Children’s health and the environment
WHO training package for the health sector

HOUSEHOLD AIR POLLUTION
TRAINING FOR HEALTH CARE PROVIDERS

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. Present only those slides that apply most directly to the local or regional situation. Where relevant, adapt the information, statistics and photos within each slide to the particular context in which this module is being presented. For instructions on how to use this module visit: https://www.who.int/publications/i/item/WHO-CED-PHE-EPE-19-12-02;

• Household air pollution is one module from a larger training package focused on children’s environmental health. Consult these other modules where relevant. Throughout Household air pollution, a number of different modules are suggested that contain additional relevant information. To see the full package visit: https://www.who.int/teams/environment-climate-change-and-health/settings-populations/children/capacity-building/training-modules;

• Household air pollution is part of a selection of modules within the training package that discuss children’s health and air pollution. These include Ambient air pollution, Childhood respiratory diseases linked to the environment, Indoor air pollution and Second-hand smoke. Consult these modules for relevant additions;

• the World Health Organization (WHO) reference number for the module Household air pollution: training for health care providers is WHO/HEP/ECH/CHE/23.07;

• for more information on WHO’s work on children’s environmental health, please visit: https://www.who.int/health-topics/children-environmental-health.
This module is an introduction to child health and household air pollution.

By the end of this presentation, learners should be able to:

• describe the basic concepts of household air pollution;
• explain the major sources and routes of exposure to household air pollution;
• describe associated and suspected child health outcomes linked to household air pollution;
• understand interventions and strategies to reduce household air pollution at clinical, personal, national and international levels.
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.

This training module includes the following sections:
• introduction and magnitude of the problem;
• children’s exposure to household air pollution;
• children’s health effects associated with household air pollution;
• interventions and solutions at clinical, personal, national and international levels that can be taken to reduce children’s exposure to household air pollution;
• an example of a trial on efforts to assess child and maternal health outcomes linked to switching to clean household fuels and technologies.

Photo:
• © WHO/ Yoshi Shimizu. A woman prepares lunch in a remote village in Vanuatu.
This training module starts with an introduction to household air pollution and the magnitude of the problem.

Photo:
• © WHO/ Yoshi Shimizu. A woman prepares lunch in a remote village in Vanuatu.
Household air pollution is air pollution in and around the home generated by inefficient combustion of fuels for cooking, heating and lighting, leading to indoor and ambient (outdoor) air pollution (1). Household air pollution is a type of indoor air pollution that can affect children’s health.

When the term “household air pollution” is used, it considers the mixture of pollutants released through the incomplete combustion of fuels, using inefficient technologies, for cooking, heating and lighting needs. This occurs inside the home, as well as in areas close to the home, for example in backyards or community areas. Common fuels used in inefficient technologies for household cooking, heating and lighting needs include (2,3):

- wood
- biomass
- coal
- kerosene.

There are several reasons the term “household air pollution” is used to differentiate these sources of pollution from the broader term of “indoor air pollution,” including (2,3):

1. much of the health-related exposure to household air pollution occurs in areas close to homes and residential areas, not just within the home itself. Some sources of household air pollution may be in outdoor areas of the home. For example, households may have primary cooking equipment such as cookstoves or fires just outside the house or in a courtyard;
2. the use of polluting fuels for household activities contributes significantly to ambient air pollution levels, affecting communities far from the original source;
3. the term “indoor air pollution” may be used to refer to indoor pollution from other types of sources, such as radon, dust and mould;
4. the term “indoor” suggests that effective ventilation or a chimney may solve the problem. However, the key issue in household air pollution is the combustion of polluting fuels using inefficient technologies.

Note: for more information, please see the modules Ambient air pollution and Indoor air pollution.

References:


Air quality is interconnected. The simple graphic on this slide illustrates the interconnectedness of the three primary types of air pollution affecting children’s health.

**Ambient air pollution** is air pollution in the ambient (outdoor) environment. Ambient air pollution can enter homes and buildings, contributing to indoor and household air pollution \((1,2)\). Ambient air pollution is primarily made up of pollutants from fossil fuel combustion for transport and energy supply, open burning and waste management activities, agricultural practices, industrial activities, and pollutants from natural processes, such as sandstorms or wildfires \((3,4)\).

**Household air pollution**, as discussed on the previous slide, is pollution created by the inefficient combustion of fuels using inefficient technologies for household cooking, heating and lighting requirements. Examples of this include burning wood on an open fire or burning coal in an inefficient stove \((5)\). Household air pollution is a type of indoor air pollution and contributes significantly to ambient air pollution.

**Indoor air pollution** is a broad term commonly used to discuss air quality within and around buildings and structures, especially as it relates to the health and comfort of building occupants. In addition to household air pollution, it also includes non-combustion air pollutants found in indoor environments from everyday products and materials, such as formaldehyde in building materials or benzene from furniture. Personal activities, such as tobacco smoking and products used indoors, including chemicals used for cleaning purposes, can also pollute indoor environments. Additionally, biological pollutants due to humid conditions, for example moulds, are another form of indoor air pollution \((6)\).

References:


Figure:

• © WHO.
This slide illustrates how household air pollution can contribute to ambient air pollution. This photo shows a smoking fire in an outdoor space near homes and community areas in a slum area. The ‘neighbourhood pollution’ created by the outdoor fire can move into nearby homes and outdoor household areas, exposing household members and neighbouring homes to dangerous concentrations of pollutants.

**Photo:**
- © WHO/ Diego Rodriguez. Nearly 3 billion of the world’s poorest still rely on solid fuels (wood, animal dung, charcoal, crop wastes and coal) burned in inefficient and highly polluting stoves for cooking and heating, India.
This map shows the proportion of the global population with primary reliance on clean fuels and technologies for cooking in 2021 (1). The map illustrates the countries with the lowest proportion of the population with primary reliance on clean fuels and technologies in yellow (less than 50% of the population), while the highest proportions are in blue (more than 50% of the population). As can be seen on the map, people living in countries in the World Health Organization’s (WHO) African, South-East Asia and Western Pacific Regions in 2021 had the lowest reliance on clean fuels and technologies for cooking. In 2021, an estimated 2.3 billion people globally relied primarily on polluting fuels and technologies for cooking (1,2).

Not shown on this map is the significant divide in access to clean fuels and technologies for cooking between urban and rural areas. Across all WHO regions, urban areas have consistently greater access to clean fuels and technologies for cooking. For example, in 2021, in the WHO African Region, only 6.8% of the rural population had access to clean fuels and technologies for cooking, compared to 40.5% of the urban population (3).

Note: find the proportion of the population with primary reliance on clean fuels and technologies for cooking in 2021 in your country by visiting: https://www.who.int/data/gho/data/themes/air-pollution/household-air-pollution.

Note: the map on the slide is from the WHO household energy database. This database monitors the global progress of the transition to cleaner fuel and stove combinations in households. The database includes household air pollution data from more than 150 countries (4).

References:
In 2019, an estimated 3.2 million people died globally due to illnesses attributed to household air pollution. As shown in the graphic on the slide, of the estimated 3.2 million deaths globally attributable to household air pollution in 2019:

- 32% were due to ischaemic heart disease;
- 23% were due to stroke;
- 21% were due to lower respiratory infection;
- 19% were due to chronic obstructive pulmonary disease;
- 6% were due to lung cancer.

Pneumonia is one of the leading causes of child mortality worldwide. Exposure to household air pollution during early childhood almost doubles the risk of a child contracting a lower respiratory infection, including pneumonia. In 2019, more than 237 000 deaths in children under the age of 5 globally were attributed to pneumonia due to household air pollution exposure. In 2019, this accounted for 44% of all pneumonia deaths in children under the age of 5 globally.

Note: find the number of deaths attributable to household air pollution in your country in 2020 by visiting: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/household-air-pollution-attributable-deaths.

Note: the statistics listed on the slide come to 101% due to decimal rounding.

References:

Figure:
- © WHO.
Socio-economic and environmental determinants influence access to clean fuels and technologies for everyday household cooking, heating and lighting needs.

Household air pollution is an issue of poverty. Access to clean fuels and efficient technologies, as well as the initial cost of purchasing items, can be prohibitive to many households in countries around the world. Additionally, the cost of regularly purchasing fuels for daily household requirements, such electricity or liquified petroleum gas (LPG), and regularly maintaining technologies to ensure their appropriate functioning can be out of reach for many low-income families. Low- and middle-income countries (LMICs) are the most affected by household air pollution (as is illustrated by the map on Slide 8) (1,2). Globally, in rural areas, reliance on clean fuels and technologies is lower than in urban areas. A study conducted across village households in a rural area of India found that 99% of the population studied had used wood as fuel at least once (3).

Household air pollution is linked to a range of adverse child health outcomes, including increased risk of pneumonia. Poor health throughout childhood can reduce time at school, consequently leading to reduced economic opportunities as an adult, and making it more difficult to improve socio-economic status. This can create a vicious cycle of poor health outcomes due to household air pollution, and reliance on polluting fuels and technologies due to poverty-related factors (1).

There is global recognition that expanding access to clean options for household cooking, heating and lighting needs will improve several socio-economic and environmental issues. These include (1,2):

- **improving numerous child health outcomes**, especially in LMICs where reliance on polluting fuels and inefficient technologies is highest, as is the burden of disease associated with household air pollution;
- **increasing gender equality**, by reducing the time spent gathering fuels by women and girls, who in many areas of the world are the primary collectors of fuel, and increasing time for other productive activities (see Slide 11 for more detail);
- **improving education outcomes**, with more available time for schooling, and consequently **improving economic opportunities** and development. Economic opportunities may also be improved with greater time available for productive, income-generating activities;
- **advancing environmental protection** by reducing biodiversity loss due to use of wood for fuel and deforestation and reducing carbon dioxide, black carbon, methane and carbon monoxide emissions from combustion of polluting fuels (3).
References:


Photo:
- © WHO/ Anna Kari. A couple push a bike with wood through the mud. They will use it to make charcoal. Manila, Philippines.
Women and children in low- and middle-income countries (LMICs) bear the greatest burden of mortality and morbidity due to household air pollution.

In many regions of the world, women and children are responsible for household chores including (1,2):
- cooking;
- collecting firewood or other fuels;
- tending to fires, stoves or other fuels and technologies used for household cooking, heating and lighting needs.

Consequently, women and children spend more time around the domestic hearth and are likely exposed to greater levels of harmful smoke from polluting fuels and technologies.

A study conducted across village households in a rural area found that 96 per cent of primary cooks were female (3). Additionally, gathering fuel, such as firewood, places women and children at risk of musculoskeletal injuries and, in less secure environments, at risk of violence or sexual assault (1,2). Cooking, heating and lighting in homes using polluting and inefficient fuels and technologies is also more time consuming than using fuels and technologies that are clean for health. For example, more time is required searching for fuels, such as wood, and this may take many hours at significant distances from home. This can reduce women and children’s time available for other productive activities, such as education and income generation. In a World Health Organization (WHO) report published in 2016, country surveys in sub-Saharan Africa estimated that girls in households that cook with polluting fuels spent an average of 18 hours per week gathering fuel compared to five hours per week in household that used clean fuels (2).

Finally, the use of polluting fuels and inefficient technologies for household cooking is a significant risk factor for childhood scalds, burns and poisonings. Fire, heat and other hot substances, and poisonings are among two of the most common unintentional injuries in childhood leading to death (4). Ingestion of kerosene is the leading cause of unintentional childhood poisonings (1). Additionally, polluting fuels and technologies for cooking are linked to childhood scalds and burns, especially in young children under 2 years of age (5). These unintentional injuries can have lifelong physical, psychosocial and socioeconomic consequences (see Slide 30 for more details) (2).

Note: for more information on unintentional childhood injuries linked to environmental factors, please see the module Why children.
References:


Figure:

• © WHO.
Many pollutants harmful to human health can be produced using polluting fuels and inefficient technologies for household cooking, heating and lighting needs. The illustration on this slide shows examples of polluting fuels, such as wood, coal, charcoal, kerosene, animal dung and crop waste, that are burnt using inefficient technologies, including inefficient stoves, open fires and burning, poorly ventilated or malfunctioning fireplaces, furnaces, generators and water heaters, and oil and kerosene lamps, resulting in high levels of household air pollutants.

During combustion, different chemicals are emitted as either gases or particulates (suspended liquids and solids). The major household air pollutants that pose threats to children’s health are (1,2):

- particulate matter (PM)
- carbon monoxide
- black carbon
- nitrogen dioxide
- sulfur dioxide.

Various other organic and inorganic compounds may also make up part of combustion particulates, such as polycyclic aromatic hydrocarbons (PAHs), benzene and formaldehyde (1–4).

Household air pollution is a complex, ever-changing mixture of health damaging pollutants: particles, gases and other chemical compounds. The components of household smoke from combustion overlap in part with the known components of traffic, industry pollution and tobacco smoke. The type and amounts of pollutants produced during combustion activities for household cooking, heating and lighting depend upon (2,3):

- fuel composition (including water content);
- combustion conditions (high or low temperature, air flow and humidity);
- mode of burning;
- functioning of some technologies.

Natural gas and liquified petroleum gas (LPG) are considered clean for health by the World Health Organization (WHO). However, if they are used in malfunctioning or poorly maintained household appliances, they can pollute indoor environments with dangerously high levels of pollutants, especially carbon monoxide.

Note: for more information on major air pollutants, please see the module Ambient air pollution. Additionally, for an example of a study on carbon monoxide exposure please see the module The paediatric environmental history.
References:


This slide discusses the properties of the four major air pollutants released through polluting fuels and inefficient technologies used for household cooking, heating and lighting.

**Particulate Matter (PM)** is a common proxy indicator used globally to measure levels of air pollution (1). It is a complex mixture of solid and liquid particles from organic and inorganic substances suspended in the air. Some particles are emitted directly, while others are formed through reactions in the atmosphere. The main components of PM include sulfates, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water (2,3). Some particles are big or dark enough to be visible to the naked eye. However, other particles are so small they can only be seen using a microscope. The combustion of polluting fuels using inefficient and malfunctioning technologies for household cooking, heating and lighting needs can cause significant amounts of PM pollution to be released into indoor air (4). There are two primary types of PM discussed in this training module due to their significant effects on human health. These are visualized in the graphic on the left of the slide in comparison to a single strand of human hair and grains of beach sand (3–5):

- **PM$_{10}$**: refers to particles that are under 10 (µm) in diameter. PM$_{10}$ is illustrated by the blue circles in the left image;
- **PM$_{2.5}$**: refers to particles that are equal to or less than 2.5 µm in diameter. Also referred to as fine PM, these particles are considered the greatest risk to human health. PM$_{2.5}$ is illustrated by the pink circles in the left image.

**Carbon monoxide** is a colourless, odourless, tasteless and non-irritant gas. It is combustible and can form explosive mixtures in the air (3,6). Carbon monoxide is very harmful to human health. Once inhaled into the human body, carbon monoxide is dissolved in blood where it competes with oxygen to bind to haemoglobin. This process reduces oxygen availability for tissues and leads to numerous health effects. At very high levels, carbon monoxide can quickly lead to death. Carbon monoxide pollution in the home is primarily due to combustion of carbon-based fuels, such as coal, in poorly ventilated areas. Additionally, gas and liquified petroleum gas (LPG) are considered clean for health, however if a gas appliance, for example a stove or water heater, is malfunctioning or has been poorly maintained, carbon monoxide can be produced and pollute household air (6–8). **Carbon monoxide is not detectable by humans by sight, smell or taste** (6). Consequently, other means of detecting carbon monoxide levels in the home are required, such as carbon monoxide detectors.

**Nitrogen dioxide** is a reddish-brown gas with a distinctive, pungent odour (3,5). It is often used as an indicator for the wider group of nitrogen oxides, including nitric acid. Nitrogen dioxide plays a key role in ambient air pollution levels globally and is also associated with numerous human health outcomes, especially asthma and other
respiratory outcomes (9). Nitrogen in fuels is converted to nitrogen dioxide under high temperature combustion. Gas and LPG contain much lower levels of nitrogen, however, elevated levels of nitrogen dioxide in homes may be found due to unvented gas heaters and stoves (2,6).

**Sulfur dioxide** is a colourless gas with a pungent odor originating from combustion of fuels containing sulfur, such as coal, oil and biomass. Historically, sulfur dioxide has been a primary component of air pollution, and a significant amount of research has focused on how it effects human health (3,5). Concentrations of sulfur dioxide in household air pollution are primarily linked to combustion of coal and kerosene for cooking and heating purposes (2).

**Note:** for more information on major air pollutants, please see the module *Ambient air pollution*. Additionally, for an example of a study on carbon monoxide exposure please see the module *The paediatric environmental history.*

**References:**

**Figures:**
- Left: © US EPA.
- Right: © WHO.
The pathways of human exposure to air pollution include inhalation, dermal and ocular absorption and ingestion. The primary pathway of exposure is **inhalation**, as is illustrated on the slide. Pollutants in the air reach different parts of the respiratory system depending on several factors. Particulate matter (PM) size is the most important factor in determining how far particles can penetrate the respiratory system. Other factors include (1,2):

- characteristics of the pollutant, for example particle size and chemical composition;
- physiological factors of an individual, for example presence of disease and level of activity or exercise.

The illustration on the slide shows how far particles can penetrate in the respiratory system depending on their size (3,4):

- **particles larger than 10 microns (µm), or large coarse particles (PM)**, are too large to be inhaled beyond the nasal passages and are deposited in the nose and throat;
- **particles between 10 and 2.5 µm (PM$_{10}$)** are small enough to reach the trachea, bronchi and bronchioli, where they can cause irritation and consequently coughing;
- **particles less than 2.5 µm, or fine particles (PM$_{2.5}$), and ultrafine particles, less than 0.1 µm (PM$_{0.1}$)**, are further able to enter the lung, cross the lung barrier and can be absorbed into circulation where they may travel to other organs and have systemic effects (5).

**Note:** the illustration on the slide of the respiratory system highlights key aspects of the upper and lower respiratory tracts including the nose, mouth, throat, trachea, bronchi, bronchioli and pulmonary alveoli. Pulmonary tissue and the circulatory system are not shown in the illustration. Additionally, the circle on the illustration highlights in greater detail the bronchiole and alveoli that are found throughout the lungs.

**References:**


Figure:

- Reproduced with permission of the © ERS 2023.
The quantity of household air pollution, and the amount of time that children are exposed to household air pollution, are significant factors in determining children at risk and potential adverse health outcomes.

The World Health Organization’s (WHO) air quality guidelines recommends a 24-hour average of 15 micrograms per cubic metre ($\mu$g/m$^3$) for fine particulate matter (PM$_{2.5}$) (1). Studies measuring household air pollution due to cooking with polluting fuels and inefficient technologies have found significantly elevated levels of PM$_{2.5}$ in homes. In poorly ventilated homes, smoke from cooking, heating and lighting with polluting fuels and technologies can reach concentrations 100 times higher than acceptable levels for PM$_{2.5}$ (2). In one study, average kitchen concentrations of PM$_{2.5}$ over a 24-hour period due to cooking with firewood ranged from 387 to 3100 $\mu$g/m$^3$ (3).

Exposure to household air pollution is highest among those who spend the most time in and around the home, engaging in home-based activities. As discussed on Slide 11, in many parts of the world cooking and other household activities are often the responsibility of women and children. Consequently, women and children are exposed to household air pollution more frequently and for greater periods of time compared to other household members (4).

Poverty is a significant risk factor for exposure to household air pollution (this is discussed in further detail on Slide 10).

References:
Photo:

• © WHO/ Guerchom Ndebo. Sofia (right), 60, prepares a meal for her family in front of their shelter in Bulengo camp, about 15 kilometres from Goma in the east of the Democratic Republic of the Congo.
The next section of this module discusses children’s vulnerability and susceptibility to household air pollution.

Photo:
It is important that health care providers recognize children’s unique vulnerability and susceptibility to household air pollution. Although household air pollution is an environmental threat to the health of many people all over the world, not everyone is affected equally. Children constitute one group that is more significantly affected by household air pollution.

To understand the risks faced by children related to household air pollution it is important to understand the concepts of **susceptibility** and **vulnerability**:

- **susceptibility** refers to an innate or acquired physical predisposition which increases the relative risk of experiencing health effects due to air pollution exposure (such as a pre-existing condition or disease). A susceptible population may have an increased response to a concentration of air pollution, in comparison to the general population. Examples of the susceptibility of children to air pollution include their **age** and **developmental status** (1,2);

- **vulnerability** refers to people who have increased exposure to air pollution due to either external factors, such as **place of residence** or **socio-economic status** (3,4).

The following three slides go into greater detail of the different and unique exposures that make children one of the most susceptible groups to the adverse health effects of household air pollution.

**Note:** for more information, please see the *Children are not little adults* and *Why children* modules.

**References:**

Children are not little adults

Different and unique exposures:
- Intrauterine
- Stature and breathing zone
- Time spent indoors

Dynamic developmental physiology:
- Anabolic, rapidly growing
- Developmental physiology
- Windows of vulnerability
- Cognitive immaturity

As with many environmental hazards, children are often at increased exposure risk for several reasons. Household air pollution is no exception.

Children have different and unique exposures to polluted household air compared to adults. Some pollutants found in household air pollution can cross the placenta, exposing the developing fetus to pollutants experienced by the mother. Studies have linked prenatal household air pollution exposure and increased risk of some adverse birth outcomes (1). As children are small and frequently play close to the ground, their exposures to some pollutants may be increased compared to adults. Furthermore, infants and young children in many cultures tend to spend greater time indoors, often accompanying their parents to complete household chores, which can increase their exposure to dirty household air. Preambulatory children may spend significant time attached to their mother, or another carer, and may be exposed to significant levels of particulate matter due to combustion of fuels using inefficient technologies for household cooking, heating and lighting needs (2).

Time spent inside the home is influenced by many factors, including geographical region, climate, seasons and weather. Whether an area is urban or rural can influence the amount of time spent indoors, as can the economic development of the region. Social and cultural aspects may also influence household activities (2).

Due to their dynamic developmental physiology children are often subjected to higher exposure to pollutants found in household air pollution.

As they are anabolic and rapidly growing, children breathe faster and breathe more air per unit of body weight than adults (3). Thus, pollutants in the air are delivered to children at higher internal doses relative to adults. Children also have high rates of mouth-breathing, bypassing nasal filtration, which can expose them to higher levels of household air pollution, including fine particulate matter (PM$_{2.5}$) (4).

In terms of developing physiology, children have immature immune, respiratory and central nervous systems and are highly sensitive to environmental stimuli, including household air pollution. The immature respiratory system is a target of air pollution. At birth, a newborn only has 30–50% of the alveoli that will be present in adulthood (5). Alveolar development occurs most rapidly during the first 18–24 months of life, although it may continue until 8 years of age. During this period, children experience a higher ratio of lung surface area to lung volume than adults, as well as a larger lung surface area to body weight ratio relative to adults. These factors facilitate greater absorption of particles from air pollution (5,6).

Airway passages in children are smaller than those in adults, so inflammation resulting from air pollution causes
proportionately greater airway obstruction. Irritation caused by air pollution that may produce only a slight response in an adult can result in potentially significant obstruction in the airways of a young child (see Slide 19 for more detail) (4).

**Windows of vulnerability** to permanent alternations to lung function persist throughout childhood. While alveolar development is substantially complete by 2 years of age, lung growth continues through adolescence and parallels somatic growth. It is thought to be complete by approximately 18 years in females and 20–23 years in males. Until adult systems are fully developed, exposure to air pollution may alter function in reversible and irreversible ways (5,6).

Finally, **cognitive immaturity** also increases children’s exposure risk to polluted air. Young children do not know to stay away from sources of household air pollution, and the youngest children lack agency to move away at all. Children also tend to be more physically active than adults, increasing their breathing rate and exposure to household air pollution. Children are less likely than adults to cease activity when they begin to have respiratory symptoms such as bronchospasm, leading to prolonged exposure and more acute illness (4).

**Note:** for more information, please see the *Children are not little adults* and *Why children* modules.

**References:**

**Photo:**
• © WHO/ Alex Swanepoel. Lady Buxton Preschool group of 4-year-olds and teachers, South Africa.
Smaller airway passages: effects of oedema on airway diameter

Diagram of the Effect of Edema on the Cross-Sectional Airway Diameter

**Adult Airway**

Area = \( \pi R^2 = \pi \times 10^2 = 100\pi \text{ mm}^2 \) (Normal)

If have 1 mm Edema: Area = \( \pi (R - 0.1)^2 = \pi \times 9.9^2 = 31.31\pi \text{ mm}^2 \) or 31% of normal

**Full Term Newborn**

Area = \( \pi R^2 = \pi \times 5.5^2 = 97.35\pi \text{ mm}^2 \) (Normal)

If have 1 mm Edema: Area = \( \pi (R - 0.1)^2 = \pi \times 5.4^2 = 90.43\pi \text{ mm}^2 \) or 44% of normal

Children’s airway passages are narrower than those of adults. Consequently, irritation from exposure to air pollutants can result in proportionately greater airway obstruction (1). The graphic on this slide illustrates the difference in airway size between an adult and a full-term newborn. Irritation that may not affect adults may result in severe obstruction or damage to children’s lungs as they are more vulnerable to the effect of the oedema than adults. As shown in the illustration, one millimetre (mm) of oedema can reduce the diameter of the adult airway by 19%, whereas it can reduce the diameter of the full-term newborn airway by as much as 56% (2).

**Note:** for more information, please see the Children are not little adults and Why children modules.

**References:**


**Figure:**

- © 1992-2023 Donna M. D'Alessandro, M.D. and Michael P. D'Alessandro, M.D. and the authors. Figure used with permission of the authors. Figure available at: https://www.virtualpediatrichospital.org/providers/ElectricAirway/Diagrams/AirwayDiameterEdema.shtml.
As children have longer life expectancies than adults, any chronic conditions developed during childhood can affect the entire lifetime. Effects of air pollution have time to manifest for diseases with long latency periods. Insults from air pollution to children’s health early in life may impact them for years to come (1).

Finally, children depend upon the adults in their lives to provide a safe environment in which to grow, learn and thrive. Infants may be strapped to the back of their parents while they tend to the domestic hearth, potentially exposing them to very high levels of household air pollution. Pre-ambulatory children are also dependent upon adults to move them away from sources of household air pollution, such as stoves, heaters or open fires. Children may be required to stay at home to help with collection of fuel, such as wood, and to help with daily household activities. This can reduce their time at school, which may lead to ongoing reduction in education, academic achievement and future economic opportunities (2).

Household air pollution requires individual level actions in addition to local and national policies that aim to ensure universal access to fuels and technologies for household cooking, heating and lighting that are clean for health. Children trust the adults in their lives to nurture and protect them with actions and decisions until they can protect themselves through their own individual, collective and political action (1,2).

Note: for more information, please see the Children are not little adults and Why children modules.

References:

Photo:
• © WHO/ Alex Swanepoel. Lady Buxton Preschool group of 4-year-olds and teachers, South Africa.
The third section of this module discusses children’s health effects associated with exposure to household air pollution. The health outcomes discussed here are primarily linked to the major pollutants discussed on Slides 12–14.

Photo:
• © WHO/ Yoshi Shimizu. A woman prepares lunch in a remote village in Vanuatu.
This section discusses the health effects during pregnancy and childhood that have been associated with household air pollution. Household air pollution has been linked to a diverse range of birth and child health outcomes. There is robust evidence linking some household air pollutants to (1,2):

1. **Adverse birth outcomes**
   - Preterm birth
   - Low birth weight
2. **Childhood respiratory effects**
   - Acute lower respiratory infection

Significantly fewer studies have been conducted on child health outcomes and exposure household air pollution compared with research on ambient air pollution. There is emerging research on associations between household air pollution and increased risk of other child health outcomes including (1,2):

1. Lung function and asthma
2. Impaired neurodevelopment
3. Other birth outcomes
4. Otitis media
5. Increased risk of NCDs later in life
6. Childhood cancer

**References:**

Maternal exposure to household air pollution has been linked to several adverse birth outcomes and evidence is continuing to grow. There is robust evidence linking maternal exposure to fine particulate matter (PM$_{2.5}$) from the combustion of polluting fuels in the home and the following adverse birth outcomes:

1. **Preterm birth**, defined as birth before 37 completed weeks of gestation, is the leading cause of death in children under 5 years of age (1). In 2019, preterm birth complications were responsible for approximately 910,000 deaths in children under 5 years of age globally (1, 2). There is a robust body of evidence linking maternal exposure to household PM$_{2.5}$ and an increased risk of preterm birth. A meta-regression and analysis of available data estimated that in 2019 more than 3.9 million preterm births globally were due to PM$_{2.5}$ in household air pollution. This accounted for approximately two thirds of preterm births globally due to total PM$_{2.5}$ exposure in 2019 (3).

2. **Low birth weight** is commonly used to assess the possible effects of household air pollution on healthy fetal growth. There is consistent evidence linking maternal exposure to household air pollution and low birth weight. In 2014, the WHO guidelines for indoor air quality: household fuel combustion found that research has consistently linked maternal exposure to household air pollution with increased risk of low birth weight (4). Since the publication of the WHO guidelines, research has continued to highlight the links between exposure to household fuel combustion and low birth weight. A meta-regression and analysis of available data estimated that 1.8 million low birth weight infants globally born in 2019 were due to PM$_{2.5}$ in household air pollution. This accounted for approximately two thirds of low birth weight infants globally due to total PM$_{2.5}$ exposure in 2019 (3).

Other adverse birth outcomes associated with household air pollution have been suggested. These include stillbirth, congenital anomalies and small for gestational age. Results from available research warrant further attention (5).

References:
3. Ghosh R, Causey K, Burkat K, Wozniak S, Cohe A, Brauer M. Ambient and household PM2.5 pollution and


Photo:
• © WHO/ Fanjan Combrink. Community health worker Wezzie weighs Beauty at a health facility in rural Lilongwe, Malawi.
Acute lower respiratory infections, including pneumonia, bronchitis, bronchiolitis and other acute respiratory diseases, are the second leading cause of child mortality worldwide. In 2019, an estimated 740,000 children under 5 years of age died from acute lower respiratory infections globally. Low- and middle-income countries (LMICs) carry the highest burden of childhood mortality from lower respiratory infections, in particular countries in the World Health Organization’s (WHO) African and South-East Asia Regions. Together, these two regions accounted for 76% of the global burden of child mortality from acute lower respiratory infections in 2019 (1). Acute lower respiratory infections are strongly associated with environmental risks, including ambient and household air pollution, crowded living conditions, parental smoking and poor access to adequate water, sanitation and hygiene services (2).

Incidence of acute lower respiratory infections in children is strongly associated with exposure to fine particulate matter (PM$_{2.5}$) from combustion of polluting fuels using inefficient technologies for household cooking, heating and lighting needs (3). In 2019, more than 237,000 children under the age of 5 years globally died from acute respiratory infection associated with PM in household air pollution (4,5). In 2019, this accounted for 44% of global pneumonia deaths in children under the age of 5 (4). Incidence and mortality due to acute lower respiratory infections are highest in countries and regions where reliance on polluting household energies is also high (5).

Note: find the household air pollution attributable deaths in children under 5 years in your country by visiting: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/household-air-pollution-attributable-deaths-in-children-under-5-years-. Compare this data with the proportion of the population with primary reliance on polluting fuels and technologies for cooking in your country by visiting: https://www.who.int/data/gho/data/indicators/indicator-details/GHO/gho-phe-population-with-primary-reliance-on-polluting-fuels-and-technologies-for-cooking-proportion.

Note: for more information on children and respiratory infections, please see the modules Ambient air pollution, Childhood respiratory diseases linked to the environment and Indoor air pollution.

References:

Childhood respiratory effects:

Acute lower respiratory infections

- A leading cause of under 5 mortality globally:
  - Estimated 740,000 deaths in 2019
  - PM from household air pollution is a major risk factor for pneumonia in children under the age of 5
- In 2019 in children under 5 years:
  - More than 237,000 deaths globally
  - Responsible for 44% of all pneumonia deaths globally

PM$_{2.5}$ strongly associated with incidence of acute lower respiratory infection in children

Exposure to household air pollution almost doubles the risk of childhood lower respiratory infection


It is well established that microbes are essential in the pathogenesis of acute lower respiratory infections. For a pathogen to infect the lower respiratory tract, it must avoid the body’s innate immune system. Household air pollution may cause modulation of the innate immune system, leading to increased susceptibility to infection. The precise pollutant or pollutants in household air pollution that affect modulation of the immune system is currently uncertain, however, particulate matter (PM) is believed to play a crucial role. Particle size and chemical mixture may affect immune system response (1). Additionally, size and chemical composition can alter particles’ ability to evade protective barriers and penetrate the respiratory system. Respiratory health effects are dependent on these combination of characteristics, among other things such as children’s special vulnerabilities (2).

PM in household air pollution may modulate the innate immune system through (1):

- impairment of bacterial recognition;
- changes to release and response of monocytes to bacterial cell products;
- enhanced bacterial and viral binding to cells, resulting in larger numbers of infected cells.

Excessive pulmonary inflammation, in addition to changes to the immune system, may lead to (1):

- increased risk of lung injury
- increased susceptibility to infection
- lung damage.

Exposure to household air pollution during prenatal and early childhood may predispose children to incidence of acute lower respiratory infection (2).

References:


Photo:
• © WHO/ Nazik Armenakyan. Paediatricians Dr Ghazaryan and Dr Harutyunyan examine the lungs of 9-month-old Nare who has bronchiolitis, at Wigmore Clinic in Yerevan, Armenia.
Lung function is a measure of how effectively the lungs move air in and out of the body to exchange oxygen with blood and remove carbon dioxide. Lung function indicates how well a person breathes. Windows of vulnerability for permanent alternations to lung function persist throughout childhood. While alveolar development is substantially complete by 2 years of age, lung growth continues throughout adolescence and parallels somatic growth. It is thought to be complete by approximately 18 years of age in females and 20–23 years of age in males (1,2). Until adult systems are fully developed, exposure to air pollution may alter lung function and development in irreversible ways.

While many studies have investigated links between ambient air pollution and children’s lung function and development, fewer studies have been published on household air pollution. Exposure to household air pollution in early life, including during pregnancy and infancy may (3):

- affect lung development;
- predispose children to compromised lung function, as measured by forced vital capacity (FVC) and forced expiration volume in 1 second (FEV1);
- increase the risk of chronic respiratory disease later in life.

Trial interventions have indicated some improvement in childhood lung function associated with use of improved household cookstoves (4). Some studies have also indicated that significant reductions in levels of household PM$_{2.5}$ are required to observe meaningful improvements in childhood lung function (5).

Asthma is a common chronic, noncommunicable childhood disease. It is a diffuse, obstructive lung disease with hyper-reactivity of the airways to a variety of stimuli and a high degree of reversibility of the obstructive process, which may occur either spontaneously or due to treatment. Symptoms can be continuous or intermittent and can change over time. There are multiple phenotypes, and the causes of asthma in individuals are multifactorial including genetic predisposition, gene environment interactions especially early in life, infections, and exposure to allergens and various environmental conditions and triggers (6,7). The Global Initiative for Asthma (GINA) defines asthma as (8):

- “a heterogeneous disease, usually characterized by chronic airway inflammation. It is defined by the history of respiratory symptoms, such as wheeze, shortness of breath, chest tightness and cough, that vary over time and in intensity, together with variable expiratory airflow limitation.”
The global burden of disease from asthma is significant. In 2019, an estimated 262 million people were affected by asthma, causing an estimated 455,000 deaths and 21.7 million disability-adjusted life-years (DALYs) globally (9–11). There are many environmental factors and exposures linked to exacerbation of asthma symptoms. These include (7):

- diet;
- urbanization and industrialization;
- poverty and other social determinants of health;
- environmental risks, such as second-hand smoke, ambient and household air pollution, microbial exposures, pollen and animal allergens.

Several studies have found positive associations between household cooking with polluting fuels and inefficient technologies and asthma development in children. Particularly, cooking on an open fire has been suggested as increasing the risk of asthma development in children (12). The WHO guidelines for indoor air quality: household fuel combustion concluded that there is suggestive evidence for a causal effect of exposure to household air pollution and exacerbation of asthma in children (3).

Note: for more details on asthma, please see the modules Ambient air pollution and Childhood respiratory diseases linked to the environment. For additional slides on common asthma symptoms and key suggestions for asthma diagnosis and management, please see Slides 37, 49 and 50 of the Ambient air pollution module.

References:

Associations between prenatal and early childhood exposure to household air pollution and adverse neurodevelopmental outcomes is an emerging area of research. Conclusions regarding neurodevelopmental outcomes in children and household air pollution associations are hampered by the limited number of studies conducted in household air pollution contexts (1).

Studies that have been conducted as of 2023 have investigated:

- personal maternal exposure to carbon monoxide was associated with reduced cognitive development, as measured by neuropsychological performance, in children aged 6–7 years. This study consisted of only 39 children and found that carbon monoxide exposure during the third trimester of pregnancy was associated with reduced cognitive development (2);

- open fire cooking using solid fuels, primarily wood, was examined in a retrospective study across four countries. This study found that memory and building block skills (as indicators of cognitive development) in children aged 3–9 years were lower in those who were exposed to open-fire cooking using solid fuels (3).

Studies from other contexts, including ambient air pollution, investigating pollutants also known to be found in household air pollution provide some support for the effects of chronic early life exposure on children’s neurodevelopmental outcomes. These include studies of fine particulate matter (PM$_{2.5}$), polycyclic aromatic hydrocarbons (PAHs) and carbon monoxide. Given the important consequences of neurological development for children’s futures, further research on the influence of household air pollution is warranted (1).

References:


Photo:

Studies have investigated many other health effects in children. Research is emerging regarding possible associations between household air pollution and the following adverse health outcomes in children:

- **Other adverse birth outcomes**, including infant mortality and congenital anomalies. Currently, there are too few studies on household air pollution and congenital anomalies to draw any conclusions. Results from available research warrant further attention. Importantly, maternal exposure to tobacco smoke has been linked to increased risk of congenital anomalies in children (1). Infant mortality, the death of a child 0–11 months of age, has been the subject of a growing number of research articles. Most studies to date have focused on acute, ambient exposures in high-income contexts. Studies that have been completed on household air pollution suggest possible associations to increased risk of infant mortality. Neonatal mortality (death during the first month of life) has been correlated with household air pollution exposure (2). In 2019, the Global Burden of Disease study estimated that 64% of neonatal deaths due to air pollution globally were related to household air pollution exposure (3). Windows of exposure to household air pollution and risk of both neonatal and infant mortality are unclear (4).

- **Otitis media** has also been the subject of a significant amount of research linking risk of incidence with increased concentrations of ambient air pollution. Available studies indicate a suggestive association between combustion-derived household air pollution and an increased risk of otitis media (5). An association between parental tobacco smoking and otitis media in young children is well documented (6).

- **Increased risk of noncommunicable diseases (NCDs) later in life** due to childhood exposure to household air pollution is an area of growing interest. Several NCDs in adults are strongly associated with exposure to household air pollution, particularly stroke, ischaemic heart disease, chronic obstructive pulmonary disease and lung cancer. These diseases make up a considerable burden of air pollution-related mortality and morbidity (7). Links between exposure to household fine particulate matter (PM$_{2.5}$) during childhood and increased risk of cardiovascular disease, lung cancer and chronic lung disease later in life have been suggested. One study in low- and middle-income countries (LMICs) has suggested that people with long-term exposure to household air pollution from combustion of polluting fuels have twice the risk of developing chronic obstructive pulmonary disease (8). Greater research is needed to identify key windows of exposure and insults to the developing lung and cardiovascular system associated with household air pollution exposure during the prenatal period and childhood that may persist into adulthood, affecting the onset of some NCDs.
• Debate on the risk of some childhood cancers, particularly leukaemia, has been ongoing. The International Agency for Research on Cancer (IARC) has evaluated emissions from household combustion of coal as a Group 1 carcinogen – carcinogenic to humans. Additionally, IARC has classified emissions from household combustion of biomass fuel, in particular wood, as a Group 2A - probably carcinogenic to humans (9). Emissions from household air pollution are strongly correlated with several types of cancer in adults, such as lung cancer, but few studies have been conducted on cancer risk in children. A study conducted in Australia found increased risk of childhood leukaemia by 1.41 times associated with exposure to wood burners to heat the home during pregnancy, and by 1.25 times when exposed after birth (10).

References:
The most important sources of exposure to carbon monoxide in household air pollution are from (1,2):

• indoor burning of wood, charcoal and biomass using inefficient technologies in poorly ventilated rooms;
• unvented kerosene technologies;
• faulty, incorrectly installed, poorly maintained or poorly ventilated cooking, heating and lighting appliances that burn fuel. This can include fuels that are considered clean for health, such as gas, propane or liquefied petroleum gases (LPG);
• clogged chimneys, wood-burning fireplaces, gas heaters, stoves and water heaters that are malfunctioning or poorly vented can result in high levels of carbon monoxide in closed spaces.

Over time, in indoor environments, emissions from the sources listed above can lead to high levels of carbon monoxide especially in household spaces that are:

• small
• closed
• poorly ventilated.

Carbon monoxide is likely to be globally underdiagnosed as the gas is imperceptible to human senses and can cause nonspecific symptoms that may be confused with symptoms of common viral illnesses. Clinical presentation of mild carbon monoxide poisoning may be confused with viral symptoms, such as (2):

• dizziness and headaches;
• nausea and vomiting;
• fatigue, lethargy, drowsiness and weakness;
• confusion and irritability.

While headache, nausea, and vomiting are the most common presenting symptoms in children, the most common symptom in infants is consciousness disturbance (1). Additionally, prolonged or acute exposure to carbon monoxide can lead to loss of consciousness and death (2). Survivors of carbon monoxide poisoning may have irreversible neurological sequelae. The long-term effects of chronic, low-level exposure to carbon monoxide include increased risk of certain chronic diseases, such as cardiovascular disease, and, in pregnant women, reduced infant birth weight (3).
Fetuses, pregnant women and infants are particularly vulnerable to carbon monoxide poisoning as they have increased metabolic demand and young children may be unable to vocalize symptoms of poisoning. Newborn infants are particularly vulnerable to carbon monoxide poisoning due to the persistence of fetal haemoglobin, which has a high affinity for carbon monoxide (2).

The Global Burden of Disease study has found that while global cases of carbon monoxide poisoning have remained stable over time, mortality due to carbon monoxide poisoning has decreased. Between 1990 and 2017, children under the age of 5 years experienced the largest decrease in mortality rate due to carbon monoxide poisoning globally (4).

As carbon monoxide is not perceptible by human senses, health care workers should have a high index of suspicious for carbon monoxide poisoning if children present with inexplicable symptoms listed on the slide.

References:
Finally, childhood burns, scalds, unintentional poisonings and other unintentional injuries are associated with the use of polluting fuels and inefficient technologies for household cooking, heating and lighting needs. The use of these fuels and technologies are a major risk factor for childhood:

- **Scalds**: due to contact with hot substances, such as food, water or steam. Estimates from the World Health Organization’s (WHO) Global Burn Registry 2018–2021 suggest that up to 85% of childhood scalds are due to cooking-related incidents (1);

- **Burns**: due to direct contact with fire or hot surfaces, or due to unintentional incidents such as an explosion. Estimates from the WHO Global Burn Registry 2018–2021 suggest that almost a third of all paediatric burns are related to cooking (1). Kerosene lamps are a common cause of childhood burns globally (2). Data from the WHO Global Burn Registry 2018–2021 found that more boys were reported for burns, but girls were more likely to sustain fatal burns. The predominance of girls in burn severity may be due to traditional cooking roles and consequently girls might spend more time in close contact with dangerous cooking fires and hot liquids than boys. Children under the age of 2 years were the most affected by burns (1);

- **Unintentional poisonings**: especially from the unintentional ingestion of kerosene. Kerosene is frequently sold in old soft drink or water bottles and children may unintentionally ingest it, leading to poisoning. Kerosene ingestion is the most common cause of global childhood poisoning and is likely to be under-reported and underestimated. The overwhelming majority of childhood poisoning due to kerosene ingestion occurs in low- and middle-income countries (LMICs) (2).

Additionally, children who participate in collection and transport of fuels, such as wood, on their heads, backs or in their arms are at risk of a range of other injuries, including (2):

- musculoskeletal injuries, including spinal injuries and muscle strains;
- headaches;
- bone fractures.

Burns, scalds, unintentional poisonings and other injuries during childhood can lead to lifelong physical, psychosocial and socioeconomic consequences.

**Note**: visit the WHO Global Burns Registry to see if health facilities in your region submit data to the registry: https://www.who.int/teams/social-determinants-of-health/safety-and-mobility/burns/global-burn-registry.
References:


Photo:

• © WHO/Atul Loke/Panos Pictures. Daily life in Kandanar village in Bastar district of Chhattisgarh, India.
The fourth section of this module discusses interventions and solutions at clinical, personal, national and international levels to reduce children's exposure to household air pollution.

**Photo:**
Health professionals should have a high index of suspicion for household air pollution exposure in children, especially those living in communities where there is limited access to electricity or where households are known or suspected to rely heavily on polluting fuels and inefficient technologies for cooking, heating and lighting needs. From a clinical perspective, it is important to include household air pollution as an environmental etiology in differential diagnoses. For example, when patients present with unexplained respiratory symptoms, repeated respiratory infections or exacerbated asthmatic episodes.

Health professionals can reduce and prevent children’s exposure to household air pollution by:

1. Being informed of household air pollution, its sources and child health effects. Sources, polluting fuels and inefficient technologies can differ from community-to-community, and it is important to identify local trends. Additionally, it is important to remember that in some areas household air pollution is a major contributor to ambient air pollution and children may also be exposed outside the home;
2. Identifying children at high risk of household air pollution. Health professionals can identify air pollution-related risk factors by asking pertinent questions about a child’s or pregnant mother’s home environment. For example, by asking about main sources of energy used in the home. Additionally, health professionals should be aware of patients who are particularly susceptible to household air pollution, for example children with asthma or pregnant women. These groups may be at greater risk to the effects of air pollution on their health;
3. Diagnosing and treating children affected by household air pollution and associated illnesses;
4. Prescribing transitional and permanent solutions to reduce and prevent household air pollution. Any prescribed solutions should be based on local feasibility and affordability;
5. Educating and communicating with patients and their carers, community members, colleagues and students about the main sources of household air pollution, risks to child health and methods to prevent and reduce exposure based on locally available resources;
6. Contributing to research, especially on child health effects linked to household air pollution and effectiveness of interventions that aim to reduce levels of household air pollution;
7. Advocating for policies that lead to sustainable and healthy transitions to cleaner sources of household energy. Health professionals are well positioned to share their knowledge with decision-makers. Health professionals can convey the health burden of household air pollution to decision-makers, conduct health-based assessments, support improved standards and policies to reduce harmful exposure, advocate for monitoring, and emphasize the need to protect children.
References:


Health professionals can ask their patients and families key questions that can help in detecting levels of air pollution inside the home and identifying at risk children or pregnant women. Key questions can help to build a paediatric environmental history, assess whether a child is suffering from symptoms related to household air pollution and identify methods to reduce and prevent exposure. These questions must be context specific to each patient.

Examples of questions that can be asked include (3,4):

- Are there open fires or sources of smoke in or around the home?
- Are fuels such as wood, coal, charcoal or other biomass, used inside or nearby the home for cooking, heating or lighting needs?
- Do cookstoves have hoods or chimneys? How is the home ventilated?
- Are cooking, heating and lighting appliances that are used in the home regularly maintained?
- How many hours per day does your child spend indoors?
- How and where do you store fuel used for cooking, heating and lighting? Particularly kerosene?

Note: for more detailed questions on household air pollution please see reference (4).

Note: if you have examples of questions that have been useful in your context or region they can be used here.

Note: for more information on completing a paediatric environmental history please see the module *The paediatric environmental history.*

References:
There are suggestions that health professionals can make to children, pregnant women, their families and communities to reduce their exposure to household air pollution. It is important to note that reducing exposure to household air pollution often requires access to resources and, in some locations, considerations of ambient air pollution are also necessary when considering how to reduce air pollution within the home. Therefore, it is important to adapt these actions to the specific context of each patient.

Examples of actions that can be suggested include:

- If wood must be burned, make sure it is dry to reduce smoke.
- Reduce household air pollution by ventilating the home, such as chimneys, windows and vents.
- Reduce time spent close to polluting sources, such as cookstoves, especially for susceptible populations such as pregnant women and young children.
- Identify and engage with local or national programs working to make clean fuels and technologies universally accessible.
- Reduce household air pollution by recommending the use of transitional fuels and technologies if clean fuels and technologies are not yet available or accessible.
- Control household air pollution at the source by only using clean fuels and technologies such as LPG and electricity where feasible.

Note: if you have examples of successful actions that have been suggested or used in your context or region they can be mentioned here.

References:

At the national level, policy and governmental action is vital to reduce household air pollution. Actions must be broad in scope and done in collaboration with stakeholders across governmental, nongovernmental and private sectors including environment, health and energy.

National governments can take many actions to help protect their citizens from hazardous household air pollution, including (1–3):

- **supporting programs and interventions** that aim to implement clean cooking, heating and lighting solutions for long-term adoption. This may include interventions that aim to replace traditional stoves with cleaner technologies and subsidizing clean fuels and technologies for household energy needs;
- **monitoring and evaluating** household energy policies and interventions that promote progress towards clean fuels and technologies for household energy production;
- **supporting clean and renewable** sources of energy, such as solar power, through installation of panels on rooftops and by subsidizing clean fuels and technologies;
- **improving housing design and ventilation** through methods that adequately vent smoke from cooking, heating and lighting and reduce the need for additional heating or cooling through passive principles, consequently reducing exposure to household air pollution;
- **spreading awareness** of the dangers that polluting fuels and inefficient technologies pose to child health. This may include training programs for health care workers or counselling for parents, families and caregivers;
- **organizing communication campaigns** to encourage clean energy use and behaviour change among households. Campaigns may target at risk children, families and communities and may aim to promote health, financial and time saving benefits that can be achieved through switching to cleaner fuels and technologies.

**Note:** if you have examples of national policies, regulations or interventions to reduce household air pollution that have been developed or used in your country they can be mentioned here.

**References:**

In 2018, the International Organization for Standardization (ISO) released a set of voluntary performance targets for household sources of energy. These targets classify household cooking, heating and lighting technologies using different tiers according to emissions and fuel standards. Technologies are classified using numerical indications from 0 (polluting) through to 5 (clean) \((1)\). The figure on this slide highlights key factors that define polluting, transitional and clean fuels and technologies for household cooking, heating and lighting needs.

The World Health Organization’s (WHO) definition of clean, transitional and polluting fuels and technologies is also relevant. WHO defines \((1,3)\):

- **Polluting fuels and technologies** as those that do not provide a health benefit. WHO recommends against the use of unprocessed coal and discourages the use of kerosene, and both these fuels are considered polluting. Technologies classified as 0, 1 and 2 for both fine particulate matter (PM\(_{2.5}\)) and carbon monoxide emissions are considered polluting;

- **Transitional fuels and technologies** are those that provide a substantial reduction in emissions and some health benefits, but the fuel and technology combination does not meet WHO recommendation levels. Fuels that may be used in transitional technologies include charcoal and biomass. Additionally, maintenance of combustion technologies and appliances may help to minimize exposure through technical revisions and interventions aimed at reaching the lowest possible emissions. Technologies classified as 3 for PM\(_{2.5}\) emissions and Tier 3 and 4 for carbon monoxide emissions are considered transitional;

- **Clean fuels and technologies** are those that are known to be clean for health at point of use and are categorized as clean for PM and carbon monoxide emissions. These include technologies that use solar power, electricity, biogas, natural gas, liquefied petroleum gas (LPG) and alcohol fuels, such as ethanol. Technologies classified as Tier 4 or Tier 5 for PM\(_{2.5}\) emissions and Tier 5 for carbon monoxide emissions are considered clean for health.

**Note:** if there are examples of specific polluting, transitional and clean fuels and technologies that are relevant for your context, mention them here. Reference \((2)\) gives some specific examples of technologies that are considered transitional and clean for health.

**References:**


**Figure:**
- © WHO.
The World Health Organization (WHO) provides technical support, capacity building and tools and resources to countries to evaluate and scale-up health promoting household fuels and technologies. WHO provides this support through (1):

- global air quality guidelines for major air pollutants, indoor air quality and household fuel combustion. The WHO Guidelines for indoor air quality: household fuel combustion provide health-based recommendations on the types of fuels and technologies that protect health, and effective strategies for the dissemination and adoption of cleaner household fuels and technologies (2). These guidelines are discussed in greater detail on Slide 38. Additionally, the WHO Global air quality guidelines provide quantitative, health-based recommendations for air quality, expressed as short- or long-term concentrations for the major air pollutants. The air quality guidelines outline optimal achievable air quality levels to protect human health worldwide and are applicable to both indoor and outdoor environments (3);

- building country capacity and supporting governments through tools and resources such as the Clean Household Energy Solutions Toolkit (CHEST) (4,5), the Health and Energy Platform of Action and the Benefits of action to reduce household air pollution (BAR-HAP) tool (6), maintaining the WHO household energy policy repository and BAR-HAP tool (6), and through delivery of consultations, workshops and trainings on household energy and health (for more information on BAR-HAP tool and CHEST, see Slides 39 and 40);

- as part of the Global Health Observatory, WHO maintains the Household Energy Database, monitoring progress of the transition to cleaner fuels and stove combinations in households around the world (9);

- monitoring as the custodian agency for indicators within Sustainable Development Goals (SDG) 3 and 7 (10) (see Slide 42 for more information about the SDGs and household air pollution).

Note: to learn more about WHO’s work on air pollution and for more information on the WHO Global air quality guidelines, please see the module Ambient air pollution.

References:


**Figures:**

- WHO.
The World Health Organization's (WHO) issued the first-ever health-based guidelines on clean fuels and technologies for household cooking, heating and lighting in 2014. These guidelines aim to help policy-makers, researchers and technical staff understand and implement best approaches to reducing household air pollution. The guidelines identify which energy systems (including technologies and fuels) can be considered clean for health in homes and specify the level of pollutant emissions that pose health risks (1).

The table displayed on the slide shows the two pollutants considered in the guidelines, type of device (either vented or unvented) and the WHO emission rate targets for each. It is important to note that these rates are the minimum that should not be exceeded (1).

**Fine particulate matter (PM$_{2.5}$):**
- WHO emission rate target for **vented** devices = 0.23 milligrams per minute (mg/ min)
- WHO emission rate target for **unvented** devices = 0.80 mg/ min.

**Carbon monoxide:**
- WHO emission rate target for **vented** devices = 0.59 grams per minute (g/ min)
- WHO emission rate target for **unvented** devices = 0.16 g/ min.

Importantly, to meet the recommendation of “clean for health at point of use”, devices and fuels must reach both the relevant PM$_{2.5}$ and carbon monoxide emission rate targets (1).

Additionally, the **WHO guidelines recommend against the use of unprocessed coal and discourage the use of kerosene as household fuels.** Another recommendation in the guidelines addresses the need for policies that prioritize achieving health benefits during phases where transitional fuels and technologies are required, with a particular focus on low- and middle-income countries (LMICs) (1).

**Note:** for more information on the WHO global air quality guidelines, please see the module Ambient air pollution.

References:

Figure:

• WHO.
The Clean Household Energy Solutions Toolkit (CHEST) is the World Health Organization’s (WHO) resource to help countries design and implement policies in line with the recommendations found in the WHO Guidelines on indoor air quality: household fuel combustion. CHEST is made up of six modules aimed at providing policy-makers and health practitioners with the tools and resources they need to promote the selection and implementation of clean household energy solutions, consequently improving health, livelihoods, environment and climate change outcomes. The tools and resources provided in CHEST have been piloted and used in countries around the world and include models for estimating emissions, health impacts and communication strategies.

Of the six modules that make up CHEST, Modules 1, 5 and 6 are of particular interest for health care professionals:

- **Module 1, Stakeholder mapping and situational assessment**, provides guidance on identifying key stakeholders and performing a country-wide assessment of household energy use. It identifies gaps in available data, priority areas for policy development and provides tools to develop evidence-based arguments and potential paths forward for action in clean household energy;
- **Module 5, Engaging the health community**, is designed to empower the health sector to tackle household air pollution. It provides concrete resources to assist the health care sector to promote clean household energy solutions, assess household energy as a risk factor for disease and prescribe clean solutions;
- **Module 6, Communication and awareness raising**, provides guidance on how to communicate and raise awareness about the health and livelihood impacts of household energy among key audiences, such as important stakeholders, the general public and health professionals. This module also includes tools for planning campaigns and materials to educate the public on the benefits of clean household air.

References:


**Figures:**
- WHO.
Benefits of Action to Reduce Household Air Pollution (BAR-HAP) tool

- Estimates the cost of household energy interventions (government and private)
- Compares costs with benefits to:
  - Health
  - Time savings
  - Climate
  - Environment
- Can be used to identify clean cooking policies and technology interventions that will economically achieve desired outcomes

The Benefits of Action to Reduce Household Air Pollution (BAR-HAP) tool is a planning tool for assessing the costs and benefits of different interventions that aim to reduce cooking-related household air pollution. BAR-HAP is a resource in the World Health Organization’s (WHO) Clean Household Energy Solutions Toolkit (CHEST) and allows users to model 16 different cooking transitions from polluting fuels and technologies to cleaner options, including both transitional and clean for health options.

The tool can help decision-makers compare costs of implementing an intervention against benefits to:

- health
- time savings
- climate
- environment.

Additionally, the tool can be used to identify clean cooking policies and technology interventions that best meet the needs and priorities of a particular context, as well as available finances and other resources (1).

References:

Figure:
- WHO.
The World Health Organization’s (WHO) Household Energy Policy Repository is an online clearing house for national, regional and local policies, regulations and legislations for household energy use (1). It serves as a knowledge base summarizing policies targeting cooking, heating and lighting using a variety of clean fuels and technologies. In 2023, the repository included 120 clean household energy policies or policy statements from more than 30 countries and the European Union and included examples from all WHO regions (2).

The repository is aimed at providing policy-makers and other stakeholders with examples of how other countries have implemented policies and addressed challenges encountered and can constructively use this information to design policies of their own. The repository includes policies on financial measures, regulatory instruments, standards for energy efficiencies and awareness raising campaigns, as well as independent evaluations of some policies (2).

References:

Figure:
- © WHO.
Expanding access to clean cooking, heating and lighting unlocks progress across the entire Sustainable Development Goals (SDGs) agenda. SDG 7 aims to “ensure access to affordable, reliable, sustainable and modern energy for all (1).” SDG 7 sets an ambitious target for ensuring universal access to clean household energy by 2030. The graphic on this slide shows progress towards achieving this target as of 2023, broken down into some key indicators.

SDG 7 measures global (2):
- access to electricity;
- access to clean fuels and technologies for cooking;
- proportion of renewable energy share;
- energy intensity;
- financial flows to low- and middle-income countries (LMICs) to support clean energy research and development.

Additionally, achieving universal access to clean household energy is closely linked to SDG 3 (“ensuring healthy lives and promoting well-being for all at all ages”) and SDG 9 (“building resilient infrastructure, promoting inclusive and sustainable industrialization and foster innovation”) (1). Improving household air quality and achieving the SDGs is essential to ensuring the health and futures of children across the world.

References:

Figure:
- © WHO.
The final section of this module explores an example study related to pregnant women’s exposure to household air pollution and an intervention aiming to reduce their exposure to fine particulate matter (PM$_{2.5}$) and assess related child and maternal health outcomes.

Note: if you have examples that detail local, regional or national household air pollution interventions targeting the reduction of exposures, implementation of clean household energies and improvement of child or maternal health, they can be used here.

Photo:
The Household Air Pollution Intervention Network (HAPIN) trial is an international multi-centre study aiming to assess women and children’s health outcomes associated with switching from household energy relying on combustion of biomass fuels to liquified petroleum gas (LPG) cookstoves and fuel. Beginning in 2018, the HAPIN randomized controlled trial followed more than 3,200 participating households for an initial 18 months in four countries: Guatemala, India, Peru and Rwanda. The trial participants were pregnant women and their babies, and older, adult women in households across selected trial sites in all four countries. Half the participating households were randomly assigned to receive an LPG cookstove and fuel, while the other half (the control group) continued using traditional cooking fuels and technologies (1).

Participating households were regularly monitored for stove use and personal exposure to household air pollution. Additionally, the HAPIN trial is investigating health outcomes linked to household air pollution exposure. Primary health outcomes include (2):

- infant birth weight;
- stunting at 1 year of age;
- severe pneumonia in children under 1 year of age;
- blood pressure in non-pregnant adult women.

Additionally, secondary health outcomes investigated by the trial include gestational hypertension, preterm birth, fetal growth and infant development (1).

References:


Photo:

© WHO/ Violaine Martin.
The Household Air Pollution Intervention Network (HAPIN) trial measured reduction in personal exposure to household air pollution when switching from biomass fuels to liquified petroleum gas (LPG) cookstoves and fuel. The trial measured changes in pregnant women’s personal exposure who received LPG cookstoves and fuel, compared to the control group (1).

The trial found that the LPG fuel and stove intervention was linked with significant reductions in personal exposure to fine particulate matter (PM$_{2.5}$) in pregnant women. Over two follow-up visits aligned with trimester, the study found the following changes in median personal exposure to PM$_{2.5}$ in 1590 pregnant women who received LPG stoves and fuel at trial sites in Guatemala, India, Peru and Rwanda (1):

- **Intervention group median PM$_{2.5}$**:
  - Baseline: 82 μg/m$^3$
  - First follow-up: 24 μg/m$^3$
  - Second follow-up: 24 μg/m$^3$

- **Control group median PM$_{2.5}$**:
  - Baseline: 83 μg/m$^3$
  - First follow-up: 72 μg/m$^3$
  - Second follow-up: 70 μg/m$^3$

In comparison, the control group consisting of 1605 pregnant women recorded the following median personal exposures to PM$_{2.5}$ (1):

- Baseline: 83 μg/m$^3$
- First follow-up: 72 μg/m$^3$
- Second follow-up: 70 μg/m$^3$

Overall, the intervention group was associated with a 66% exposure reduction in personal PM$_{2.5}$ over the two follow-up visits, in comparison to the control group. Exposure reductions were consistent over time and similar across study sites. Results from the HAPIN trial suggest that LPG cookstove interventions in rural settings may reduce personal PM$_{2.5}$ exposure to, or lower than, the World Health Organization (WHO) targets (1,2).

**References**:


Photo:
• © WHO/ Ismail Taxta.
The Household Air Pollution Intervention Network (HAPIN) trial has begun releasing research investigating health effects in the study populations that may be associated with liquified petroleum gas (LPG) cookstove and fuel intervention. Thus far, research has investigated links between household air pollution and infant birth weight, stunting at 1 year of age, incidence of severe pneumonia in children under 1 year of age, elevated gestational blood pressure and elevated blood pressure among older, adult women.

One study found no significant difference in birth weight between babies born to women using LPG cookstoves and those born to women using biomass cookstoves. Infants born to women who received an LPG stove before 18 weeks' gestation had higher birth weight, suggesting that clean energy intervention during the first trimester of pregnancy may have a greater impact on birth weight than during other trimesters. Additionally, the study found that increased prenatal exposure to PM$_{2.5}$ was associated with lower infant birth weight (1).

An intention-to-treat analysis of 3195 pregnant women across all four countries found that the intervention did not show any protective effects on either gestation systolic or diastolic blood pressure. Additionally, in exposure-response analyses, both gestational systolic and diastolic blood pressure in the study group increased with higher exposure to PM$_{2.5}$, carbon monoxide and black carbon, however these increases were not statistically significant (2).

The HAPIN trial is continuing in Guatemala, India and Rwanda and is following babies born to pregnant women during the first stages of the trial until 5 years of age. The researchers are aiming to evaluate the effects of LPG cookstove intervention on the neurological and physical development of children (3).

References:


More information and recommended reading

For more information on children and air pollution see the additional training modules:
- Ambient air pollution
- Children and respiratory diseases linked to the environment
- Indoor air pollution
- Paediatric environmental history: a tool for health care providers
- Second-hand smoke

Recommended reading and additional learning on air pollution:
- Air pollution and health training toolkit for health workers (APHT)
- WHO guidelines for indoor air quality
- Chemical pollution of indoor air and its risk for children’s health: educational course

For more information on household air pollution and child health please see the World Health Organization (WHO) training package on children’s environmental health for the health care sector (1). The following modules may be of particular interest:
- Ambient air pollution
- Childhood respiratory diseases linked to the environment
- Indoor air pollution
- Paediatric environmental history: a tool for health care providers
- Second-hand smoke

To read and learn more about air pollution see the below recommended references:
- Air pollution and health training toolkit for health workers (APHT) (2)
- WHO guidelines for indoor air quality (3)
- Chemical pollution of indoor air and its risk for children’s health: educational course (4).

References:
Acknowledgements for current edition

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This module has been reviewed and align with the child health content in the Air pollution and health training toolkit for health workers (APHT), which is complementary to this module.

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Design by LTV Com Sàrl, Villars-sous-Yens, Switzerland.
Approach to development

The World Health Organization’s (WHO) Training package for the health sector is a collection of modules with internationally harmonized information and peer-reviewed materials. A team of experienced professionals from over 15 countries and nongovernmental organizations (NGOs) participated in the original conception and development of the package over several in-person workshops between 2004 and 2016. These workshops identified key areas of concern related to child health and the environment, including emerging issues, on which the global health sector require additional training.

Subsequent updates of individual modules have been completed, including Ambient air pollution: training for the health care providers, third edition. This update has been completed using a thorough literature search and review of the medical research database PubMed for relevant research published in the past 10 years. This literature search focused on published systematic reviews and meta-analyses, as well as some cohort, case-control and cross-sectional studies. WHO’s online repository was searched for any relevant publications. Literature searches were also conducted across other United Nations (UN) agencies repositories for relevant reports, data, figures and other source material. Other major repositories were searched as relevant.

All recommendations discussed in this module come from official, publicly available WHO guidelines and guidance. Other suggestions for action are not official WHO guidelines or guidance and are examples of local or national actions taken and are accordingly indicated and referenced.

The example of the Household Air Pollution Intervention (HAPIN) trial featured in this module was identified through expert recommendations.

This module has been through an extensive review process with experts and has been reviewed by relevant technical teams and departments within WHO.
Suggested citation: