviewers: Yona Amitai (Israel), Irena Buka (Canada), Ruth A. Etzel (USA); Michal Kryzanowski (Germany).

Update: June 2017

WHO CEH Training Project Coordination: Jenny Pronczuk
Medical Consultant: Katherine M. Shea (USA)
Technical Assistance: Marie-Noel Brune
Disclaimer

© World Health Organization 2019. Some rights reserved. This work is available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; https://creativecommons.org/licenses/by-nc-sa/3.0/igo).

Under the terms of the Creative Commons licence, you may copy, redistribute and adapt the work for non-commercial purposes, provided that you comply with the licence terms. The work is licensed under a Creative Commons licence (attributive, non-commercial, share-alike). The work may be downloaded from the site as is, or modified by the user. The user is responsible for any modifications made. The user may use the work in any medium or format, and for any purpose, provided that the work is properly attributed, as indicated below. Users are encouraged to consult the licence terms before using the work.

Any modification to the work must be properly attributed, as indicated below. In any use of the work, there should be no suggestion that WHO endorses any specific organization, products or services. The use of the WHO logos is not permitted. This work is distributed by the World Health Organization (WHO) in the public domain. The work is distributed without warranty of any kind, either express or implied. The user is responsible for the interpretation and use of the work. In no event shall WHO be liable for damages arising from its use.

The designations employed and the presentation of the material in this training module 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 boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufactured products does not imply that they are endorsed or recommended by the World Health Organization in preference to others that are not mentioned. Errors and omissions excepted, the name of proprietary products are distinguished by initial capital letters.

The authors alone are responsible for the views expressed in the training package and they do not necessarily represent decisions, policy or views of the World Health Organization.

Suggested citation: