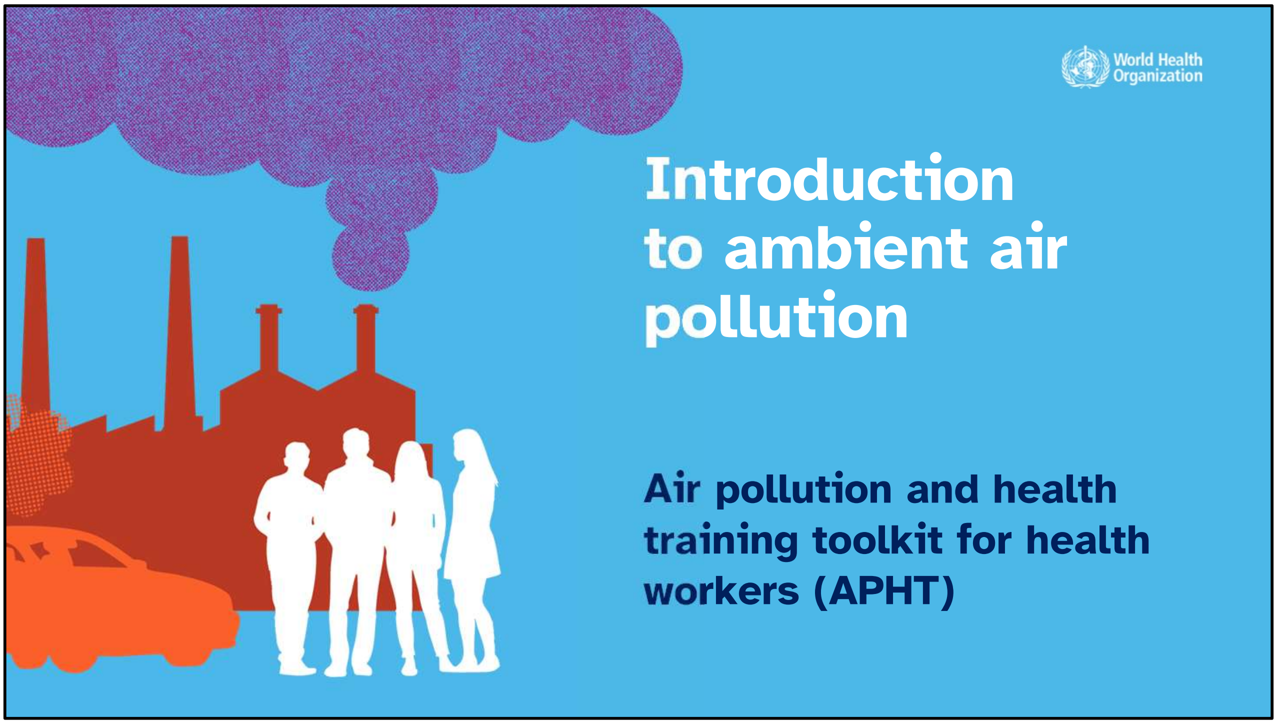


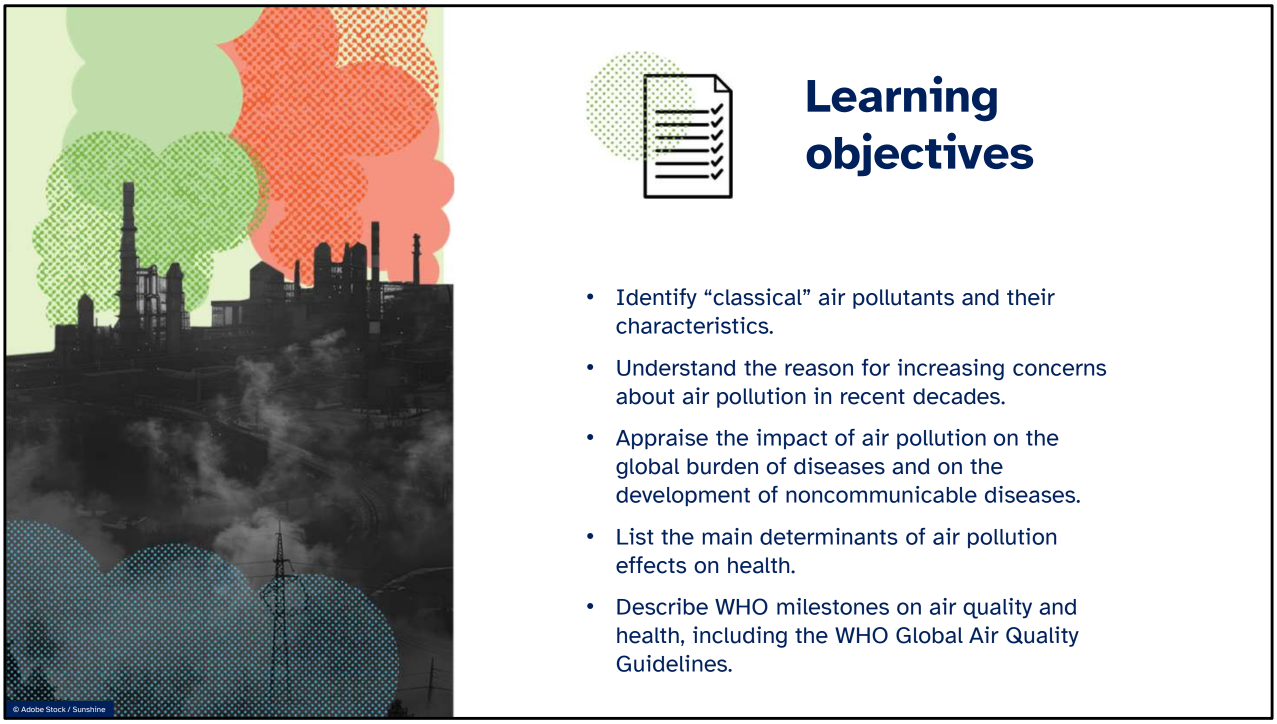
Notes

- The World Health Organization (WHO) reference number for the module ***Introduction to ambient air pollution*** is WHO/HEP/ECH/AQE/2024.3 © WHO 2024. Some rights reserved. This work is available under the CC BY-NC-SA 3.0 IGO licence.

- This module contains 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, you can adapt the information, statistics and photos within each slide to the particular context in which this module is being presented.

- This module belongs to the Air Pollution and Health Training toolkit targeting health workers (APHT). It has been developed in collaboration with more than 30 experts from government agencies, WHO collaborating centers, non-state actors, including medical and environmental health associations, as well as academic institutions. The methodology used for development included a mapping of existing air pollution and health training opportunities targeting health workers which informed gaps and needs for a global set of materials. Experts identified through existing collaborations with WHO contributed on the definition of outline and populating the training modules with contents. Peer review and pilot test coordinated by WHO ensured the collection of feedback and input for finalization of the products. WHO made all possible effort to ensure geographical and gender balance for the development of the training toolkit acknowledging limitations in terms of expertise, experience and overall feasibility. You can use and have access to other APHT modules where relevant.
  To see the full package visit: https://www.who.int/tools/air-pollution-and-health-training-toolkit-for-health-workers

- For more information on WHO's work on air quality, energy and health, please visit: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health

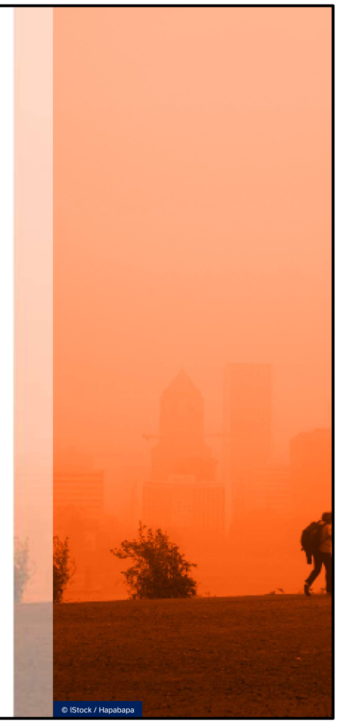


Learning objectives for this module include:

1. Identify “classical” air pollutants and their characteristics.
2. Understand the reasons for increasing concerns about air pollution in recent decades.
3. Appraise the impact of air pollution on the global burden of diseases and on the development of noncommunicable diseases.
4. List the main determinants of air pollution effects on health.
5. Describe WHO milestones on air quality and health, including the WHO Global Air Quality Guidelines.

Acronyms

AQG	air quality guidelines
ALRI	acute low respiratory tract infection
CLRTAP	Convention on Long-Range Transboundary Air Pollution
CO	carbon monoxide
COPD	chronic obstructive pulmonary disease
COVID-19	coronavirus disease
DALY	disability-adjusted life year
GBD	global burden of disease
GDP	gross domestic product
GHG	greenhouse gas
HFC	hydrofluorocarbon
IARC	International Agency for Research on Cancer
IPCC	Intergovernmental Panel on Climate Change
LMICs	low- and middle-income countries
LRTAP	long-range transboundary pollution
NCD	noncommunicable disease
NO_2	nitrogen dioxide
NO_x	nitrogen oxides
O_3	ozone
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxin
PCDF	polychlorinated dibenzofuran
PM	particulate matter
PM_{10}	particulate matter of diameter < 10 µm
$PM_{2.5}$	particulate matter of diameter < 2.5 µm
SARS	severe acute respiratory syndrome
CoV-2	coronavirus 2
SDG	Sustainable Development Goal
SLCP	short-lived climate pollutant
SO_2	sulfur dioxide
SO_x	sulfur oxides
TRAP	traffic-related air pollution
UFP	ultrafine particle
VOC	volatile organic compound
WHA	World Health Assembly
WHO	World Health Organization
WMO	World Meteorological Organization
YLD	years lived with disability
YLL	years of life lost



Module outline

1. Air pollution through history:

- London smog, 1952;
- London Clean Air Act 1956;
- WHO milestones on air quality.

2. Classical air pollutants and their sources:

- sources of air pollution;
- solid-liquid: particulate matter;
- gases: ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide.

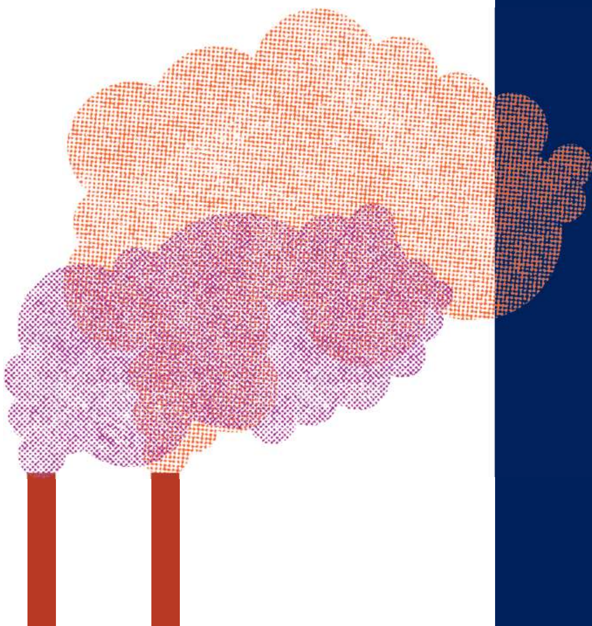
3. Air pollution and health impacts:

- air pollution and the global burden of diseases;
- the carcinogenicity of air pollution;
- air pollution in the NCDs agenda;
- the cost of ambient air pollution.

4. Determinants of air pollution and health effects:

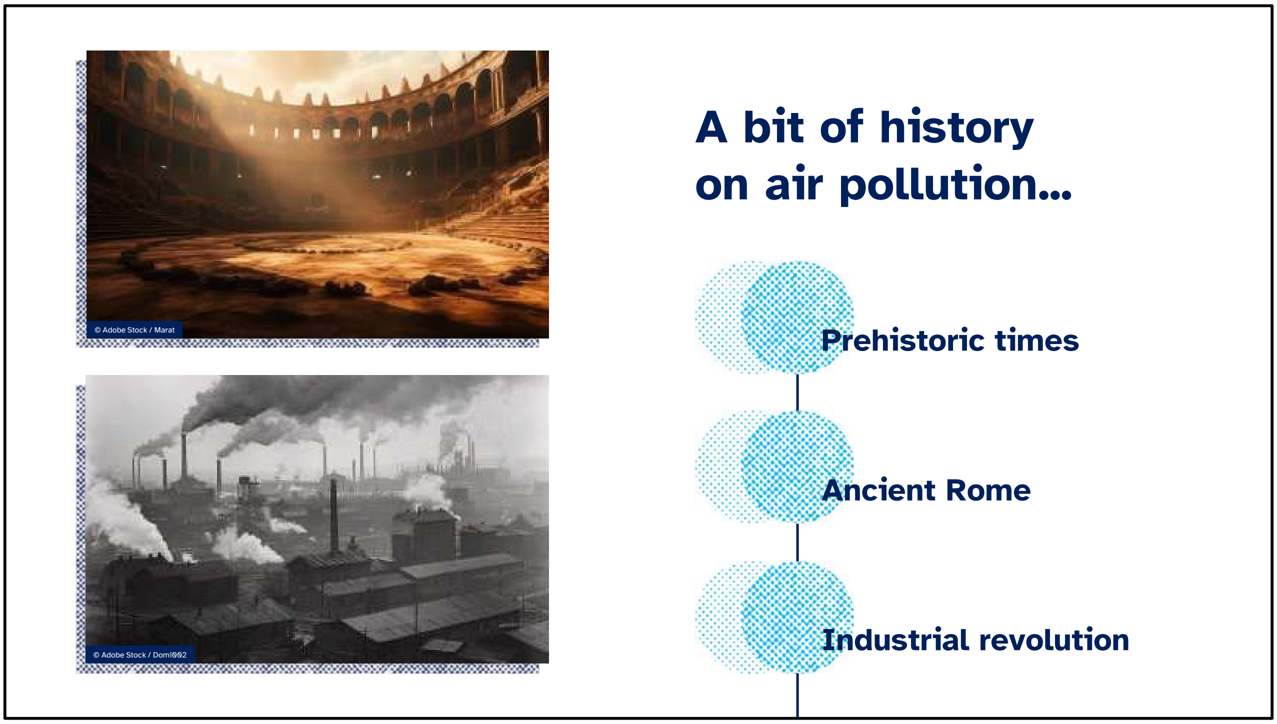
- population growth;
- urbanization;
- unsustainable production and consumption;
- climate change;
- meteorology.

World Health Organization



Unit 1

Air pollution through history



Humans have been generating air pollution ever since we learned how to make fire. Initially, the global human population was small and the scale of activities generating pollution was small; restricted to cooking and heating. However, as the global human population grew, and more advanced tools and technologies were developed, the sources, and quantity, of air pollution also grew. There are documented reports that air pollution was already a problem during the period of the Roman Empire. Air pollution exploded in intensity with the advent of the Industrial Revolution in the 18th century, and has persisted ever since.

Friends (?)

One of the **biggest problems** in addressing air pollution is that, both historically and even today, the sources of air pollution are **perceived in a positive light**, for example: contributing to our well-being, our means for getting things done or part of our entertainment.

One of the biggest problems in addressing air pollution is that, both historically and even today, the sources of air pollution are perceived in a positive light, for example: contributing to our well-being, our means for getting things done or part of our entertainment. There are still many places around the world where open fires are a necessity for cooking and heating, or where the use of polluting kerosene lamps is common, as people do not have access to clean energies. In such places fire represents an ability to function. However, even in places where people have access to clean energy such as electricity, air-polluting sources such as campfires, barbeques or candles are still perceived as our “friends”.

Enemies

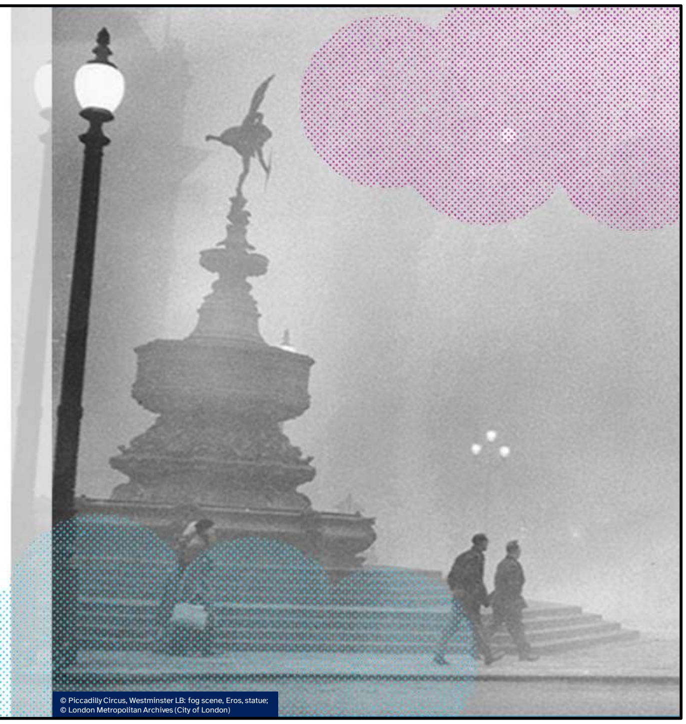
The realization that air pollution is a problem is normally only made when the situation is **drastically bad.** In this case, the levels of pollution are such that it is **difficult to see or even breathe.**

The realization that air pollution is a problem is normally only made when the situation is drastically bad. In this case, the levels of pollution are such that it is difficult to see or even breathe, as depicted in these images from different regions of the world.

London smog, December 1952

Smoke + fog = smog

- Caused by smoke from **factory and house chimneys**
- Over **4000 deaths** were attributed to smog at that time
- More recent evidence estimating over **12 000 deaths**



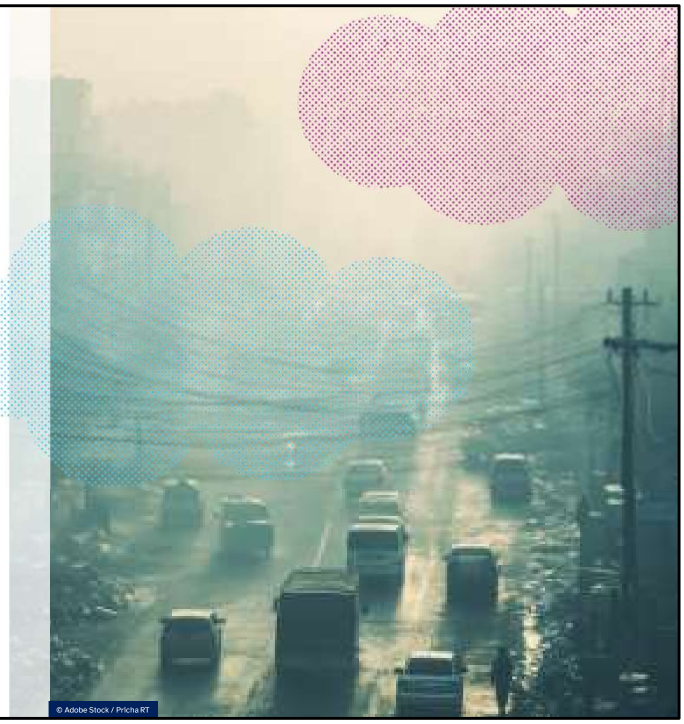
The Great Smog of London (also called the Killer Fog) of 1952 was a classic episode of severe air pollution. During the 1952 London Smog, the smog was so thick that road, rail and air transport was almost brought to a standstill. A performance at the Sadler's Wells Theatre had to be suspended when fog in the auditorium made conditions intolerable for the audience and the performers. There was a cattle show going on at the time in Smithfield, and the press reported that the cattle were asphyxiated. In many parts of London it was impossible for pedestrians to find their way during the day, even in familiar districts. People could not even see their own feet. This kind of dense fog came to be known as a "pea souper". It was very different from the clean white fog of the countryside because it contained noxious emissions from factory and house chimneys; these emissions had an unpleasant odour and turned the fog a dirty yellow or brown.

It was estimated that 4000 people lost their lives in the weeks following the London Smog, with more recent evidence estimating a 1-year death toll of 12 000 people. Many who died were already suffering from chronic respiratory or cardiovascular diseases. The Great Smog caused so many deaths that it served as a wake-up call to the public and policy-makers. The Great Smog – as well as other episodes such as the Meuse Valley fog in Belgium in 1930, the Donora Smog in Pennsylvania in 1948 and the 1966 Thanksgiving Smog in New York City – left little doubt that high levels of air pollution were associated with an increase in premature deaths, and led to the first major legislation designed to reduce air pollution. The London Smog of 1952, and its effects on health, triggered the Clean Air Act of 1956, which banned emissions of black smoke and decreed that the residents of urban areas and operators of factories must convert to smokeless fuels.

Bibliography

- Bell ML, Davis DL. Reassessment of the lethal London fog of 1952: novel indicators of acute and chronic consequences of acute exposure to air pollution. Environ Health Perspect. 2001;109(suppl 3):389–94. doi:10.1289/ehp.01109s3389.
- Logan WPD. Mortality in the London fog incident, 1952. Lancet. 1953;1:336–38. doi:10.1016/s0140-6736(53)91012-5.
- Nemery B, Hoet PHM, Nemmar A. The Meuse Valley fog of 1930: an air pollution disaster. Lancet. 2001;357:704–8. doi:10.1016/S0140-6736(00)04135-0.
- Ware JH, Thibodeau LA, Speizer FE, Colome S, Ferris BG Jr. Assessment of the health effects of atmospheric sulfur oxides and particulate matter: evidence from observational studies. Environ Health Perspect. 1981;41:255–76. doi:10.1289/ehp.8141255.

Case example:
Red alert in Beijing 2015



Most recent times: Beijing, 2015.
A red alert in the city was declared because of the very high levels of air pollution. People were advised to stay indoors, schools were closed and outdoor construction work was suspended.

Let’s jump to contemporary times. This slide shows the first red alert in Beijing declared by the municipality because of the unbearable levels of air pollution. As a protective measure, people were recommended to stay indoors., schools were closed and outdoor working activities such as constructions were suspended.

Bibliography

- China pollution: first ever red alert in effect in Beijing. BBC News; 2015 (https://www.bbc.com/news/world-asia-china-35026363, accessed 9 December 2024).

Case example:
COVID-19 lockdown effect in India

In many parts of the world, the global lockdown because of the SARS-CoV-2 (COVID-19) pandemic resulted in temporarily cleaner air and a significant drop in the levels of certain air pollutants.

On a different perspective, in many parts of the world, the global lockdown because of the SARS-CoV-2 (COVID-19) pandemic resulted in temporarily cleaner air and a significant drop in the levels of certain air pollutants. Here is an example of the improvement in air quality in New Delhi, India.

Bibliography

- Hoeller S-C. Before-and-after photos show the dramatic effect lockdowns had on pollution around the world in 2020. Reuters; 2020 (https://www.insider.com/before-after-photos-show-less-air-pollution-during-pandemic-lockdown#after-according-to-reuters-new-delhi-is-currently-experiencing-the-longest-spell-of-clean-air-on-record-8, accessed 9 December 2024).

With such a long history…

- For a long time, people did not realize that it is a problem
- New pollution sources and pollutants have been introduced
- Improvement of detection tools

…haven't we already uncovered the science of air pollution?

Initial WHO technical reports published in the 1950s and 1960s indicated the possibility of the adverse health effects of low concentrations of pollution. Air quality regulations, such as the Clean Air Act of 1956 in the United Kingdom, were not widespread until the 1990s. With such a long history, why isn't the science of air pollution better understood?

Although there were numerous signals and reports that high levels of air pollution could be having negative effects on health, it was not until the 1990s that epidemiological studies quantitatively demonstrated the link between common air pollution, especially of fine particulate matter ($PM_{2.5}$), and poor health.

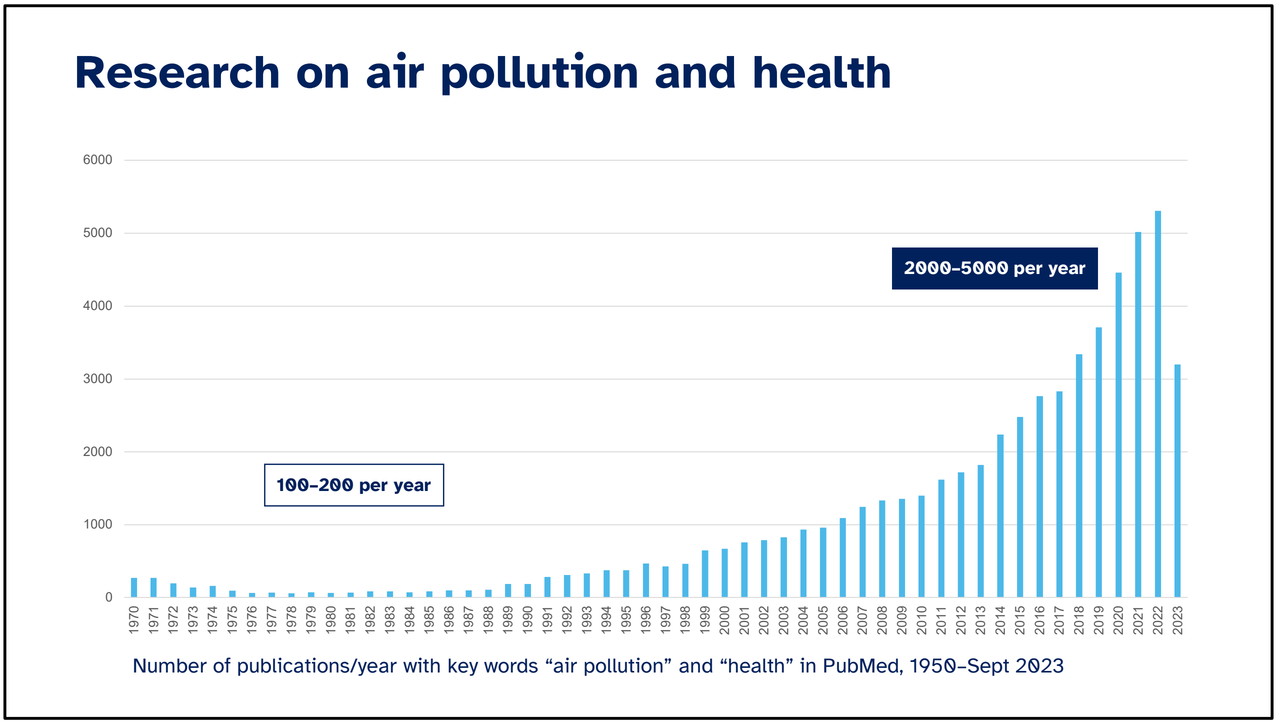
The introduction of new regulations required the systematic monitoring of air pollution, allowing a comparison of current concentrations with those required by national air quality standards or recommended by WHO guidelines. A core mandate of WHO is the development of air quality guidelines (AQG), setting the levels of air pollution under which no or minimal harm effects are anticipated. Countries or federations of countries are instead responsible for setting legally binding air quality standards, which may or may not use the same concentration values as the WHO AQG.

New products and technologies are continuously being developed, and the impacts of many of these technologies on air pollution are not considered or predicted. One example is that of laser printers: ubiquitous in indoor environments, these have been shown to contribute significant amounts of secondary pollutants.

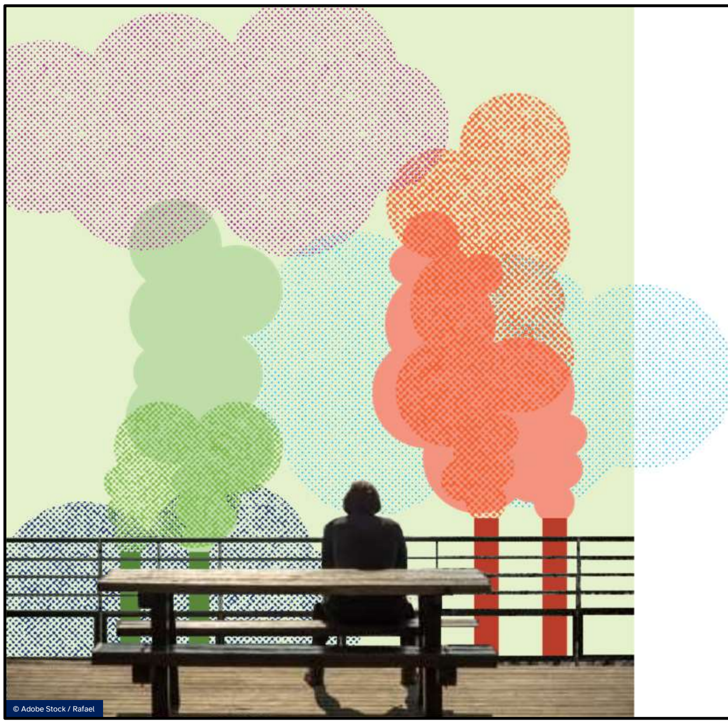
Today, modern detection and analysis techniques can detect single particles in the air or trace amounts of specific pollutants.

Bibliography

- Expert Committee on Environmental Sanitation & World Health Organization. Air pollution: fifth report of the Expert Committee on Environmental Sanitation [meeting held in Geneva from 18 to 23 November 1957]. World Health Organization; 1958 (https://apps.who.int/iris/handle/10665/40416, accessed 9 December 2024).



The number of research articles published on the health aspects of air pollution was only around 100–200 per year in 1960–1990. However, an exponential increase in the number of publications was observed after the 1990s, with up to 5000 papers published per year in recent years.



Still lack of scientific research and air quality assessment in countries and regions with high air pollution levels.

These areas would benefit most from national- and regional-based scientific research.

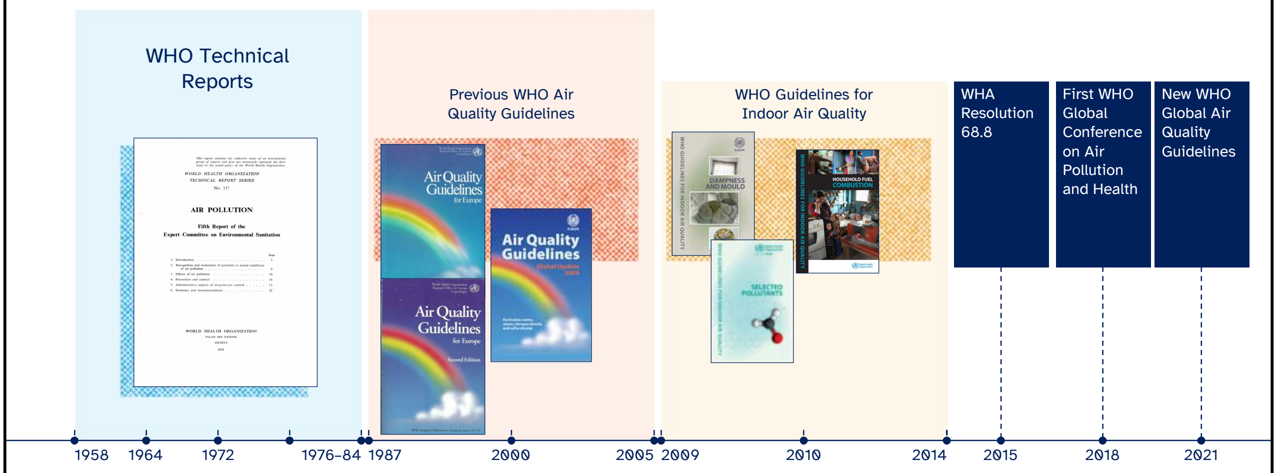
While research on air pollution and health-related issues has considerably increased, there is still a lack of scientific research and air quality assessment in many countries and regions of the world that are experiencing particularly high levels of air pollution, and which would benefit most from national- and regional-based scientific research, for the sake of:

- enhancing public awareness of air pollution as an environmental and health threat;
- as well as encouraging a stronger political will to tackle the issue.

Bibliography

- Sweileh WM, Al-Jabi SW, Zyoud SH, Sawalha AF. Outdoor air pollution and respiratory health: a bibliometric analysis of publications in peer-reviewed journals (1900–2017). Multidiscip Respir Med. 2018;13:15. doi:10.1186/s40248-018-0128-5.

WHO milestones on air quality and health



WHO has been following the growth of evidence of the impact on air quality and health since 1958, evaluating and summarizing knowledge of the health effects of air pollution.

In 1987, WHO formulated the first evidence-based health guidelines for more than 30 pollutants, based on a global synthesis of scientific evidence.

In the 2005 global update of WHO air quality guidelines, focus was made on the rapidly growing evidence of the health effects of “classical” air pollutants. The term “classical” is used to indicate the most health-damaging air pollutants. Guidelines also cover indoor dampness and mould (2009) and indoor air pollutants emitted, for example, from furnishings and from building materials stored indoors (2010). WHO guidelines for indoor air quality on air pollutants related to household fuel combustion include limits on emissions from cooking and heating stoves, as well as recommendations regarding clean fuel use by households (2014).

The WHO air quality guidelines recommended which air quality levels should be achieved in order to reduce the adverse health effects of pollution.

Since the 2005 global update, there has been a marked increase in the quality and quantity of evidence that shows how air pollution affects different aspects of health. The 2021 WHO global air quality guidelines include clearer insights into the sources of emissions and the contribution of air pollutants to the global burden of disease.

During the Sixty-eighth World Health Assembly (WHA; the supreme decision-making body of WHO, which gathers annually at the Palais des Nations in Geneva) in 2015, resolutions on key health issues were adopted to urge Member States and the WHO Director-General to undertake particular actions related to key health issues. Another important WHO milestone on air quality and health is therefore worth mentioning: the WHA Resolution 68.8 (2015) and the proposal of a road map for an enhanced global response to the adverse health effects of air pollution. The road map set the path for the first WHO global conference on air pollution and health held in 2018 and highlights the need to build the capacity of the health workforce on issues related to air pollution and health.

***

Note: The development of global guidelines ensuring the appropriate use of evidence represents one of the core functions of WHO. Recommendations that can impact upon health policies or clinical interventions are considered guidelines for WHO purposes. Topics for which WHO guidelines have been developed include antimicrobial resistance, child health, communicable and noncommunicable diseases (NCDs), mental health and substance abuse, health systems, nutrition, public health emergencies and many others.

Bibliography

- Air quality guidelines for Europe, second edition. Copenhagen: WHO Regional Office for Europe; 2000 (https://apps.who.int/iris/handle/10665/107335, accessed 9 December 2024).
- World Health Assembly, 68. Health and the environment: addressing the health impact of air pollution. Geneva: World Health Organization; 2015 (https://apps.who.int/iris/handle/10665/253237, accessed 9 December 2024).
- World Health Organization. Regional Office for Europe. WHO guidelines for indoor air quality: dampness and mould. World Health Organization. Regional Office for Europe; 2009 (https://iris.who.int/handle/10665/164348, accessed 9 December 2024).
- World Health Organization. Regional Office for Europe. WHO guidelines for indoor air quality: selected pollutants. World Health Organization. Regional Office for

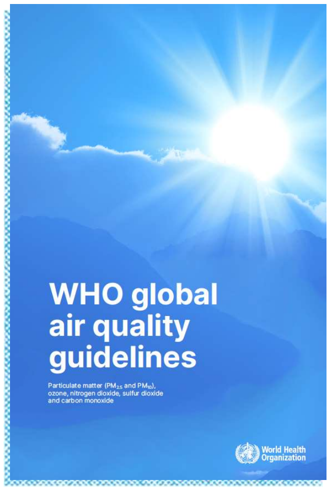
Europe; 2010 (https://iris.who.int/handle/10665/260127, accessed 9 December 2024).
- World Health Organization. WHO guidelines for indoor air quality: household fuel combustion. World Health Organization; 2014 (https://iris.who.int/handle/10665/141496, accessed 9 December 2024).
- World Health Organization. WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization; 2021 (https://iris.who.int/handle/10665/345329, accessed 9 December 2024).

WHO Global Air Quality Guidelines (AQG 2021)

Pollutant	Averaging time	AQG value
Particulate matter $PM_{2.5}$	**Annual** **24-hour***	**5µg/m³** **15µg/m³**
PM_{10}	Annual 24-hour*	15µg/m³ 45µg/m³
Ozone, O_3	peak season 8 hour, daily maximum	60µg/m³ 100µg/m³
Nitrogen dioxide, NO_2	Annual 24-hour*	10µg/m³ 25µg/m³
Sulfur dioxide, SO_2	24-hour*	40µg/m³
Carbon monoxide, CO	24-hour*	4mg/m³

* 99th percentile (i.e. 3–4 exceedance days per year)

ACQ levels recommended to be **achieved everywhere** in order to significantly reduce the adverse health effects of pollution, although **there is no threshold with no health effects.**



Rapidly growing evidence of the health effects of "classical" air pollutants – particulate matter (PM), O3, NO2 and SO2 – provided the basis for the global update of the WHO air quality guidelines (AQG). The guidelines recommend an air quality that should be achieved everywhere in order to reduce the adverse health effects of pollution. While exceedance of these levels is associated with important risk to public health, it is important to remember that risks exist below these values and that there is no threshold with no health effects.

The 2021 WHO global air quality guidelines include clearer insights into the sources of emissions and the contribution of air pollutants to the global burden of disease (GBD). After a systematic review of the accumulated evidence, several of the updated AQG levels are now lower than the previous version of the guidelines. For example, the recommended value for annual concentrations of $PM_{2.5}$ is 5 micrograms per cubic meter, whereas in the previous guidelines the threshold level was 10 micrograms per cubic meter. New features also include new AQG levels for peak-season O_3 and 24-hour NO_2 and CO, as well as new interim targets.

Interim targets are air pollutant levels that are higher than the AQG levels, but which authorities in highly polluted areas can use to develop pollution reduction policies that are achievable within realistic time frames. Therefore, the interim targets should be regarded as steps towards the ultimate achievement of AQG levels in the future, rather than as target ends.

Bibliography

- WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/345329, accessed 9 December 2024).

Places to find air quality data

The **WHO ambient air quality database** include data validated by countries showing **annual average concentrations of PM and NO_2**. OpenAQ uses an aggregated set of **current and archived air quality data gathered in real time from government agencies**, yet these data have not been validated by countries.

WHO Ambient Air Quality Database

Indicator	Concentrations of fine particulate matter (PM2.5)				
Period	2019				
Location	Total	Urban	Rural	Cities	Towns
Afghanistan	62.49 [45.04 – 86.46]	75.19 [53.87 – 102.9]	56 [39.42 – 77.13]	84.04 [60.77 – 114.9]	62.47 [44.97 – 86.91]
Albania	16.28 [14.73 – 18.21]	16.58 [14.98 – 18.62]	15.65 [14.01 – 17.67]	16.7 [15.03 – 18.8]	16.4 [14.49 – 18.62]
Algeria	22.68 [14.54 – 35.29]	22.85 [14.51 – 35.46]	22.38 [14.2 – 35.42]	23.75 [14.8 – 36.27]	21.74 [13.85 – 34.38]
Andorra	8.52 [7.49 – 10.05]	8.88 [7.88 – 10.18]	7.96 [6.59 – 9.65]		8.88 [7.88 – 10.18]
Angola	27.16 [5.85 – 89.91]	32.32 [5.47 – 129.2]	23.35 [6.13 – 61.85]	33.19 [5.47 – 135.9]	28.43 [5.54 – 100.9]
Antigua and Barbuda	8.3 [5.72 – 11.54]	8.42 [5.84 – 11.68]	8.12 [5.56 – 11.35]		8.42 [5.84 – 11.68]
Argentina	12.04 [8.92 – 15.57]	11.23 [8.67 – 13.86]	12.85 [9.05 – 17.3]	11.07 [8.82 – 13.4]	11.97 [8.14 – 16.58]
Armenia	34.13 [24.44 – 47.1]	36.24 [26.16 – 50.5]	28.41 [19.98 – 38.37]	38.26 [27.58 – 54.35]	33.24 [23.67 – 45.72]
Australia	8.93 [8.61 – 9.27]	9.12 [8.79 – 9.44]	7.94 [7.38 – 8.57]	9.08 [8.73 – 9.43]	9.19 [8.8 – 9.7]
Austria	11.51 [11.2 – 11.88]	12.42 [12.11 – 12.88]	10.34 [10 – 10.76]	13.33 [12.86 – 14.13]	11.24 [10.93 – 11.52]
Azerbaijan	24.64 [13.74 – 37.54]	26.18 [13.79 – 42.67]	23.43 [13.92 – 34.28]	27.15 [12.77 – 46.26]	24.25 [14.67 – 35.24]
Bahamas	5.2 [3.77 – 7.05]	5.2 [3.78 – 6.77]	5.2 [3.34 – 7.9]	4.86 [3.63 – 6.23]	5.52 [3.85 – 7.35]
Bahrain	51.82 [45.88 – 57.66]	51.84 [45.72 – 57.67]	51.38 [40.59 – 62.47]	51.59 [45.76 – 57.55]	56.48 [36.58 – 82.66]
Bangladesh	45.99 [41.65 – 51]	46.85 [42.47 – 51.99]	37.98 [34.32 – 41.87]	50.12 [44.91 – 56.03]	42.47 [37.86 – 47.63]
Barbados	9.79 [6.9 – 13.99]	9.83 [6.91 – 14.01]	9.19 [6.51 – 13.28]	9.83 [6.95 – 14.09]	9.84 [6.91 – 13.96]
Belarus	15.48 [13.25 – 17.71]	17.19 [14.84 – 19.86]	13.41 [11.06 – 15.92]	17.51 [15.07 – 20.2]	14.67 [12.3 – 17.24]
Belgium	11.26 [10.87 – 11.62]	11.57 [11.17 – 11.94]	9.91 [9.39 – 10.44]	12.3 [11.95 – 12.67]	11.08 [10.51 – 11.56]
Belize	10.51 [4.33 – 20.5]	10.44 [4.42 – 20.12]	10.51 [4.32 – 20.56]	10.45 [4.57 – 20.74]	10.44 [4.31 – 19.96]
Benin	31.51 [20.62 – 47.27]	31.78 [22.36 – 45.17]	31.27 [18.62 – 52.5]	32.61 [23.25 – 45.85]	30.8 [20.55 – 45.63]
Bhutan	26.1 [23.46 – 28.81]	16.91 [14.56 – 19.46]	26.44 [23.69 – 29.23]	16.91 [14.56 – 19.46]	

Annual averages

Source: https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database

OpenAQ

Real-time, daily, weekly, monthly and historical data depending on the context.

Source: https://openaq.org/

This slide illustrates two open access online databases that can be used to find air quality data.

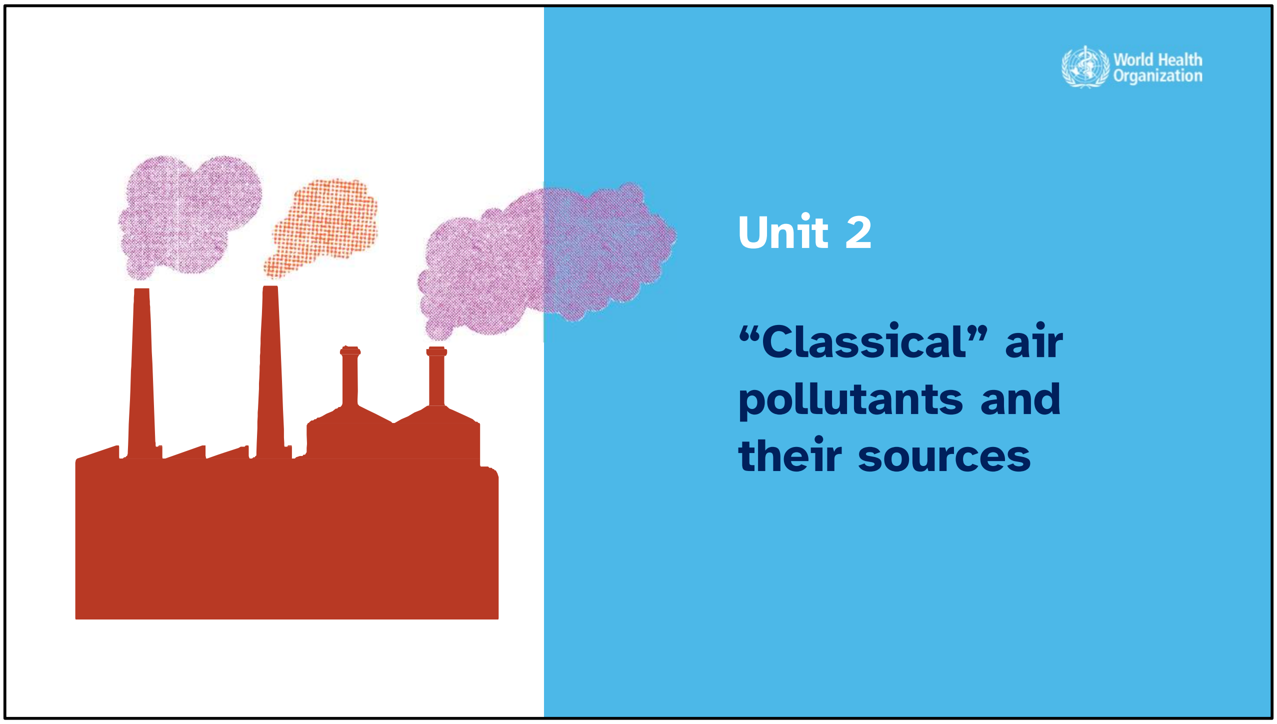
1. **World Health Organization (WHO) Ambient Air Quality Database**: provides information on ground measurements of **annual average concentrations** of nitrogen dioxide and particulate matter (PM), including PM_{10} and $PM_{2.5}$, for specific cities, towns, urban and rural areas based on available measurements. One strength of the WHO database is that all data included has been validated. However, as this database gives an annual concentration representative of a city or town as a whole, rather than individual monitoring stations, it cannot be used to share real-time air quality information with the general public or provide advice on air pollution-related health risks in the short term. The database has been updated regularly since 2011 and is used as an input to derive the Sustainable Development Goal (SDG) indicator 11.6.2, Air quality in cities (1,2).

2. **OpenAQ**: is a non-profit organization providing universal access to air quality data estimates. It uses an aggregated set of current and archived air quality data gathered in real time from government agencies so everyone has the means to analyse, communicate and advocate for clean air. One strength of OpenAQ is that it provides real-time data from a large number of air quality monitoring stations around the world. The frequency of updates can vary based on the monitoring stations and regions, with some offering near-real-time data and others providing daily or even weekly averages. However, the data on OpenAQ have not been validated. OpenAQ aims to empower policy-makers around the world to ensure everyone breathes clean air (3). Despite the progress made in monitoring and in data access, many publicly funded agencies still do not provide easy access to data.

Note: Use these two sources to highlight any air quality information relevant to your context available from these databases.

References

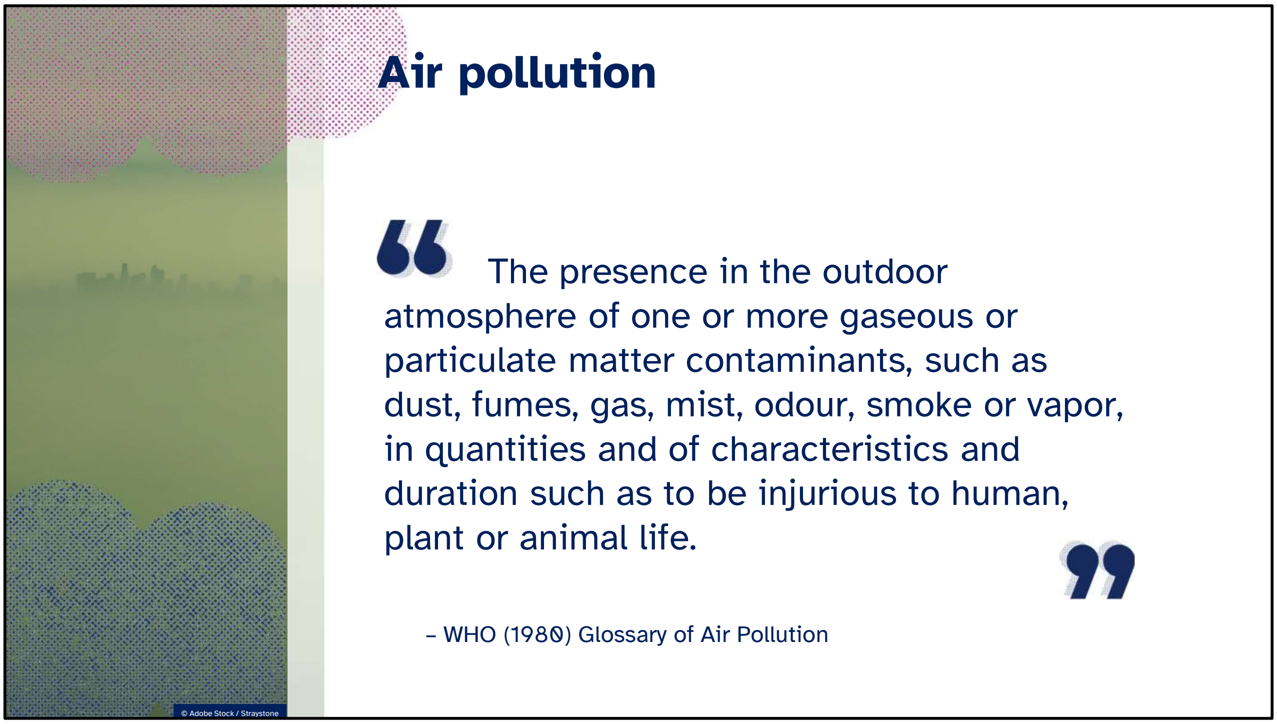
1. WHO ambient air quality database [website]. Geneva: World Health Organization; 2023 (https://www.who.int/data/gho/data/themes/air-pollution/who-air-quality-database, accessed 9 December 2024).
2. WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021 (https://apps.who.int/iris/handle/10665/345329, accessed 9 December 2024).
3. OpenAQ [website]. Washington (DC): OpenAQ; 2023 (https://openaq.org/, accessed 9 December 2024).



The term “classical” is used to indicate the most health-damaging air pollutants.

<this is a video to recap, the video has sound but you can also use the text below to provide explanations>

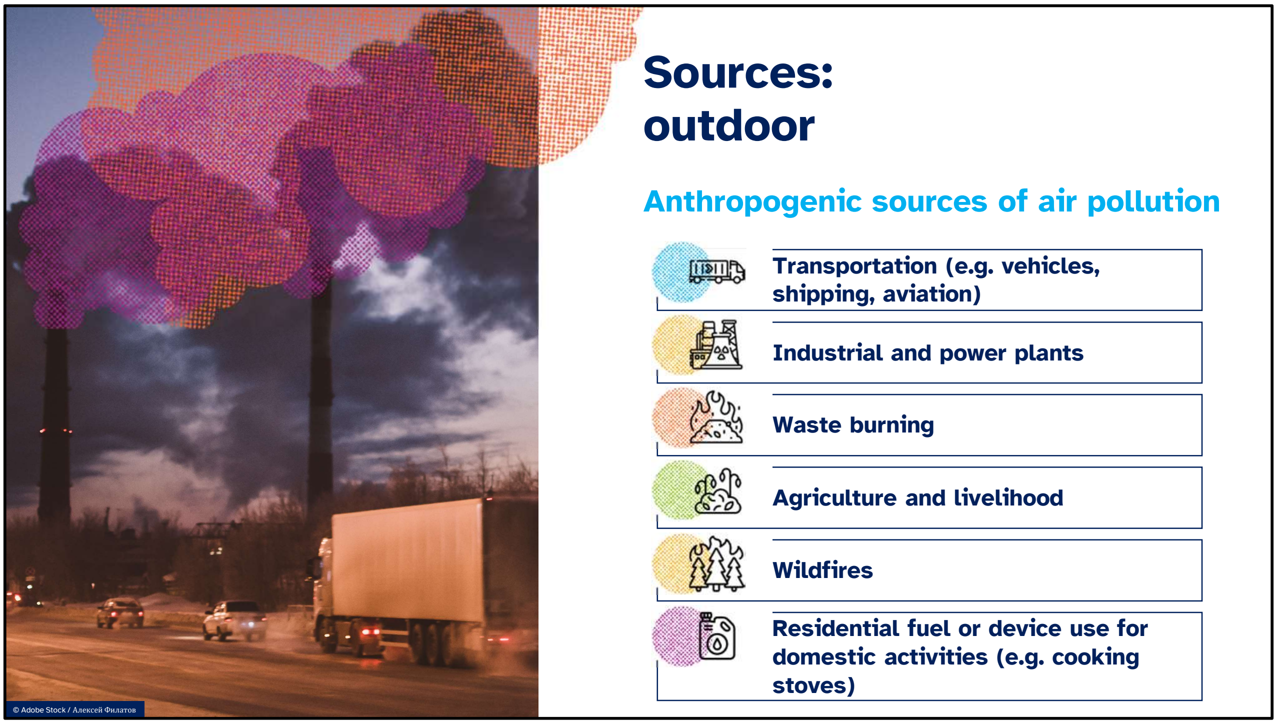
Air pollution is a combination of gases and particles that surround us. Even in a clean room there are 5000 particles in every cubic centimetre of air, and we breathe these particles in and out. There are many natural particles such as allergens, bacteria and viruses, which our immune system deals with. However, there are also anthropogenic particles as well as combustion particles, which although very tiny can agglomerate the gases and toxins surrounding them. These particles can grow to such a scale that they are able to be transported around our cities or even across regions.



To sum up the video from the previous slide, air pollution can be defined as the presence in the outdoor atmosphere of one or more gaseous or particulate matter contaminants, such as dust, fumes, gas, mist, odour, smoke or vapour, in quantities and of characteristics and duration such as to be injurious to human, plant or animal life.

Bibliography

- EJC Policy Statement. Air pollution and its control. J (Am Water Works Assoc). 1958;50(11):1483–89.
- Glossary on air pollution. Copenhagen: WHO Regional Office for Europe; 1980 (https://apps.who.int/iris/handle/10665/272866, accessed 9 December 2024).



Air pollution originates from both **outdoor** and **indoor** sources.

The most significant are the various **outdoor anthropogenic combustion sources** – most of them including fossil fuels combustion – such as:

- transport (like vehicles, shipping and aviation);
- industrial and power plants; and
- waste burning.

Agriculture and livelihood activities also play an important role. Another significant combustion source is biomass burning, including controlled and uncontrolled forest and savannah fires. Although being technically considered a natural source of air pollution, wildfires are increased in frequency and severity by climate change due to anthropogenic activities. Also, some wildfires are lit deliberately.

Residential fuel use for domestic activities is also a major source of outdoor air pollution in some regions and seasons of the year.

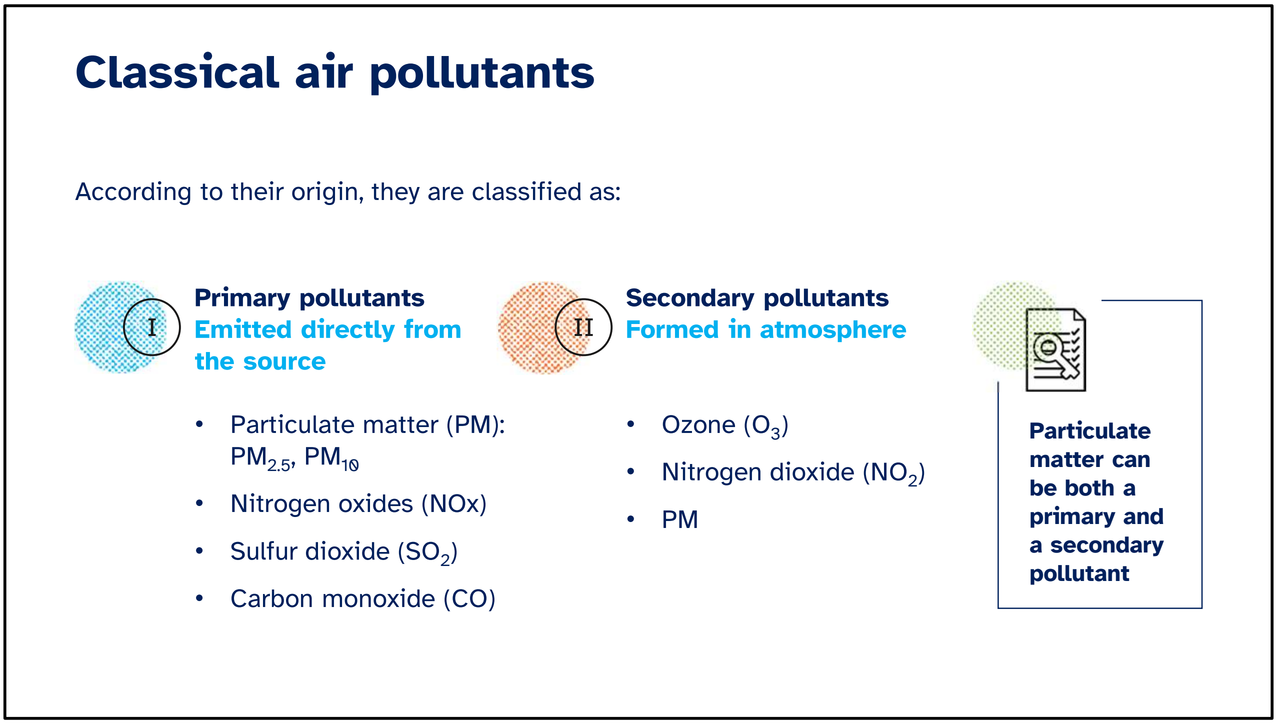
Many of these sources, including fossil fuel combustion, also significantly contribute to global warming and climate change.

Indoor sources include:

- incomplete combustion of polluting fuels for cooking, heating and lighting (such as, wood, coal, charcoal, kerosene, crop or animal waste);
- use of unclean devices for cooking heating and lighting (such as old inefficient stoves);
- tobacco smoking;
- building materials; and furnishing and cleaning agents.

The use of polluting fuel and devices at the household levels is referred to as household air pollution.
Emissions from household sources contribute to elevated concentrations of outdoor air pollution.
This is because the pollutants generated indoors (such as smoke from old cooking stoves) are exhausted outdoors.

In this unit, we will focus on the most health damaging air pollutants, also called **classical air pollutants**.



Air pollutants can be classified in different ways. According to their origin, they are called **primary pollutants** when they are emitted directly from the source. Examples of these are:

- particulate matter;
- nitrogen oxides;
- sulfur dioxide; and
- carbon monoxide.

By contrast, **secondary pollutants** are formed in the atmosphere by chemical interactions between primary pollutants and normal atmospheric constituents.

Some of these processes require light, such as the **photochemical oxidants** including ozone or nitrogen dioxide.

Particulate matter (or PM) can be both a primary and a secondary pollutant.

Bibliography

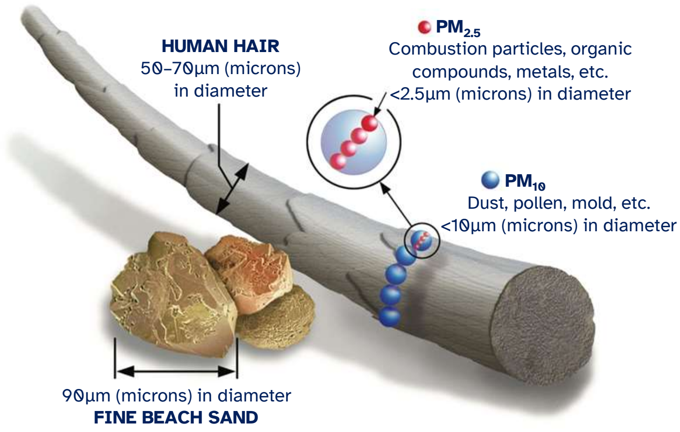
- Seinfeld JH, Pandis SN. Atmospheric chemistry and physics: from air pollution to climate change, second edition. New York: John Wiley & Sons, Inc.; 2006.
- Air quality criteria for particulate matter. Washington, DC: United States Environmental Protection Agency; 2004. Report no. EPA 600/P-99/002aF-bF.
- Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Copenhagen: WHO Regional Office for Europe; 2006 (https://apps.who.int/iris/handle/10665/107823, accessed 9 December 2024).

Particulate matter: classification

PM is classified according to its diameter:

- Coarse particles ($PM_{10-2.5}$)
- Fine particles ($PM_{2.5}$) ≤ 2.5 µm
- Ultrafine particles < 0.1 µm (100 nm)

smaller particles = greater harm to the body



Source: US Environmental Protection Agency

Air pollutants can be differentiated in PM, which comprises material in either solid or liquid phase suspended in the atmosphere, as well as gases.

Solid or liquid: particulate matter. PM is a mixture of solid particles and liquid droplets found in the air. The major components of PM are sulfates, nitrates, ammonia, sodium chloride, black carbon, mineral dust and water. Some particles are big or dark enough to be visible with the naked eye. Others can only be detected using an electron microscope. In the picture on the left-hand side, you can see the size of PM compared with the diameter of human hair or of a grain of beach sand.

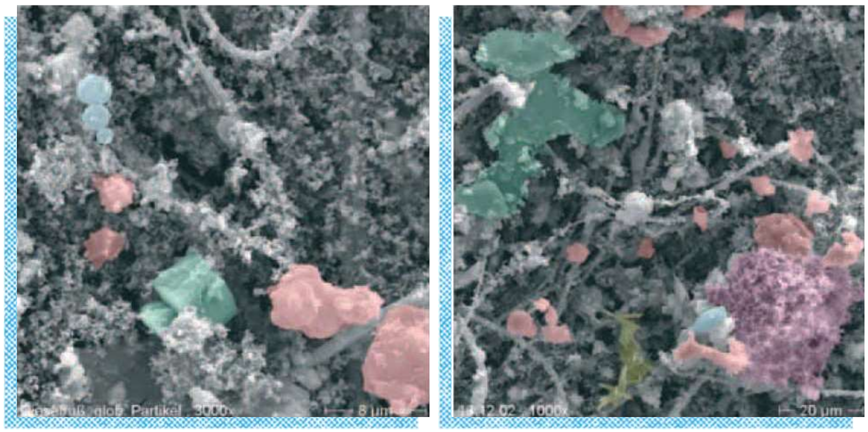
Because PM can have a wide range of sizes, it is classified according to its diameter. This size grading is important for what we will see in the next slides discussing the route of exposure: the smaller the particles, the further along the respiratory tree they can reach, and the more likely they are to enter the blood stream, causing great harm to the body. $PM_{2.5}$ and PM_{10} denote the mass concentrations of particles with diameters of ≤ 2.5 µm and ≤ 10 µm, respectively. By contrast, ultrafine particles (UFP) are those of diameter < 0.1 µm (100 nm), and are usually measured by particle number, not mass concentration.

Bibliography

- Seinfeld JH, Pandis SN. Atmospheric chemistry and physics: from air pollution to climate change, second edition. New York: John Wiley & Sons, Inc.; 2006.
- Air quality criteria for particulate matter. Washington (DC): United States Environmental Protection Agency, 2004. Report no. EPA 600/P-99/002aF-bF.
- Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Copenhagen: WHO Regional Office for Europe; 2006 (https://apps.who.int/iris/handle/10665/107823, accessed 9 December 2024).

Heavy metals in particulate matter

Electron microscopic images of PM_{10} sampled at two monitoring sites in Austria



Heavy metals can be absorbed by fine and ultrafine particulate matter, enabling their transport into the respiratory system and systemic circulation, contributing to cardiovascular and other diseases.

WHO 2006

As noted, PM exists in various shapes, sizes and composition. Here you can appreciate the electron microscopic images of PM_{10} sampled at two monitoring sites in Austria.

Heavy metals like lead, cadmium, arsenic, mercury and nickel can adhere to fine particulate matter ($PM_{2.5}$ and smaller), allowing them to reach the respiratory system and systemic circulation. These metals can induce inflammation via oxidative stress and cellular disruption, contributing to cardiovascular risk. This inflammatory response promotes endothelial dysfunction, increases blood clotting potential, and accelerates atherosclerosis, all key mechanisms linking heavy metal exposure in PM to higher cardiovascular disease risk.

Bibliography

- Brook RD, Rajagopalan S, Pope CA 3rd, Brook JR, Bhatnagar A, Diez-Roux AV, Holguin F, Hong Y, Luepker RV, Mittleman MA, Peters A, Siscovick D, Smith SC Jr, Whitsel L, Kaufman JD; American Heart Association Council on Epidemiology and Prevention, Council on the Kidney in Cardiovascular Disease, and Council on Nutrition, Physical Activity and Metabolism. Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association. Circulation. 2010 Jun 1;121(21):2331-78. doi: 10.1161/CIR.0b013e3181dbece1.
- Health risks of particulate matter from long-range transboundary air pollution. Copenhagen: WHO Regional Office for Europe; Joint WHO/Convention Task Force on the Health Aspects of Air Pollution; 2006 (https://apps.who.int/iris/handle/10665/107691, accessed 9 December 2024).
- Nucera S, Serra M, Caminiti R, Ruga S, Passacatini LC, Macrì R, Scarano F, Maiuolo J, Bulotta R, Mollace R, Bosco F, Guarnieri L, Oppedisano F, Ilari S, Muscoli C, Palma E, Mollace V. Non-essential heavy metal effects in cardiovascular diseases: an overview of systematic reviews. Front Cardiovasc Med. 2024 Jan 23;11:1332339. doi: 10.3389/fcvm.2024.1332339.

Classification of particle sizes

PM_{10} and $PM_{2.5}$

- Typically measured as **mass** concentration of particles with diameter < 10µm and <2.5µm respectively

Ultrafine particles (UFP)
<0.1µm

- **Number concentration,** count/cm^3

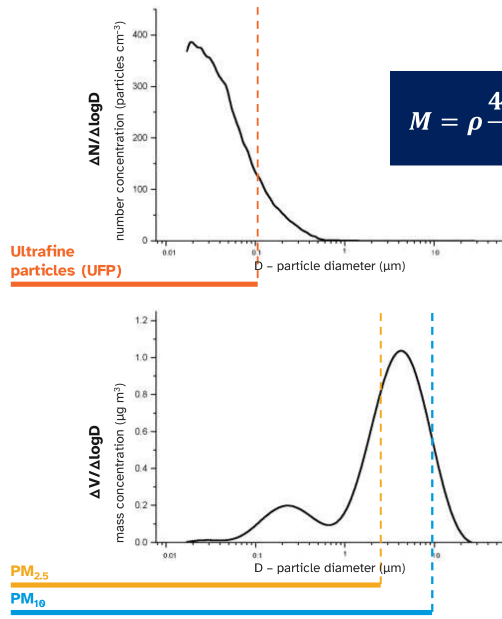
$PM_{2.5}$ and PM_{10} are typically measured according to their diameter and expressed as mass concentration.

Ultrafine particles (UFPs) are particles of diameter < 0.1 µm (100 nm), are usually measured by particle number (concentration/number of particles per cm3), not mass concentration. UFPs are detected by diffusional methods, electrical mobility and other techniques.

Particle number and mass size distributions

Concentration of particles smaller than 0.1 µm (ultrafine particles of UFP), measured in terms of number of particles/cm^3, is typically high (upper diagram).

UFP have little mass, and therefore make a very small contribution to total mass concentration of particles smaller than 2.5 or 10 µm in diameter ($PM_{2.5}$ or PM_{10}). This mass concentration (µg/m^3) is dominated by a smaller number of larger, and therefore heavier, particles (lower diagram).



$$M = \rho \frac{4\pi R^3}{3}$$

The concentration of particles of diameter < 0.1 µm (UFPs), measured in terms of number of particles/cm^3, is typically high as shown in the upper diagram.

UFP have little mass, and therefore make a very small contribution to the total mass concentration of particles of diameter < 2.5 µm ($PM_{2.5}$) or < 10 µm (PM_{10}). This mass concentration (measured in µg/m^3) is dominated by the smaller number of larger, and therefore heavier, particles, as shown in the lower diagram.

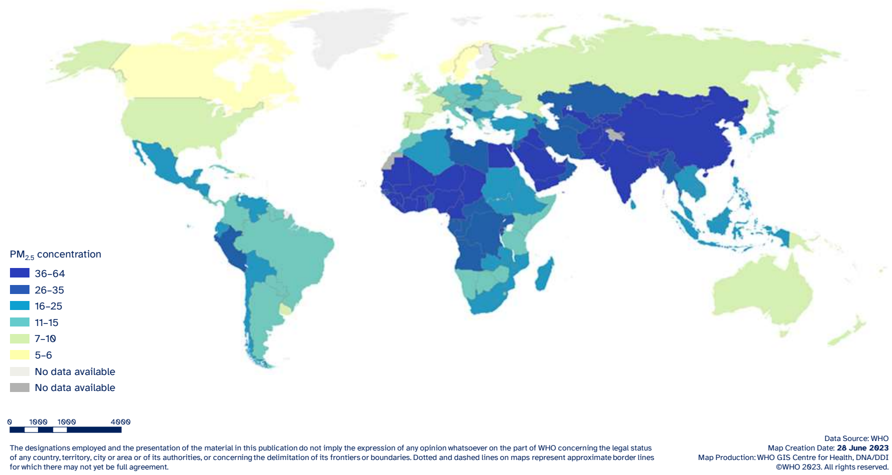
Here you have two graphs representing the distribution of particulate matter. The upper graph is the particle number distribution, which clearly shows that, typically in urban environments, most of the particles are in the ultrafine range. But if we look at the graph below, which represent the mass size distribution of particles, we note that $PM_{2.5}$ and PM_{10} make the biggest contribution to the total mass of PM.

Simplified message: In terms of particle numbers, UFPs are the most representative, particularly in urban environments, while $PM_{2.5}$ and PM_{10} make the biggest contribution to the total mass of PM.

Annual mean concentrations of fine particulate matter ($PM_{2.5}$), 2019

Estimates based on combination of air quality monitoring data, chemical transport models and satellite observations.

https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5)



This map of the world developed by WHO depicts the annual average of $PM_{2.5}$ estimated by combining air quality monitoring data, chemical transport models and satellite observations.

The darkest areas of the map indicate where the levels of $PM_{2.5}$ are above 35 µg/m^3.

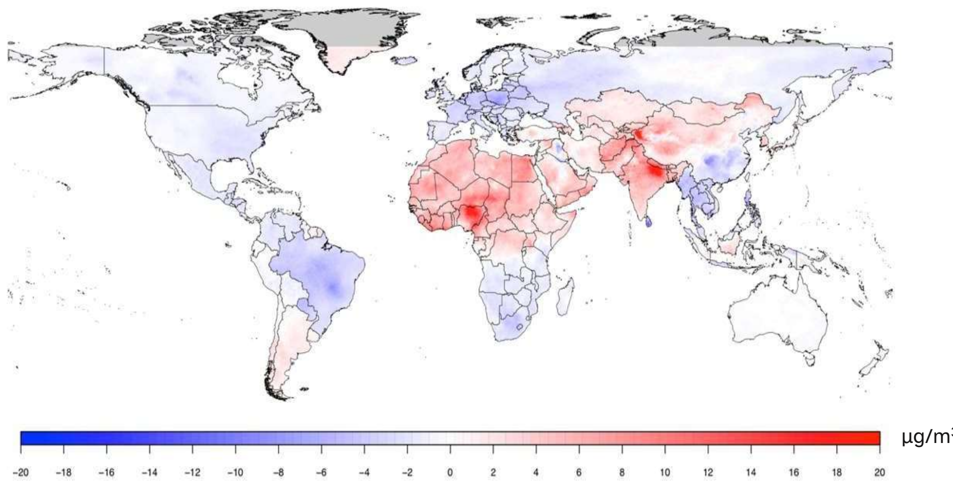
It is worth highlighting that this map is referring only to $PM_{2.5}$, which is just one of the air pollutants (although it is a very important one, as it causes the greatest burden of disease associated with air pollution globally).

Although PM is measured at many thousands of locations throughout the world, the number of monitors in different geographical areas varies, with some areas having little or no monitoring. In order to produce global estimates at high resolution (0.1◦ grid-cells), additional data are required. Annual urban mean concentration of $PM_{2.5}$ is estimated with improved modelling using data integration from satellite remote sensing, population estimates, topography and ground measurements.

Bibliography

- SDG Indicator 11.6.2 Concentration of fine particular matter ($PM_{2.5}$): https://www.who.int/data/gho/data/indicators/indicator-details/GHO/concentrations-of-fine-particulate-matter-(pm2-5)

Changes in ambient $PM_{2.5}$ concentrations, 2010–2016



Has the quality of the air we breathe improved in the last decade? The quick reply to this question is: it depends.

The map here depicts how air pollution ($PM_{2.5}$) levels have changed during 2010–2016. Blue shading indicates the regions in which air pollution has decreased over this 6-year period, and red shading indicates those for which air pollution has increased.

Bibliography

- Shaddick G, Thomas ML, Mudu P, Ruggeri G, Gumy S. Half the world's population are exposed to increasing air pollution. npj Clim Atmos Sci. 2020;3:23. doi:10.1038/s41612-020-0124-2

Video: What are the current air pollution levels in Ghana?

2018 video series at First WHO Global Conference on Air Pollution and Health

Dr Emmanuel Appoh, Ghana Environmental Protection Agency

Source: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic/cities-regions-and-countries/africa#

<2 min 44 sec video>

Note: You can use other videos and embed them in the presentation using the WHO video mosaic series on air pollution and health: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic

Bibliography

- https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic/cities-regions-and-countries/africa#

Video: What is the situation in Malaysia, with regard to air pollution?

2018 video series at First WHO Global Conference on Air Pollution and Health

Dr Norlen Bin Mohamed, Ministry of Health, Malaysia (2018)

Source: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic/cities-regions-and-countries/africa#

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Note: You can use other videos and embed them in the presentation using the WHO video mosaic series on air pollution and health: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic

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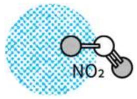
- https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic/speakers/norlen-bin-mohamed#



Nitrogen dioxide

Characteristics	• Reddish-brown gas with characteristic pungent odour; • Strong oxidant.
Other properties	• Absorbs visible solar radiation (impaired visibility); • Plays critical role in determining ozone concentration in the troposphere; • Key role in the formation of other secondary pollutants (nitrate particles) that contribute to particulate matter concentrations globally; • Highest concentrations are usually in densely populated urban areas.
Sources	• Concentrations strongly linked to mobile sources • (vehicles): often used as a surrogate of TRAP; • Combustion processes (heating, power generation, internal combustion engines).
Atmospheric transport	• Ambient air concentration decreases rapidly with distance from the source (scale of hundreds of metres).

Beyond the solid or liquid phase suspended in the atmosphere, some important air pollutants are in gas phase.

This slide is about nitrogen dioxide (NO_2).

Many chemical species of NOx exist, but from the viewpoint of human health the most important is NO_2. NO_2 is a reddish-brown gas with a characteristic pungent odour. Nitric oxide spontaneously produces the dioxide when exposed to air. NO_2 is a strong oxidant and reacts with water to produce nitric acid and nitric oxide.

NO_2 is an important atmospheric trace gas not only because of the health effects it induces but also because:
- It absorbs visible solar radiation and contributes to impaired atmospheric visibility.
- It plays a critical role in determining O_3 concentrations in the troposphere because the photolysis of NO_2 is the only key initiator of the photochemical formation of O_3.
- It contributes to the formation of other secondary pollutants, such as sulfate particles, that contribute to concentrations of particulate matter.

Exposure to NO_2 in the ambient air is strongly linked to mobile sources, such as cars, trucks and other combustion vehicles. Unlike PM or O_3, NO_2 shows a distinct urban-rural gradient and the highest concentrations are usually found in densely populated urban areas. Due to the development and enforcement of air quality standards, average NO_2 concentrations have decreased in many high-income countries (HICs), especially in North America and Europe. However, in many low- and middle-income countries (LMICs), trends in NO_2 concentrations have dramatically increased due to rapid urbanization and industrialization. This is especially evident in some east Asian countries.

NO_2 is often used as a surrogate for traffic related air pollution (TRAP).
Sources includes combustion processes (heating, power generation and internal combustion engines).

With regards to atmospheric transport properties, the ambient air concentration of NO_2 decreases rapidly with distance from the source (over a scale of hundreds of metres).

Bibliography
- Air quality criteria for oxides of nitrogen. Research Triangle Park (NC): United States Environmental Protection Agency; 1993. EPA Report No. EPA/600/8-91/049aF-cF. 3v.
- Air quality criteria for ozone and related photochemical oxidants. Research Triangle Park (NC): United States Environmental Protection Agency; 1995. EPA Report No. EPA/600/P-93/004aF-cF.3v.
- Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Copenhagen: WHO Regional Office for Europe; 2006 (https://apps.who.int/iris/handle/10665/107823, accessed 9 December 2024).
- WHO Air quality and health. Types of pollutants. [internet]. Accessible at: https://www.who.int/teams/environment-climate-change-and-health/air-quality-

and-health/health-impacts/types-of-pollutants

Tropospheric ozone

Characteristics	• Colourless gas, each molecule of which comprises three oxygen atoms; • Is one of the principal components of smog; • **Secondary pollutant:** formed in the atmosphere through a series of reactions of NOx , non-methane VOCs and methane, also known as “ozone precursors”, in the presence of sunlight and heat; • Concentrations are higher in summer and in the afternoon.
Other properties	• Is an efficient short-lived climate pollutant (SLCP) and greenhouse gas (warming potential): contribute to climate change.
Sources	• Precursor gases are mainly emitted from traffic, energy production and industry.
Atmospheric transport	• Strongly influenced by wind patterns; • May occur in high concentrations far away (thousands of kilometres) from the source of precursor gases.

This slide is about tropospheric ozone (O_3).

Tropospheric, or ground-level, ozone is is a colourless gas, each molecule of which comprises three oxygen atoms.

- O_3 is on of the principal components of “smog”. where its precursors react in the presence of sunlight.
- O_3 is a secondary pollutant because it is not directly emitted by primary sources. Instead, it is formed through a series of complex reactions in the atmosphere. NOx , non-methane VOCs and methane, also known as “ozone precursors”, in the presence of sunlight and heat.
- O_3 concentrations are normally higher in summer and in the afternoon, as temperature and solar radiation also play a role in its formation. Climate change is expected to increase levels of O3 pollution.

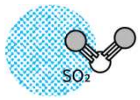
The precursors of O_3 are mainly emitted from traffic, energy production and industry. Industrialization has caused significant increases in O_3 precursor emissions, leading to increases in O_3 concentrations worldwide.

O_3 is also a greenhouse gas and an efficient short-lived climate pollutant (SLCP); although it has a shorter atmospheric lifetime than CO_2, it has a greater warming potential and therefore contributes substantially to climate change.

With regards to the atmospheric transport properties, it is strongly influenced by wind patterns. O_3 may occur in high concentrations far away (thousands of kilometres) from the sources of the precursor gases.

Bibliography

- Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Copenhagen: WHO Regional Office for Europe; 2006 (https://apps.who.int/iris/handle/10665/107823, accessed 9 December 2024).
- WHO Air quality and health. Types of pollutants. [internet]. Accessible at: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants



Sulfur dioxide

Characteristics	• Colourless gas readily soluble in water. Strong odour.
Other properties	• Reacts in the atmosphere to produce sulfuric acid and sulfates (solid particles); • Highest concentrations in ambient air often during winter.
Sources	• Strongly linked to the combustion of fossil fuels (coal, oil) for domestic heating, stationary power generation and motor vehicles if they contain sulfur; • Volcanic eruptions.
Atmospheric transport	• Transported up to thousands of kilometres in the atmosphere (as gas or its products).

This slide is about sulfur dioxide (SO_2).

SO_2 is a colourless gas, readily soluble in water, with a strong odour.

Historically, SO_2 and PM derived from the combustion of fossil fuels have been the main components of air pollution in many parts of the world. The most serious problems have been experienced in large urban areas where coal has been used for domestic heating or for poorly controlled combustion in industrial installations.

SO_2 is derived from the combustion of sulfur-containing fossil fuels and is a major air pollutant in many parts of the world. The oxidation of SO_2, especially at the surface of particles in the presence of metallic catalysts, leads to the formation of sulfurous and sulfuric acids. Neutralization by ammonia leads to the production of bisulfates and sulfates (precursors to the formation of PM).

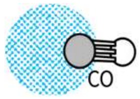
The sources of SO_2 are both natural (e.g. from volcanic eruptions) or anthropogenic, including the use of sulfur-containing fossil fuels for domestic heating, stationary power generation and motor vehicles. In recent years the use of high-sulfur coal for domestic heating has declined in many European countries, and power generation and industrial combustion are now the predominant sources.

In many LMICs, however, the use of high-sulfur coal is increasing for power production, as well as for domestic heating and cooking, and ground-level SO_2 concentrations remain at very high levels.
With regards to atmospheric transport properties, SO_2 can be transported thousands of kilometres in the atmosphere as a gas of its products.

Note: Sulfur oxides (SOx) are a group of compound pollutants containing both sulfur and oxygen molecules. Sulfur oxides are primarily produced through burning fossil fuels and include sulfur monoxide, sulfur dioxide and sulfur trioxide. Sulfur dioxide is considered the most prevalent and dangerous to human health. Interventions that target sulfur dioxide are generally considered to protect human health from other sulfur oxides.

Bibliography

- Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Copenhagen: WHO Regional Office for Europe; 2006 (https://apps.who.int/iris/handle/10665/107823, accessed 9 December 2024).
- Sulfur dioxide (SO2) pollution: sulfur dioxide basics [website]. Research Triangle Park (NC): United States Environmental Protection Agency; 2023 (https://www.epa.gov/so2-pollution/sulfur-dioxide-basics, accessed 9 December 2024).
- WHO Air quality and health. Types of pollutants. [internet]. Accessible at: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants



Carbon monoxide

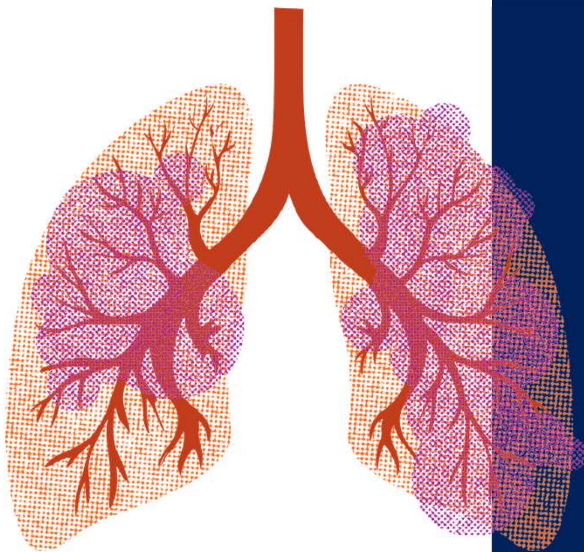
Characteristics	• Colourless and odourless gas.
Other properties	• Carbon monoxide diffuses across the lung tissues and into the bloodstream, making it difficult for the body's cells to bind to oxygen (hypoxia).
Sources	• Incomplete combustion of carbonaceous fuels such as wood, petrol, coal, natural gas and kerosene in simple stoves, open fires, wick lamps, furnaces, fireplaces; • The predominant source of carbon monoxide (CO) in ambient air is from motor vehicles.

Carbon monoxide (CO) is a colourless, odourless gas produced by the incomplete combustion of carbonaceous fuels such as wood, petrol, coal, natural gas and kerosene in simple stoves, open fires, wick lamps, furnaces, fireplaces. The predominant source of CO in ambient air is from motor vehicles.

Carbon monoxide diffuses across the lung tissues and into the bloodstream, making it difficult for the body's cells to bind to oxygen. This lack of oxygen damages tissues and cells. Exposure to carbon monoxide can cause difficulties breathing, exhaustion, dizziness, and other flu-like symptoms. Exposure to high levels of carbon monoxide can be deadly.

Bibliography

- Air quality guidelines global update 2005: particulate matter, ozone, nitrogen dioxide and sulphur dioxide. Copenhagen: WHO Regional Office for Europe; 2006 (https://apps.who.int/iris/handle/10665/107823, accessed 9 December 2024).
- WHO Air quality and health. Types of pollutants. [internet]. Accessible at: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/health-impacts/types-of-pollutants



World Health Organization

Unit 3

Air pollution and health

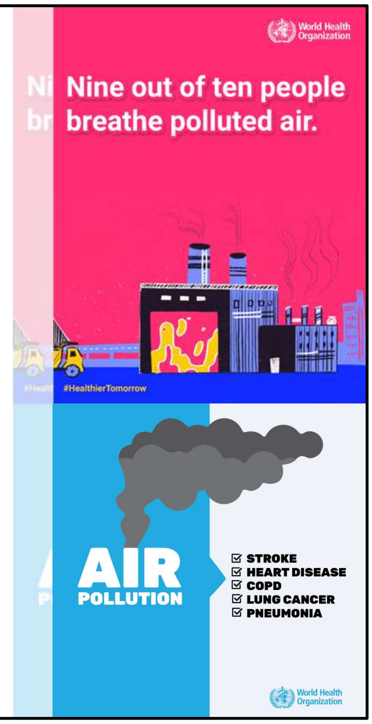
The big picture in data

Air pollution kills around **7 million people** every year.

> 9 out of 10 people live in areas where air pollution is exceeding WHO global air quality guidelines.

2.1 billion people still rely on polluting energy for cooking, being exposed to harmful air pollution.

¼ of global deaths are associated with environmental risks factors.



Globally, air pollution kills around 7 million people every year (data from 2019). WHO data show that 99% of people worldwide breathe air containing high levels of pollutants. These data are based on $PM_{2.5}$ as this is considered the best indicator for estimating the health impacts of air pollution.

In 2022, 2.1 billion people still rely on polluting energy for cooking, being exposed to harmful air pollution.

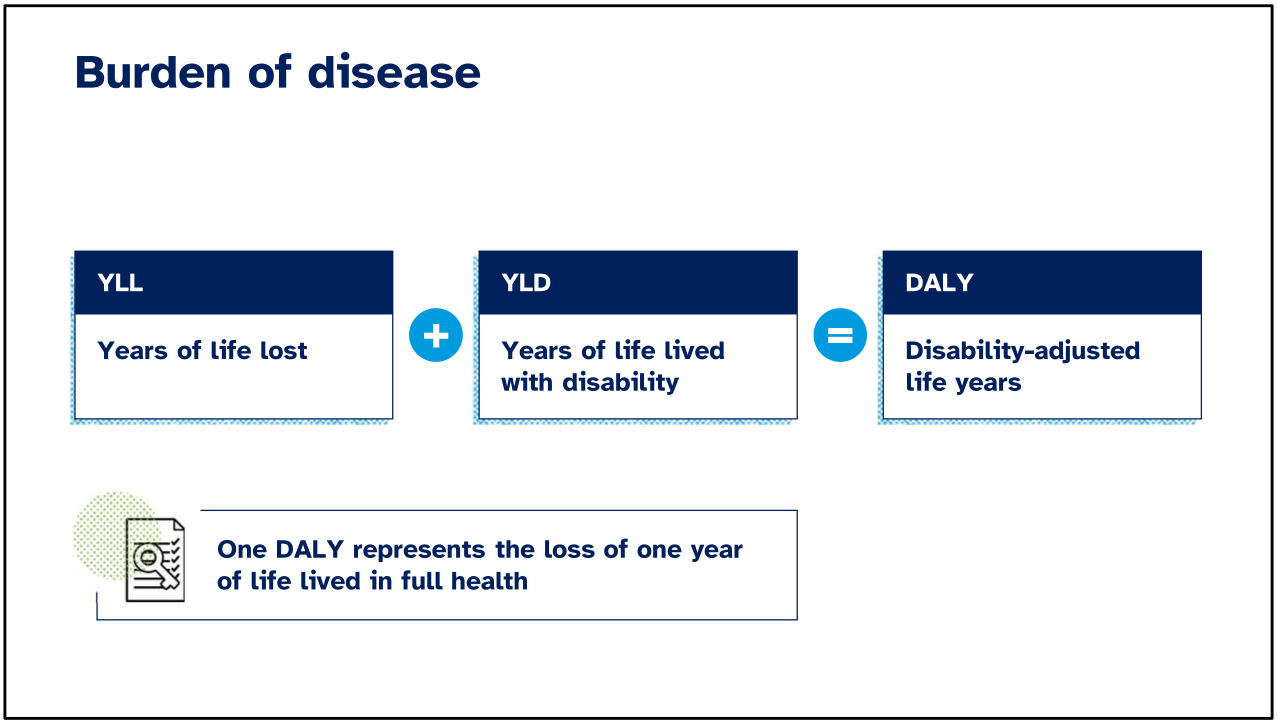
Globally, 1 in 4 death is associated with environmental risk factors.

Mortality wise, diseases for which there is strong evidence of the causal role of air pollution as an environmental risk factor, are:

- **cardiovascular diseases**, such as ischaemic heart disease and ischaemic stroke;
- **respiratory diseases**, such as chronic obstructive pulmonary diseases and acute lower respiratory infections; and
- **lung cancer**.

Bibliography

- The global health observatory. Geneva: World Health Organization; 2024 (https://www.who.int/data/gho, accessed 9 December 2024).
- Sustainable Development Goal indicator 3.9.1: mortality attributed to air pollution. Geneva: World Health Organization; 2024. Licence: CC BY-NC-SA 3.0 IGO (https://iris.who.int/handle/10665/379020, accessed 9 December 2024).



When it comes to the morbidity and mortality of a certain risk factor, in our case air pollution, an important topic must be introduced: the burden of disease.

The **burden of disease** is a concept initially introduced by WHO in the 1990s to describe death and loss of health due to diseases, injuries and risk factors for all regions of the world.

The burden of a particular disease or condition is estimated by adding together:

1. The number of years of life a person loses as a consequence of dying early because of the disease (called years of life lost or YLL); and
2. The number of years of life a person lives with disability caused by the disease (called years of life lived with disability or YLD).

Adding together YLL and YLD gives a single-figure estimate of disease burden, called the disability-adjusted life year (or DALY).

One DALY represents the loss of o1 year of life lived in full health.

Bibliography

- The global burden of disease: a critical resource for informed policymaking. Seattle: Institute for Health Metrics and Evaluation; 2022 (http://www.healthdata.org/gbd/about, accessed 9 December 2024).
- Global Health Observatory: Life expectancy and leading causes of death and disability. Geneva: World Health Organization; 2024 (https://www.who.int/data/gho/data/themes/mortality-and-global-health-estimates, accessed 9 December 2024).

Global Burden of Disease: risk factors

Global rank in 2021 for deaths per 100 000 (both sexes, all ages) – Level 3

1	High blood pressure	17	Child growth failure
2	Particulate matter	18	Low vegetables
3	Smoking	19	Unsafe water
4	High fasting plasma glucose	20	Low omega-6
5	High body-mass index	21	Low nuts and seeds
6	High LDL	22	Low physical activity
7	Kidney dysfunction	23	Low omega-3
8	High sodium	24	Low fiber
9	High alcohol use	25	Unsafe sanitation
10	Low fruit	26	Occupational particulates
11	Low birth weight & short gestation	27	Ozone
12	Low whole grains	28	Occupational injury
13	Lead	29	Drug use
14	Low temperature	30	Low bone mineral density
15	Secondhand smoke	31	Handwashing
16	Unsafe sex	32	High temperature

Metabolic risks — Environmental/occupational risks — Behavioural risks

Using information from epidemiological studies, the Global Burden of Disease project attributes fractions of the burden of disease to various risk factors.

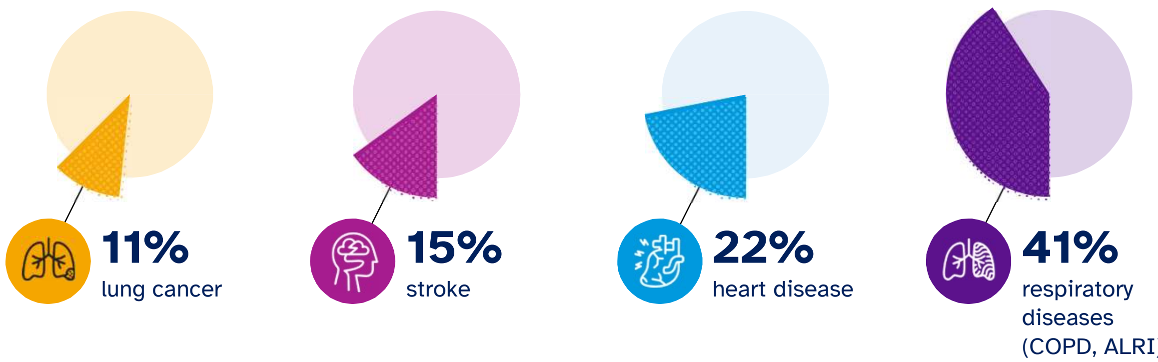
Particulate matter pollution is the second-highest risk factor for globally mortality, considering all ages and both sexes.

Bibliography

- The global burden of disease: a critical resource for informed policymaking. Seattle: Institute for Health Metrics and Evaluation; 2024 (http://www.healthdata.org/gbd/about, accessed 9 December 2024).
- Health Effects Institute. 2024. State of Global Air 2024. Special Report. Boston, MA:Health Effects Institute. ISSN 2578-6873 © 2024 Health Effects Institute

Deaths attributable to ambient air pollution per disease outcome

Proportion of deaths attributable to air pollution per disease outcome (Population Attributable Fraction, PAF, %)



Source: WHO

WHO data allow us to estimate the percentage of deaths attributable to air pollution per disease outcome. This is an epidemiological concept called “population attributable fraction”.

The latest results show that ambient air pollution is globally responsible for:

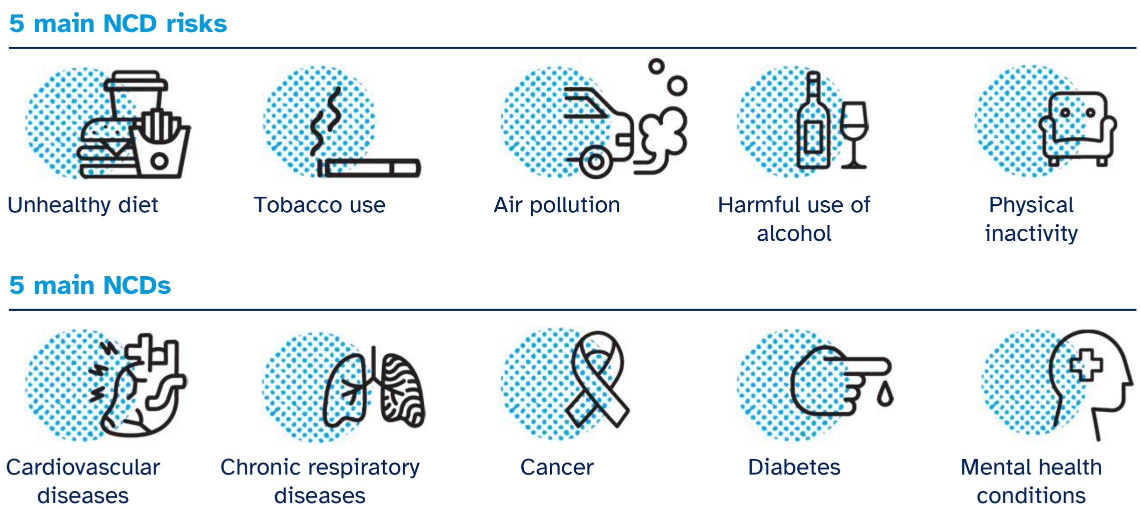
- 11% of all lung cancer deaths;
- 15% of deaths resulting from stroke;
- 22% of all deaths from heart disease; and
- 41% of all deaths from respiratory diseases: chronic obstructive pulmonary disease (COPD) and acute low respiratory tract infections (ALRI)

The population attributable fraction represents the proportion of disease or health outcome in a population that can be attributed to a specific risk factor. It estimates the proportional reduction in population disease or mortality would occur if exposure to a risk factor were reduced to an alternative ideal exposure scenario, assuming a causal relationship.

Bibliography

- Population attributable fraction. In: The global health observatory. Geneva: World Health Organization; 2023 (https://www.who.int/data/gho/indicator-metadata-registry/imr-details/1287, accessed 9 December 2024)
- Sustainable Development Goal indicator 3.9.1: mortality attributed to air pollution. Geneva: World Health Organization; 2024. (https://iris.who.int/handle/10665/379020, accessed 9 December 2024)
- The global health observatory. Geneva: World Health Organization; 2022 (https://www.who.int/data/gho, accessed 9 December 2024).

Air pollution and noncommunicable diseases (NCDs)



In September 2018, the United Nations General Assembly staged the third High-level Meeting on the prevention and control of noncommunicable diseases (NCDs).

The meeting undertook a comprehensive review of the global and national progress achieved in putting measures in place that protect people from dying too young from heart and lung diseases, cancers and diabetes.

A political declaration was adopted, transforming the historically 4 x 4 agenda (4 risk factors and 4 main diseases) into a 5 x 5 agenda, including air pollution as a risk factor and mental health as a disease

Bibliography

- Political declaration of the third high-level meeting of the General Assembly on the prevention and control of non-communicable diseases A/73/L.2. United Nations General Assembly; 2018 (https://www.un.org/ga/search/view_doc.asp?symbol=A%2F73%2FL.2&Submit=Search&Lang=E, accessed 9 December 2024).
- Time to deliver: third UN high-level meeting on non-communicable disease. United Nations System Standing Committee on Nutrition; 2018 (https://www.unscn.org/uploads/web/news/NCD-HLM-Brochure-WHO.pdf, accessed 9 December 2024).

The cost of ambient air pollution and investment in its reduction

In 2019, the global cost of health damages from fine particulate matter in ambient air was US$ 6.43 trillion, including:

- US$ 5.47 trillion in welfare loss due to increased mortality risk from ambient air pollution.
- US$ 0.96 trillion in lost income due to illnesses from ambient air pollution.

- Equivalent to 4.8% of global GDP.
- Cost varies considerably between countries.

For the period 2015–2021:

- Only 2% of climate finance commitments by international funders specifically tackled outdoor air pollution.

Ambient air pollution places a considerable burden on the global economy. In 2019, the World Bank estimated that fine particulate matter ($PM_{2.5}$) in ambient air cost the global economy US$ 6.43 trillion due to health damages, including US$ 5.47 trillion in welfare loss due to increased mortality risk from ambient air pollution and US$ 0.96 trillion in lost income due to illnesses from ambient air pollution. This was equivalent to 4.8% of global gross domestic product (GDP) in 2019. Costs to national GDPs due to $PM_{2.5}$ in ambient air in 2019 varied considerably between countries.

The World Bank also found that in 2019 the costs of air pollution due to health damage were 40% higher in real terms than they were in 2013 (the previous estimate developed). This is due to changes in exposure-response functions, improvements in methodology and available data, and the inclusion of the costs of morbidity in global estimates.

Actions to reduce ambient air pollution will improve health and reduce health-related costs to the global economy.

Despite air pollution being one of the major risk factors for health, in 2015–2021 only 2% of climate finance commitments by international funders specifically tackled outdoor air pollution.

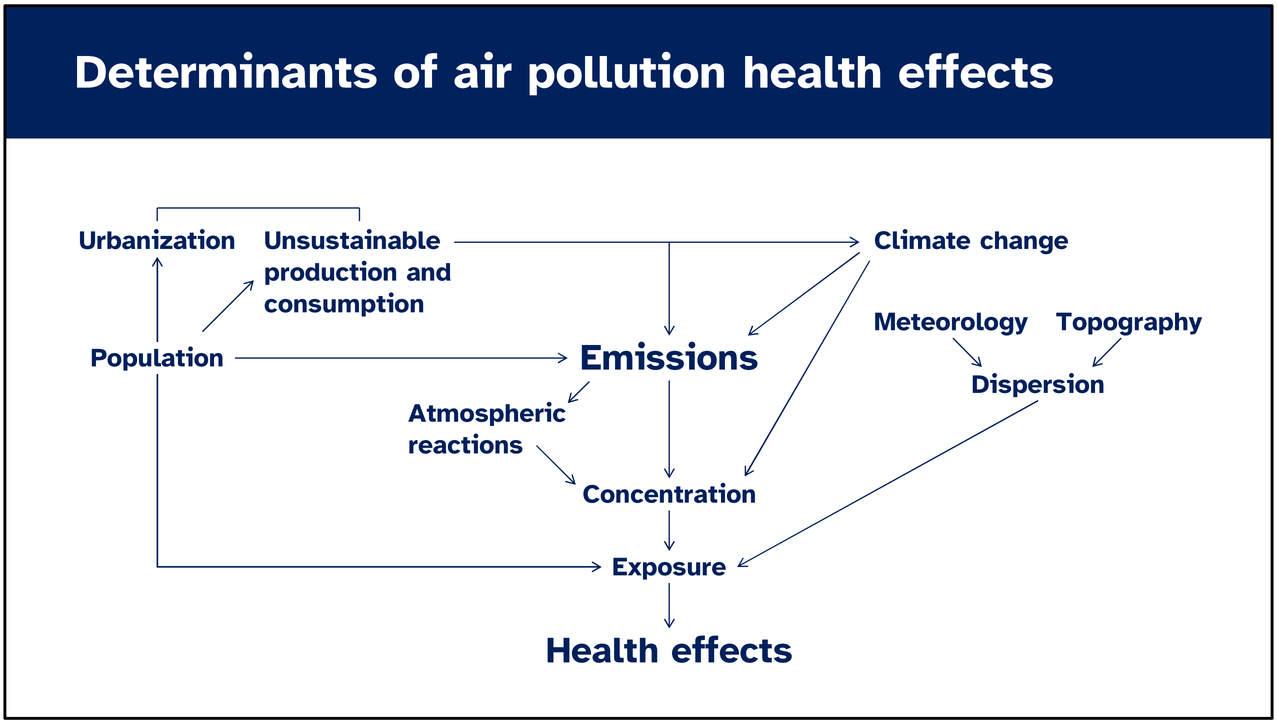
Bibliography

- Clean Air Fund (CAF) and Climate Policy Initiative (CPI). The State of Global Air Quality Funding 2023. Climate Policy Initiative; 2023 (https://www.climatepolicyinitiative.org/publication/the-state-of-global-air-quality-funding-2023, accessed 9 December 2024).
- The global health cost of $PM_{2.5}$ air pollution: a case for action beyond 2021. Washington (DC): The World Bank; 2022 (https://elibrary.worldbank.org/doi/abs/10.1596/978-1-4648-1816-5, accessed 9 December 2024).

World Health Organization

Unit 4

Determinants of air pollution health effects

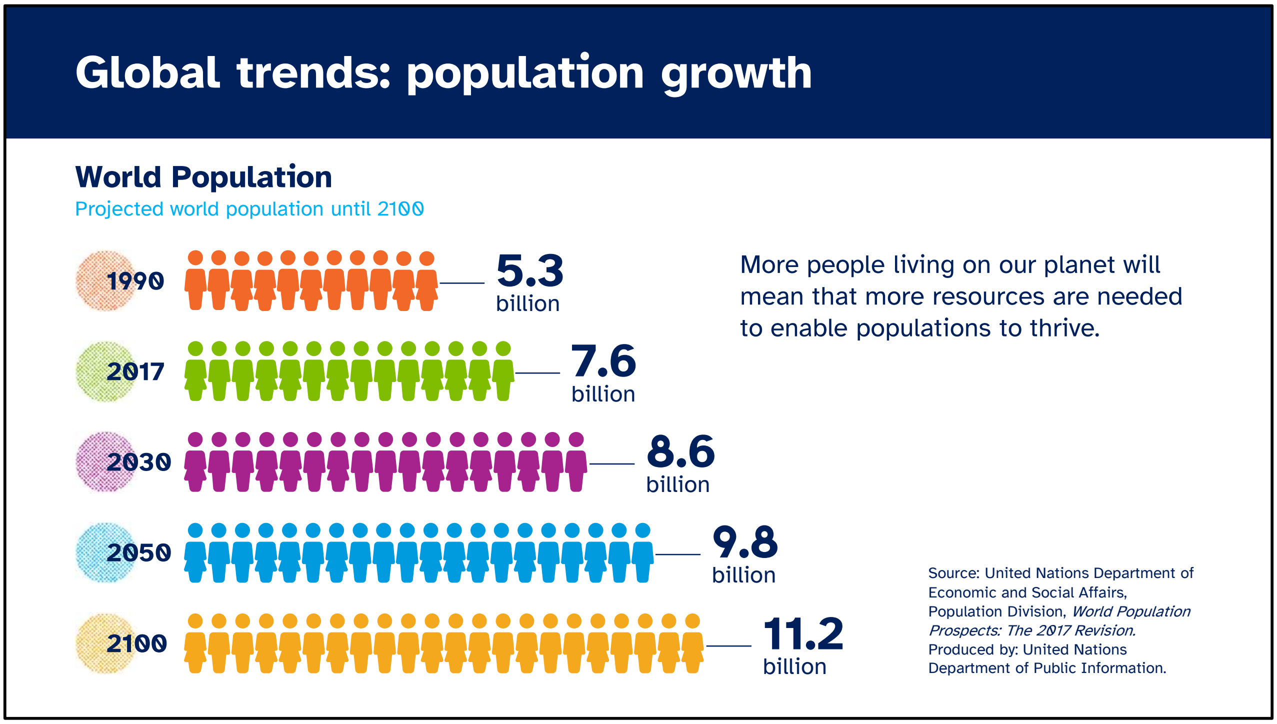


Emissions of pollutants are mainly caused by anthropogenic activities. Emissions lead to atmospheric reactions between chemicals and influence the concentrations of air pollutants and their mix in the atmosphere. Anthropogenic climate change is another important factor influencing both emissions and the concentrations of air pollutants in the atmosphere.

Factors such as topography and meteorology influence the dispersion of air pollutants in the atmosphere, and therefore affect concentration.

It is important to highlight that concentration and exposure are not the same thing. Concentration is the amount of a substance in a medium (air, in this case). It is usually expressed in terms of mass per unit volume, such as microgram per cubic metre (µg/m^3). Exposure is the contact made between a chemical, physical or biological agent and the outer boundary of an organism such as the skin, lungs or gut.

In the next slides of this section, we describe the determinants of these air pollution health effects.



The world's population is projected to increase by 2 billion individuals in the next 30 years, from 7.7 billion in 2020 to more than 9 billion in 2050.

Sub-Saharan African countries will account for most of the growth in the world's population over the coming decades, while several other regions will begin to experience decreasing population numbers.

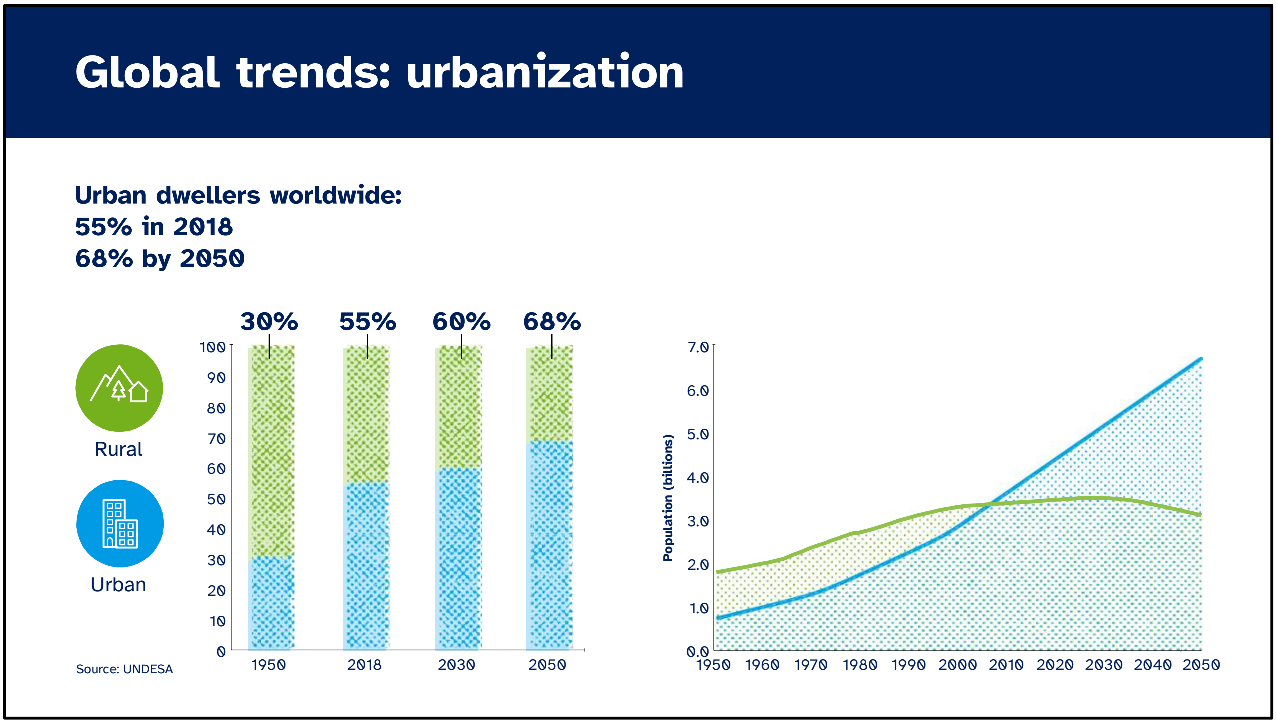
In addition to this, increasing life expectancy and falling fertility levels make the world's population growing older.

More people living on our planet will mean that more resources are needed to enable populations to thrive.

We have learned that this often has led to anthropogenic-induced emission of pollutants in the atmosphere, for example for energy production and consumption.

Bibliography

- United Nations Department of Economic and Social Affairs, Population Division (2022). World Population Prospects 2022: Summary of Results. UN DESA/POP/2022/TR/NO. 3.
- World population prospects 2019: highlights. New York: United Nations, Department of Economic and Social Affairs, Population Division; 2019. Publication no. ST/ESA/SER.A/423.



Another important factor determining air pollution health effects – closely linked to population growth – is urbanization. Globally, the majority of the world's population (55% in 2018) lives in urban areas as opposed to rural areas. This is a huge increase since the 1950s, when only 30% of the world's population was urban. This increasing urbanization trend is set to continue, with 68% of the world's population projected to be living in urban areas by 2050.

Managing effectively urban growth is essential to ensure sustainable development especially where urbanization is expected to rapidly increase.

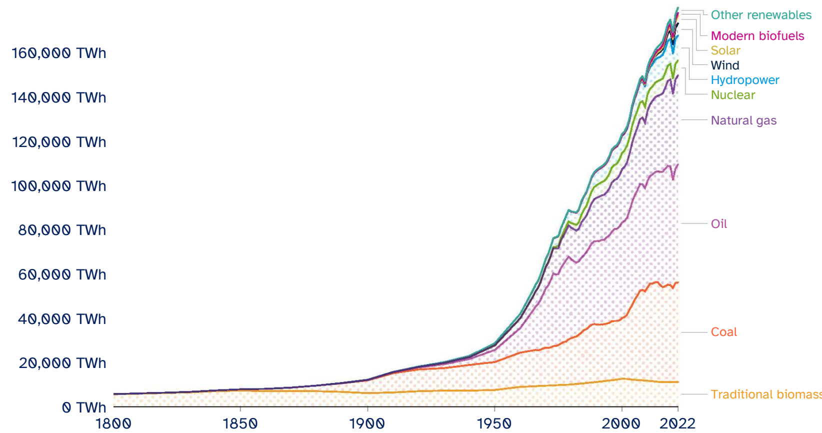
Bibliography

- World urbanization prospects: the 2018 revision. New York: United Nations, Department of Economic and Social Affairs (DESA), Population Division, Population Estimates and Projections Section; 2019 (https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf, accessed 9 December 2024).

Global problems: increasing energy consumption

Global primary energy consumption by source

Primary energy is calculated based on the ‘substitution method’ which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.



Another important factor determining air pollution health effects is the increasing energy consumption.

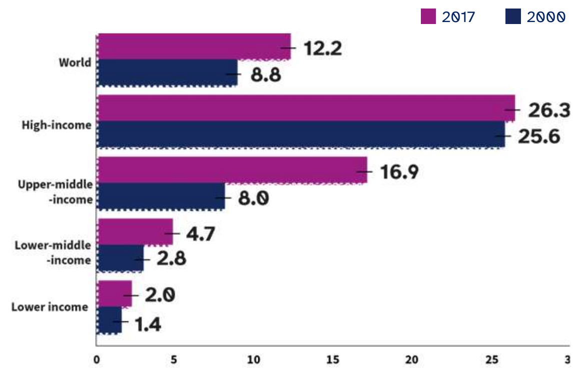
In the second half of the 20th century, energy consumption – mostly from fossil fuels (gas, oil and coal) – had grown to levels of an order of magnitude higher than during the middle of the 19th century.

Bibliography

- Hannah Ritchie. How have the world’s energy sources changed over the last two centuries? Our World In Data; 2021 (https://ourworldindata.org/global-energy-200-years, accessed 9 December 2024).
- World Economic and Social Survey 2009. New York: United Nations; 2009 (https://www.un.org/en/desa/world-economic-and-social-survey-2009, accessed 9 December 2024).
- World Economic and Social Survey 2011. New York: United Nations; 2011 (https://www.un.org/en/development/desa/policy/wess/wess_current/2011wess.pdf, accessed 9 December 2024).

Unsustainable consumption and production

Material footprint per capita in 2000 and 2017 (metric tons per person)



Source: https://unstats.un.org/sdgs/report/2019/goal-12/

ENSURE SUSTAINABLE CONSUMPTION AND PRODUCTION PATTERNS

SUSTAINABLE DEVELOPMENT GOALS

Material footprint is the total amount of raw materials extracted to meet final consumption demands, an indicator of the **pressures placed on the environment** to support economic growth and to satisfy the material needs of people.

- Globally, material footprint is rapidly growing.
- The richest countries are the most responsible.
- Material footprint has outpaced both population and economic growth.

Globally, we continue to use ever-increasing amounts of natural resources to support our economic activity – and the generation of waste is mounting.

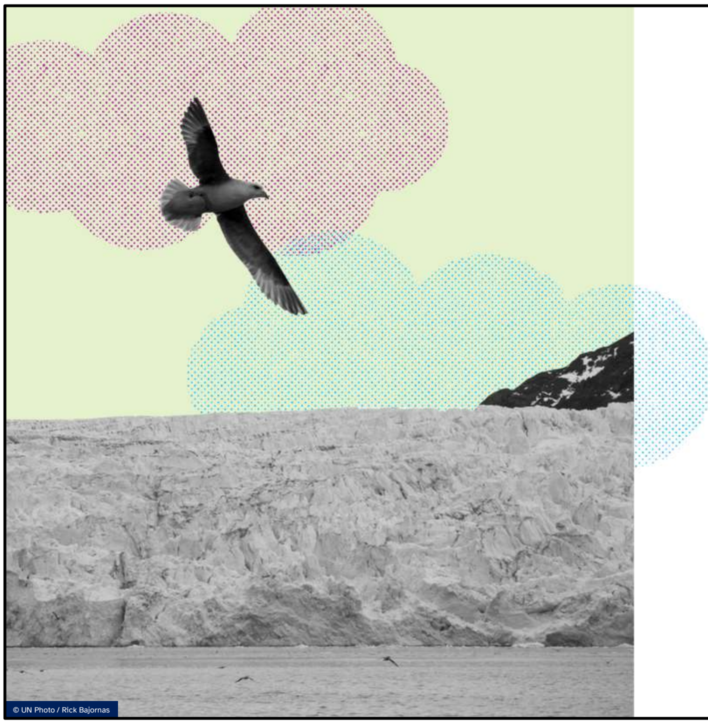
Also globally, the material footprint – the number of raw materials extracted to meet final consumption demands – showed an increase of 113% from 1990 to 2017.

Economic and social progress over the last century has also been accompanied by environmental degradation that is endangering the very systems on which our future development – indeed, our survival – depends.

The more we consume in an indiscriminate way, the more we contribute to environmental degradation, including air pollution.

Bibliography

- Ensure sustainable consumption and production patterns. New York: United Nations, Department of Economic and Social Affairs (DESA), Statistics Division; 2022 (https://unstats.un.org/sdgs/report/2019/goal-12/, accessed 9 December 2024).



Climate change and air pollution

Main links between air pollution and climate change:

- common drivers (sources);
- some air pollutants are also short-lived climate pollutants (SLCPs);
- climate change contributes to ground-level ozone formation; and
- climate-related desert dust and wildfires cause dangerous emissions of air pollutants.

Air pollution and climate change are closely interlinked.

Sources of climate change and air pollution often overlap.

Some air pollutants, such as O_3 or black carbon (a component of PM) can exert direct and indirect effects on climate due to their warming potential as short-lived climate pollutants (SLCPs). They also negatively affect ecosystems. For example, O_3 impairs the ability of plants to absorb CO_2 from the atmosphere.

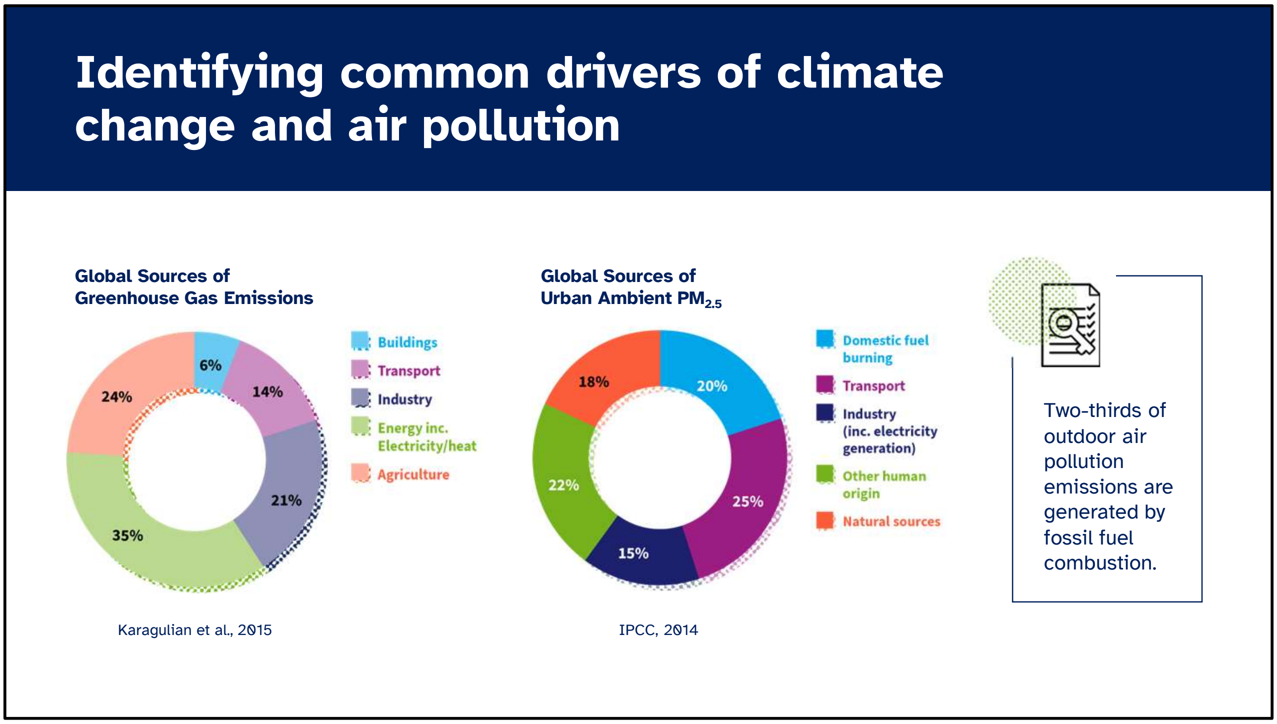
Higher temperatures contribute to O_3 formation as they increase emissions of VOCs that, as noted in the previous slides, are the precursors of O_3.

Some of the consequences of global warming – such as droughts, sand and dust storms and increased frequency of wildfires – also contribute to the release of health-threatening air pollutants to the atmosphere, such as particulate matter.

Changes in climate can impact the local air quality.

Bibliography

- COP29 special report on climate change and health: Health is the argument for climate action. Geneva: World Health Organization; 2024
- Stocker T, editor. Climate change 2013: the physical science basis. Working Group I contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: Intergovernmental Panel on Climate Change; 2014.
- WMO statement on the state of the global climate in 2018. Geneva: World Meteorological Organization; 2019 (https://library.wmo.int/doc_num.php?explnum_id=5789, accessed 9 December 2024).
- WMO 2023 State of Climate Services: Health. Geneva: World Meteorological Organization; 2023 (https://library.wmo.int/idurl/4/68500, accessed 9 December 2024).



The sectors that produce the most greenhouse gases (GHGs) – energy, transport, industry, agriculture, waste management and land use – are also the main sources of fine PM and other important air pollutants. Approximately 25% of urban ambient air pollution from fine PM is contributed by traffic, 15% by industrial activities including electricity generation, 20% by domestic fuel burning, 22% from unspecified sources of human origin and 18% from natural sources.

The global contributions of different sectors to the GHG emissions that drive climate change are 14% from transport, 35% from energy for electricity generation and heat, 21% from industry, 6% from buildings and 24% from agriculture and land use change (right-hand side of the slide). The sources of air pollution and climate change are broadly the same, and mainly involve the use of polluting energy systems.

WHO estimates that around two thirds of ambient air pollution emissions are generated by fossil fuel combustion.

Bibliography

- Summary for policymakers. In: Climate Change 2014: mitigation of climate change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Geneva: Intergovernmental Panel on Climate Change; 2014.
- Karagulian F, Belis CA, Dora CFC, Prüss-Ustün AM, Bonjour S, Adair-Rohani H et al. Contributions to cities' ambient particulate matter (PM): a systematic review of local source contributions at global level. Atmos Envir. 2015;120:475–83. doi:10.1016/j.atmosenv.2015.08.087.
- COP24 special report: health and climate change. Geneva: World Health Organization; 2018 (https://apps.who.int/iris/handle/10665/276405, accessed 9 December 2024).

Short-lived climate pollutants (SLCPs)

Short-lived climate pollutants (SLCPs) =

pollutants that, although having a shorter atmospheric lifetime, have a greater warming potential than CO_2, therefore contributing substantially to climate change.

SLCPs	Climate driver	Air pollutant harming human health
Black carbon is a component of $PM_{2.5}$ formed from the incomplete combustion of carbon-based fuels; lifetime in the atmosphere 1–2 weeks	✓	✓
Tropospheric ozone (O_3)*	✓	✓
Methane (CH_4)*	✓	
Hydrofluorocarbons (HFCS)*	✓	

* greenhouse gases (GHGs)

Anthropogenic emissions of CO_2 and other GHGs are known to be the main driver of climate change. SLCPs are pollutants that, although having a short atmospheric lifetime (spanning a few days to a couple of decades, compared with hundreds of years for CO_2), have a greater warming potential than CO_2, therefore contributing substantially to climate change. As you can see from the slide, SLCPs include methane, tropospheric O_3 and hydrofluorocarbons (HFCs), which are all GHGs. SLCPs also include black carbon, a component of $PM_{2.5}$, which is not a GHG.

Some SLCPs are also harmful air pollutants for health and can have negative effects on the ecosystem. For example, O_3 impairs the ability of plants to absorb CO_2 from the atmosphere. Black carbon is defined as the component of the fine particles in soot that makes them dark. Among all warming pollutants, black carbon is estimated to be the second-most important contributor to global warming (after CO_2). Its warming force is exerted by absorbing solar energy and transforming it into heat, although its lifetime is only 1–2 weeks.

Bibliography

- Bond TC, Doherty SJ, Fahey DW, Forster PM, Berntsen T, DeAngelo BJ et al. Bounding the role of black carbon in the climate system: a scientific assessment. J Geophys Res: Atmos. 2013;118(11):5380–552. doi:10.1002/jgrd.50171.
- Short-lived climate pollutants (SLCPs). Climate and Clean Air Coalition; 2022 (https://www.ccacoalition.org/ar/node/2689, accessed 9 December 2024).
- Malley C, Lefèvre E, Kuylenstierna J, Borgford-Parnell N, Vallack H, Benefor D. Opportunities for increasing ambition of nationally determined contributions through integrated air pollution and climate change planning: a practical guidance document. Climate and Clean Air Coalition; 2019 (https://www.ccacoalition.org/en/resources/opportunities-increasing-ambition-nationally-determined-contributions-through-integrated, accessed 9 December 2024).
- Ramanathan V, Carmichael G. Global and regional climate changes due to black carbon. Nature Geosci. 2008;1:221–27. doi:10.1038/ngeo156.
- Reducing global health risks through mitigation of short-lived climate pollutants. Scoping report for policy-makers. Geneva: World Health Organization; 2015 (https://apps.who.int/iris/handle/10665/189524, accessed 9 December 2024).

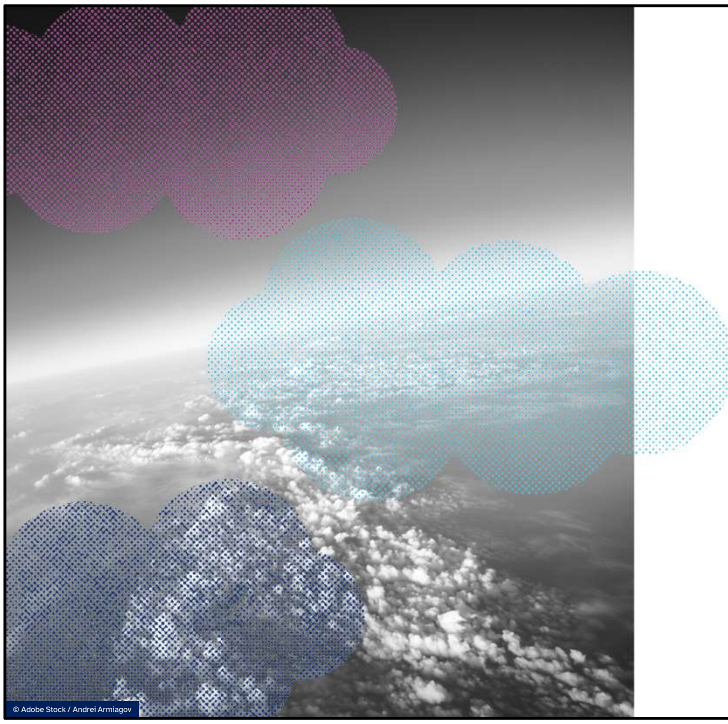
The climate effect of black carbon: a super pollutant

Among all warming pollutants, black carbon is estimated to be the second-most important contributor to global warming after CO_2.

Black carbon is a component of fine particulate matter. Among all warming pollutants, it is estimated to be the second-most important contributor to climate change after CO_2.

Bibliography

- Reducing global health risks through mitigation of short-lived climate pollutants. Scoping report for policy-makers. Geneva: World Health Organization; 2015 (https://apps.who.int/iris/handle/10665/189524, accessed 9 December 2024).



Higher temperatures contribute to ozone formation

Higher temperatures contribute to O_3 formation as they increase the emissions of volatile organic compounds (VOCs), the precursors of tropospheric ozone.

Climate change is expected to increase levels of ozone pollution. Higher temperatures increase the emissions of VOCs. These are the precursors of tropospheric O_3, a dangerous air pollutant mainly associated with respiratory morbidity and mortality.

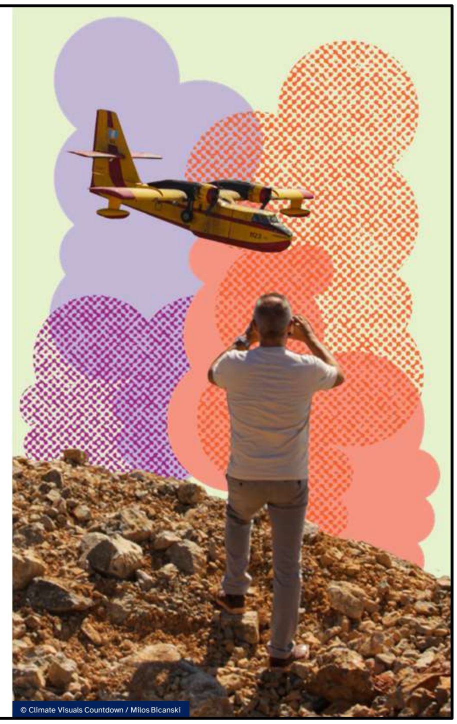
As well, O_3 in the atmosphere warms the climate.

Bibliography

- Patz J, Frumkin H, Holloway T, Vimont DJ, Haines A. Climate change: challenges and opportunities for global health. JAMA. 2014;312:1565–80. doi:10.1001/jama.2014.13186.
- WMO 2023 State of Climate Services: Health. Geneva: World Meteorological Organization; 2023 (https://library.wmo.int/idurl/4/68500, accessed 9 December 2024).

Wildfires release dangerous air pollutants

- Wildfires are increasing around the globe in frequency, severity and duration, also due to climate change.
- The risk of wildfires grows in extremely dry conditions, such as drought, heat waves and during high winds.
- Wildfire smoke is a mixture of air pollutants of which particulate matter (PM) is the principal public health threat.
- Main health effects include premature deaths, diseases of the lungs, heart, brain/nervous system, skin, gut, kidney, eyes, nose and liver, cognitive impairment and memory loss.
- Wildfires also simultaneously impact the climate by releasing large quantities of carbon dioxide and other greenhouse gases into the atmosphere.



Wildfires are increasing around the globe in frequency, severity and duration, also due to climate change and heightening the need to understand the health effects of wildfire exposure. The risk of wildfires grows in extremely dry conditions, such as drought, heat waves and during high winds.

Wildfire smoke is a mixture of air pollutants of which particulate matter (PM) is the principal public health threat. Other pollutants include NO_2, ozone, aromatic hydrocarbons, or lead. In addition to contaminating the air with toxic pollutants, wildfires also simultaneously impact the climate by releasing large quantities of carbon dioxide and other greenhouse gases into the atmosphere.

With climate change leading to warmer temperatures and drier conditions and the increasing urbanization of rural areas, the fire season is starting earlier and ending later. Wildfire events are getting more extreme in terms of acres burned, duration and intensity, and they can disrupt transportation, communications, water supply, and power and gas services.

Wildfires that burn near populated areas can have significant impact on the environment, property, livestock and human mortality and morbidity depending on the size, speed and proximity to the fire, and whether the population has advanced warning to evacuate.

$PM_{2.5}$ from wildfire smoke is associated with premature deaths in the general population, and can cause and exacerbate diseases of the lungs, heart, brain/nervous system, skin, gut, kidney, eyes, nose and liver. It has also been shown to lead to cognitive impairment and memory loss. Firefighters and emergency response workers are also greatly impacted by injuries, burns and smoke inhalation, particularly at high concentrations.

More interdisciplinary research is warranted to understand the latent and long-term health effects of wildfire exposure on vulnerable populations (children, older people, pregnant people, chronically ill people), particularly for geographic areas enduring repeated and cyclical exposure to these wildfire events.

Bibliography

- WHO. Health topics. Wildfires. Geneva: World Health Organization; 2023 (https://www.who.int/health-topics/wildfires#tab=tab_2, accessed 9 December 2024),

Sand and dust storms present a formidable, widespread threat to health and hinder the achievement of sustainable development in its economic, social and environmental dimensions. Originating from the land – as opposed to sea salt, industrial pollutants or volcanic dust – these particles of various size and composition get lifted in the air, creating storms. This is especially the case in dry regions, where vegetation is sparse or absent, such as desert. Their wide impact goes beyond human health and air quality, as it also impacts agriculture, environment, industry, transport and water quality.

Dust emissions are also aggravated by human activities, and the share of dust originating from human activities is as high as 25% of the total, according to research.

Desert dust episodes contribute directly to air pollution by increasing particulate matter concentrations. In some regions dust is a main source of air pollution. Desert dust episodes – or sand and dust storms – constitute a growing environmental and public health (mainly for respiratory diseases) concern for many areas of the world. It also has an important transboundary component.

Being a global phenomenon that affects specific areas, it is a challenge for the health sector because of the difficulty in characterizing the exposure and the limited evidence on its long-term health effects. Currently, the response from governments is based on the knowledge of short terms health effects, limited early warning systems and the provision of information to vulnerable groups in real time, as well as the impact of emergency visits.

The health sector often uses the term "desert dust" when considering the health impacts of mineral dust in the air, but not all mineral dust in the air comes from deserts. For example, there are significant threats to health when mineral soil is lifted from plowed or bare fields, which can occur in temperate or even humid climates.

Sand and dust storms are also an important transboundary issue. Although staying close to the ground, aeolian mineral dust can travel considerable distances when lifted kilometers high into the atmosphere. Examples include dust from the Sahara frequently reaching the Caribbean and dust from inner northwest Asia often reaching the Korean peninsula and Japan.

Starting in 2023, the International Day of Combating Sand and Dust Storms will be observed every year on 12 July.

The health sector should also address the gaps in knowledge and response on the health impacts of desert dust in the longer term and continue strengthening collaboration with appropriate government entities to provide a timely and effective public health response.

Key messages include:
- 25% of dust emissions originates from human activities including deforestation, land degradation, unsustainable land management, climate change and water mismanagement.
- Globally, 330 million people are exposed daily to particles transported by wind, sometimes for thousands of kilometers from source areas. For example, a person living in Barbados regularly breathes Sahara dust particles.
- Climate change contributes to desertification, which in turn may increase the frequency and spread of sand and dust storms.
- About a third of the Earth's land surface is prone to emit airborne mineral dust, composed of arid and semi-arid regions.
- In certain areas, desert dust can dominate the mix of air pollution.
- Evidence indicates that dust has immediate impacts on respiratory and cardiovascular diseases.

WHO Response

Developing normative guidance for policy makers on the health effect: promoting evidence-based policy action to protect human health
WHO plays a crucial role in developing normative guidance and recommendations to address the health impacts of sand and dust storms. WHO recognizes that exposure to aeolian mineral dust can have detrimental effects on human health and aims to provide evidence-based guidelines for protecting populations from these hazards.

Convening interdisciplinary expert groups on Desert dust and Health
In 2021, WHO establish the first WHO expert group focusing on air pollution and health, the Global Air pollution and Health - Technical Advisory Group. One of its sub-groups, the Expert Working Group on Desert Dust and Health, is working to synthetize evidence on the short- and long-term health impacts of desert dust, provide guidance on harmonized exposure assessment of desert dust and monitoring of health effects, evaluate the implementation of the current good practice statements as provided in the WHO AQG, and strengthen future normative recommendations.

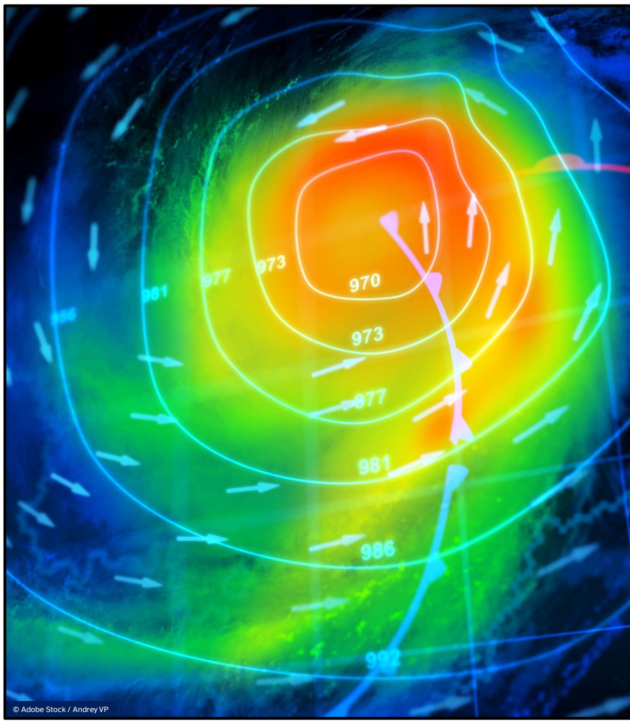
Synthesize evidence to inform policy
WHO is engaged in advancing the current knowledge on desert dust and health through research commission feeding into the Air Quality Guidelines or bringing expertise into technical reports.

WHO collaborates closely with international organizations such as the World Meteorological Organization's Sand and Dust Storm Warning Advisory and Assessment System (Forecast Maps) and leads the working group on health of the United Nations Coalition to Combat Sand and Dust Storms (SDS) to integrate health arguments and tools in action plans.

The Coalition aims, among other goals, to promote and coordinate a collaborative UN-system response to SDS on local, regional and global scales, ensuring unified and coherent actions are taken. This coalition formed in 2018 and was an important milestone in international collaboration and acknowledgment of the need for better coordination among international, multilaterals and intergovernmental entities.

Bibliography:

- General Assembly Proclaims 12 July International Day of Combating Sand and Dust Storms, Aiming to Raise Awareness about Importance for Health, Sustainability | UN Press [website]. (https://press.un.org/en/2023/ga12508.doc.htm, accessed 9 December 2024)
- United Nations Convention to Combat Desertification (UNCCD). 2022. Sand and Dust Storms Compendium: Information and Guidance on Assessing and Addressing the Risks. Bonn, Germany.
- UN Coalition to Combat Sand and Dust Storms – UN Environment Management Group [website]. (https://unemg.org/our-work/emerging-issues/sand-and-dust-storms/, accessed 9 December 2024)
- World Health Organization. Factsheet: Sand and dust storms [website]. World Health Organization; 2024 (https://www.who.int/news-room/fact-sheets/detail/sand-and-dust-storms, accessed 9 December 2024)
- World Health Organization. (2021). WHO global air quality guidelines: particulate matter ($PM_{2.5}$ and PM_{10}), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. World Health Organization. (https://iris.who.int/handle/10665/345329 CC BY-NC-SA 3.0 IGO, accessed 9 December 2024)



Meteorology and air pollution

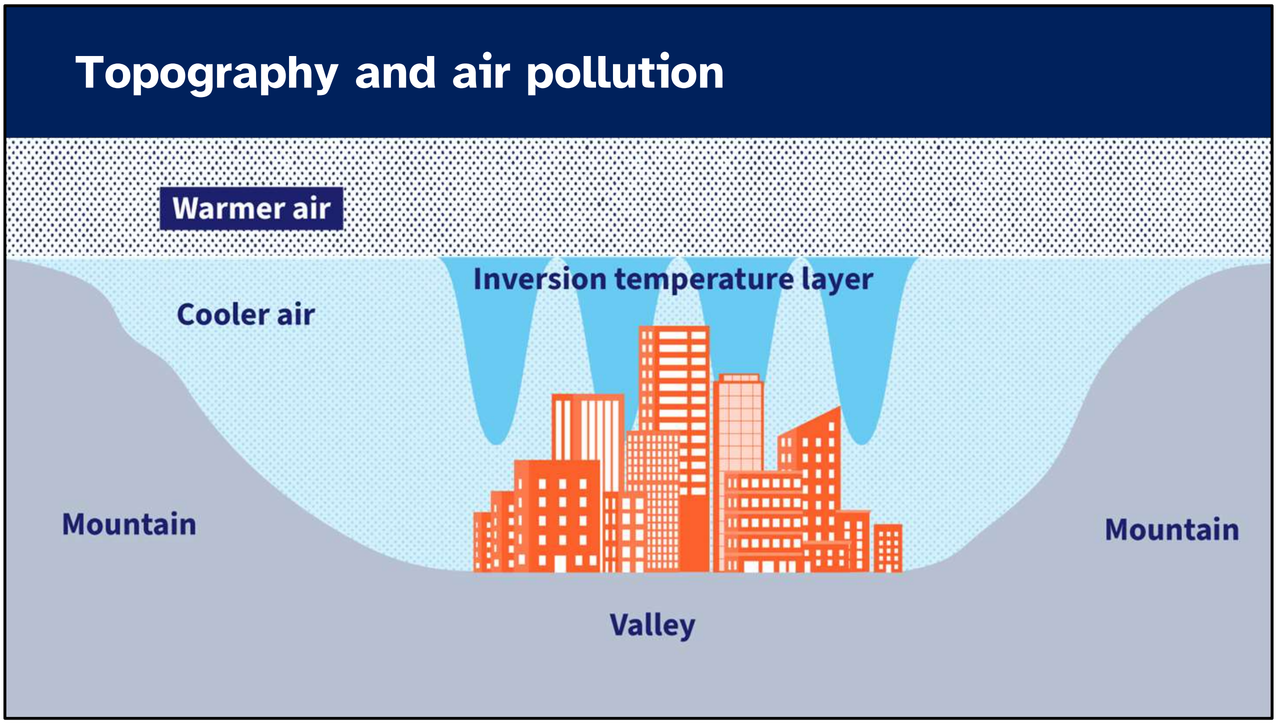
Meteorology is the study of the dynamics of the atmosphere.

Meteorological parameters:

- temperature
- relative humidity
- precipitation
- wind velocity and pressure
- solar radiation
- visibility

Meteorology is the study of the dynamics of the atmosphere, dependent on meteorological parameters such as:

- temperature
- relative humidity
- precipitation
- wind velocity and pressure
- solar radiation
- visibility.



Topography plays a significant role in how pollutants are dispersed in the atmosphere.

For example, certain topological characteristics (such as a valley or a mountain) may facilitate the formation of an inversion temperature layer that acts as a barrier for the dispersion of pollutants.

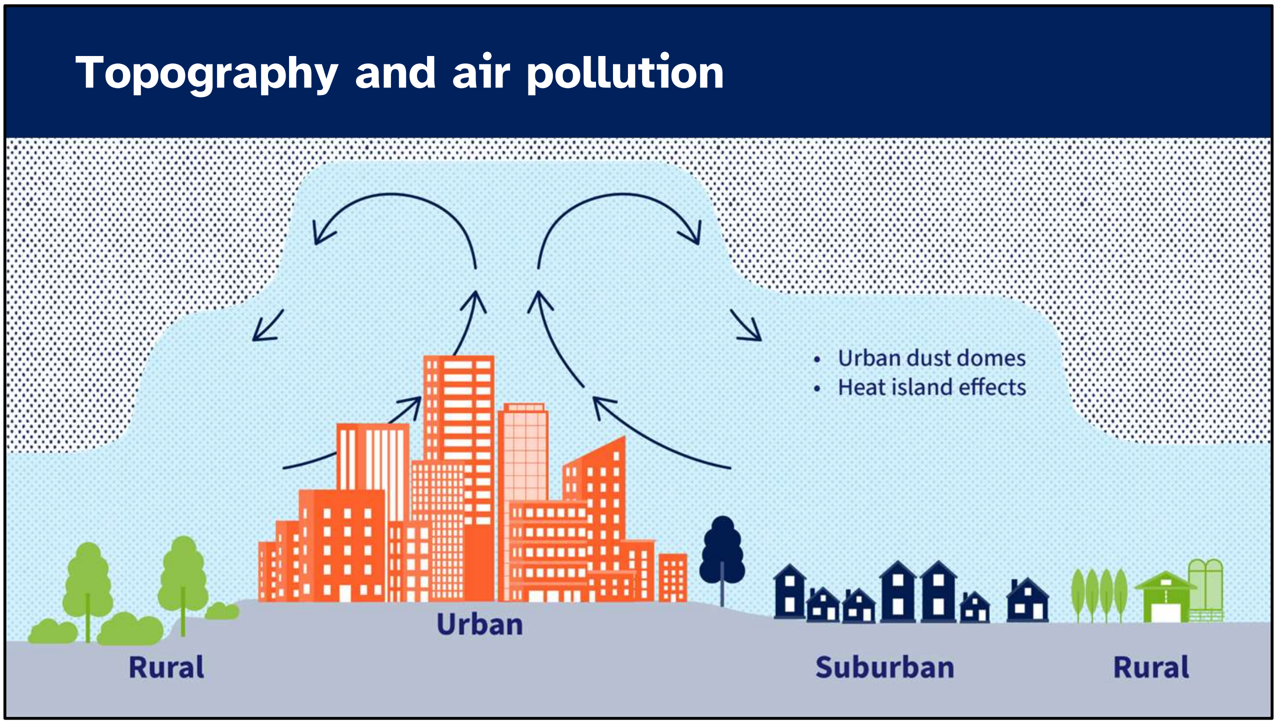
Normally, the temperature of the air decreases as altitude increases. During an inversion, this normal temperature profile is inverted and warmer air is held above cooler air.

When this happens, emitted pollutants will be trapped in, and kept afloat by, a specific air parcel. As pollutants are being increasingly emitted, the outdoor concentration will rise considerably over time.

Bibliography

- Botkin DB, Keller EA. Environmental science: Earth as a living planet. New York: John Wiley & Sons; 1997.

Picture credits: adapted from Botkin DB, Keller EA. Environmental science: Earth as a living planet. New York: John Wiley & Sons; 1997.



The combination of lingering air and the abundance of particles and other pollutants in the air produces urban dust domes and heat island effects.

Bibliography

- Botkin DB, Keller EA. Environmental science: Earth as a living planet. New York: John Wiley & Sons; 1997.

Picture credits: adapted from Botkin DB, Keller EA. Environmental science: Earth as a living planet. New York: John Wiley & Sons; 1997.

How do air pollution levels vary seasonally in Ghana?

2018 video series at First WHO Global Conference on Air Pollution and Health

Dr Emmanuel Appoh, Ghana Environmental Protection Agency

Source: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic/cities-regions-and-countries/africa#

<2 min and 50 sec video>

Note: You can use other videos and embed them in the presentation using the WHO video mosaic series on air pollution and health: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic

Bibliography

- https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health/videos/mosaic/cities-regions-and-countries/africa#

Air pollution is transboundary

Many major air pollutants can travel long distances via:

- meteorological conditions;
- air patterns and wind.

This includes:

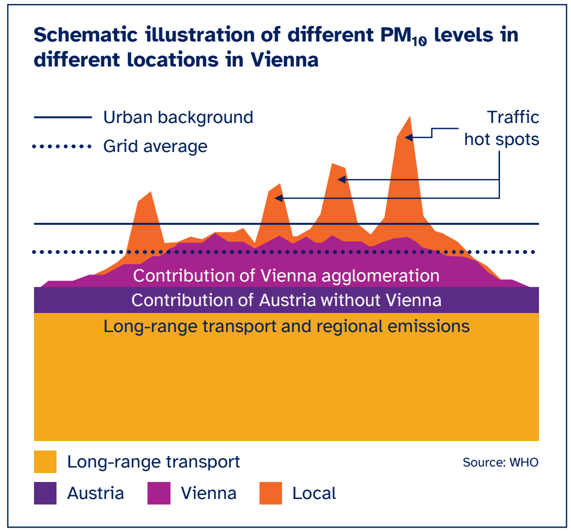
- particulate matter;
- ozone and precursor emissions;
- sulfur dioxide.

Air pollutants can travel:

- urban – rural and vice versa;
- international and transcontinental.

Mitigation efforts must be broad in scope:

- local policies may not be sufficient.



Air pollution has no boundaries. Air pollution is transboundary, and many pollutants can travel significant distances from their source of origin. Particulate matter (PM) and nitrogen dioxide from vehicle emissions, desert dust and sand, pesticide residues and mercury from coal-fired power plants have been observed to travel significant distances from points of pollution. Ambient air pollution can move from urban to rural areas and vice versa, may travel across a country, between neighbouring countries, across entire regions and can even travel from one continent to another. Some air pollutants can circulate around the world, depositing on land and in water bodies far from their sources.

Air pollution is strongly affected by meteorological conditions and pollutants are primarily distributed by air patterns and winds. Rainfall can also move air pollutants from one area and deposit them in another. Some major air pollutants discussed in this module can travel significant distances, including:

- **PM**: The transport of PM over long distances depends on chemical composition, the size of particles, climate conditions and the sources of pollution. Fine PM can remain in the atmosphere for days or weeks and is more likely to be transported across long distances than coarse PM. This primarily occurs during pollution events, such as biomass burning, wildfires or dust storms. Rainfall and wet weather can cause PM pollution to disperse over a wide area. For example, the west coast of the United States of America can be affected by plumes of PM originating in South-East Asia and the Western Pacific due to prevailing winds and dry conditions.
- **Ozone and precursor emissions**: Many precursor emissions have lifetimes that allow them to travel long distances in the atmosphere. This allows ozone to form in locations that may be hundreds or even thousands of kilometres away from the source of precursor emissions. In Europe, research has suggested that background ozone levels are associated with emissions from the entire Northern Hemisphere. Ozone pollution is often observed downwind of major industrial regions. In Europe, research has found that ozone levels are often higher in rural areas surrounding populated areas, rather than in urban areas or roadside locations due to the movement of precursor emissions.
- **Sulfur dioxide**: Sulfur dioxide has anthropogenic (such as combustion of coal for energy needs) and natural sources (such as volcanoes), and concentrations have changed significantly over time in different locations depending on activities from these sources. Sulfur dioxide has an atmospheric lifetime of about 10 days, and it can travel thousands of kilometres from its point of origin. For example, in 2022 a volcanic eruption in Tonga led to a significant sulfur dioxide plume over Australia 3 days later. This plume had travelled more than 7000 kilometres.

Recent analyses have confirmed that, in many areas in Europe, long-range transport makes a substantial contribution to PM levels. The concept of different contributions (regional, urban and local) is illustrated schematically in this slide, which shows the different PM levels at monitoring sites in and around Vienna. A large portion (yellow) is due to long-rage transport and regional emissions. The two shades of yellow-orange represent the contribution to PM in Vienna coming from outside Vienna, and from the Vienna urban agglomeration. The red part is from local sources, and the spikes are the traffic hot spots. It should be noted, however, that the regional background is to some extent influenced by emissions from the urban area, since urban hot spots influence the urban background.

Due to the ability of some air pollutants to travel significant distances from their point of origin, efforts to improve air quality must be broad in scope. Local air quality policies are important to protect human health; however, they may not be sufficient if air quality is polluted by international emissions. International and regional conventions and agreements exist to reduce emissions of long-rang air pollutants

Bibliography

- Amann M, Derwent D, Forsberg B, Hanninen O, Hurkey F, Krzyzanowski M, et al. Health risks of ozone from long-range transboundary air pollution. Copenhagen: World Health Organization Regional Office for Europe; 2008 (https://apps.who.int/iris/handle/10665/326496, accessed 9 December 2024).
- Health risks of particulate matter from long-range transboundary air pollution. Geneva: World Health Organization; 2006 (https://apps.who.int/iris/handle/10665/107691, accessed 9 December 2024).
- National Research Council. Global sources of local pollution: an assessment of long-range transport of key air pollutants to and from the United States. Washington (DC): The National Academies Press; 2010 (https://nap.nationalacademies.org/catalog/12743/global-sources-of-local-pollution-an-assessment-of-long-range, accessed 9 December 2024).
- Sulphur dioxide from Tonga eruption spreads over Australia [website]. Paris: European Space Agency; 2022 (https://www.esa.int/ESA_Multimedia/Images/2022/01/Sulphur_dioxide_from_Tonga_eruption_spreads_over_Australia, accessed 9 December 2024).
- Toxicological profile for sulfur dioxide. Atlanta: Agency for Toxic Substances and Disease Registry, U.S. Department of Health and Human Services, Public Health Service; 1998 (https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=253&tid=46, accessed 9 December 2024).
- WHO global air quality guidelines: particulate matter (PM2.5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide. Geneva: World Health Organization; 2021

(https://apps.who.int/iris/handle/10665/345329, accessed 9 December 2024).
- WHO, WHO EURO, Joint WHO/ Convention Task Force on the Health Aspects of Air Pollution. Health risks of particulate matter from long-range transboundary air pollution. Copenhagen: World Health Organization Regional Office for Europe; 2006 (https://apps.who.int/iris/handle/10665/107691, accessed 9 December 2024).

Reducing ambient air pollution: examples of international actions and initiatives

- WHA Resolution 68.8 – Health and the environment: addressing the health impact of air pollution
- Roadmap for an enhanced global response to the adverse health effects of air pollution
- Regional conventions on Long-range Transboundary Air Pollution
- Stockholm Convention on Persistent Organic Pollutants
- Clean Air and Climate Coalition
- BreatheLife Campaign
- International Day of Clean Air for Blue Skies
- World Asthma Day
- World Heart Day

Ambient air pollution is an international environmental problem threatening the health of people across the world. Actions to improve air quality must be global in scope and inclusive of stakeholders in high-, middle- and low-income countries. This slide includes some international actions and initiatives that aim to improve air quality and protect public health.

- **World Health Assembly (WHA) Resolution 68.8:** In 2015, the Sixty-eighth WHA adopted a landmark resolution, "Health and the environment: addressing the health impact of air pollution". This resolution urged Member States to research, publicize and minimize the health effects of air pollution.
- **Roadmap for an enhanced global response to the adverse health effects of air pollution:** In 2018 at the Seventy-first WHA, the Director-General of WHO announced 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.
- **Convention on Long-range Transboundary Air Pollution:** This convention was the first international legally binding instrument to address air pollution on a regional level. It sets targets and technical emission standards with the goal of reducing the health and environmental impacts of air pollution. Since its establishment in 1979, it has grown to consist of eight protocols that identify specific measures to cut emissions of air pollutants, such as sulfur dioxide, nitrogen oxides, volatile organic compounds and particulate matter.
- **Stockholm Convention on Persistent Organic Pollutants (POPs):** This convention requires parties to eliminate production, and restrict import and export, of POPs. As of 2023, there are 186 parties to the Stockholm Convention and it eliminates, restricts or requires the reduction, where possible, of 35 different POPs.
- **Clean Air and Climate Coalition:** This is a global, voluntary partnership of governments, intergovernmental organizations, businesses, scientific institutions and civil society organizations. The Coalition aims to improve air quality and protect the climate through actions to reduce short-lived climate pollutants through encouraging action by providing knowledge, mobilizing support for action through advocacy, increasing access to financial resources and enhancing scientific knowledge.
- **BreatheLife Campaign:** An initiative formed by WHO, United Nations Environment Programme (UNEP), the World Bank, and the 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 suggestions for individual action. As of 2023, the BreatheLife network includes 79 cities, regions and countries, reaching 492 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 works with municipalities to provide guidance on air pollution monitoring, implement solutions and build grassroots support. Health care professionals can use BreatheLife's resources for up-to-date data and information, policy suggestions and individual actions.
- **International Day of Clean Air for Blue Skies:** An official day observed by the United Nations, occurring annually on 7 September. It aims to build a global community of action and encourage countries to work together to protect air quality. The theme in 2023 was "The Air We Share," focusing on the transboundary nature of air pollution.
- **World Asthma Day:** Organized annually in May by the Global Initiative for Asthma to raise awareness and education on asthma. In 2023, the theme of the day was "Asthma care for All".
- **World Heart Day:** Organized annually on 29 September by the World Heart Federation to raise awareness on cardiovascular health. One of the main themes in recent years was air pollution.

Note: Search your city on the BreatheLife platform to see whether your local government is "breathing life" into your region.

Bibliography

- 1979 Convention on Long-range Transboundary Air Pollution. New York: United Nations (htthttps://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-1&chapter=27&clang=_en, accessed 9 December 2024).
- BreatheLife: a global campaign for clean air [website]. Geneva: BreatheLife; 2016 (https://breathelife2030.org/, accessed 9 December 2024).
- Clean Air and Climate Coalition to Reduce Short-Lived Climate Pollutants [website]. Nairobi: United Nations Environment Programme; 2023 (https://www.ccacoalition.org/en, accessed 9 December 2024).
- Health and the environment: road map for an enhanced global response to the adverse health effects of air pollution. In: Sixty-ninth World Health Assembly. Provisional agenda item 11.4. Geneva: World Health Organization; 2018 (WHA71/A71/10 Add.1; https://apps.who.int/iris/handle/10665/276321, accessed 9 December 2024).
- International Day of Clean Air for Blue Skies [website]. Nairobi: United Nations Environment Programme; 2023 (https://www.cleanairblueskies.org/, accessed 9 December 2024).
- Resolution WHA68.8. Health and the environment: addressing the health impact of air pollution. In: Sixty-eighth World Health Assembly, Geneva, 18–26 May 2015. Resolutions and decisions, annexes. Geneva: World Health Organization; 2015 (WHA68/2015/REC/1; https://apps.who.int/iris/handle/10665/253237, accessed 9 December 2024).

- Stockholm Convention [website]. Geneva: Secretariat of the Stockholm Convention; 2022 (http://www.pops.int/, accessed 9 December 2024).
- World Asthma Day 2023 [website]. Fontana: Global Initiative for Asthma; 2023 (https://ginasthma.org/world-asthma-day-2023, accessed 9 December 2024).
- World Heart Day 2023 [internet]. World Heart Federation (https://world-heart-federation.org/world-heart-day/about-whd/world-heart-day-2023/, accessed 9 December 2024)

Key messages

- An appreciation of the adverse effects of air pollution on health emerged after episodes of **high pollution in the 1950s.**
- Classic air pollutants include **particulate matter ($PM_{2.5}$ and PM_{10})** and gases such as **ozone, nitrogen dioxide , sulfur dioxide and carbon monoxide.**
- Air pollution is the first environmental risk factor for health and PM is one of the main risk factor for **mortality globally**, considering all ages and both sexes.
- **WHO Global Air Quality Guidelines** set the levels of air quality to be achieved everywhere in order to significantly reduce the **adverse health effects of pollution.**
- The key determinant of air quality is the **emission of pollutants to the atmosphere**, which is influenced by urbanization and population growth, the unsustainable consumption and production of goods, the use of unclean energy systems and climate change.
- **Meteorological conditions and topography** influence atmospheric dispersion and, consequently, the ambient concentration of pollutants.

Key points to understand and learn include the following:

- An appreciation of the adverse effects of air pollution on health emerged after episodes of high pollution in the 1950s.
- Classic air pollutants include particulate matter ($PM_{2.5}$ and PM_{10}), and gases such as O_3, NO_2, SO_2 and CO.
- Air pollution is the first environmental risk factor for health and PM is of the main risk factor for globally mortality, considering all ages and both sexes.
- The WHO Global Air Quality Guidelines set the levels of air quality to be achieved everywhere in order to significantly reduce the adverse health effects of pollution.
- The key determinant of air quality is the emission of pollutants to the atmosphere, which is influenced by urbanization and population growth, the unsustainable consumption and production of goods, the use of unclean energy systems and climate change.
- Meteorological conditions and topography influence atmospheric dispersion and, consequently, the ambient concentration of pollutants.

Glossary

Atmospheric inversion: Occurs when warmer air is above cooler air; restricts pollution dispersion.

Meteorology: The study of the dynamics of the atmosphere.

Population attributable fraction (PAF): represents the proportion of disease or health outcome in a population that can be attributed to a specific risk factor. It estimates the proportional reduction in population disease or mortality would occur if exposure to a risk factor were reduced to an alternative ideal exposure scenario, assuming a causal relationship.

PM_{10} and $PM_{2.5}$: Mass concentration of particles with aerodynamic diameter < 10 and 2.5 µm, respectively.

Short-lived climate pollutants (SLCPs): Climate drivers that, while remaining in the atmosphere for a shorter period of time than CO_2 , have a greater potential to warm the atmosphere. Some SLCPs are air pollutants causing negative health effects to humans and damaging ecosystems.

Smog: A term applied to fog heavily polluted by smoke, particularly under conditions of temperature inversion in winter. The term is also applied to the lachrymatory haze produced by photochemical reactions that occur under the influence of strong sunlight in air polluted by automobile exhaust gases, under temperature inversion conditions. The latter type of smog is usually referred to as photochemical smog or oxidant smog. Ozone is the most relevant component of photochemical smog.

Topography: The study and description of the physical features of an area, for example its hills, valleys and rivers, or the representation of these features on maps.

Bibliography

- Short-lived climate pollutants (SLCPs). Climate and Clean Air Coalition; 2024 (https://www.ccacoalition.org/ar/node/2689, accessed 9 December 2024).
- Collins English Dictionary. Glasgow: HarperCollins Publishers, 1994.
- Glossary on air pollution. Copenhagen: WHO Regional Office for Europe; 1980 (https://apps.who.int/iris/handle/10665/272866, accessed 9 December 2024).
- Population attributable fraction. In: The global health observatory. Geneva: World Health Organization; 2023 (https://www.who.int/data/gho/indicator-metadata-registry/imr-details/1287, accessed 9 December 2024)

Contributors and acknowledgements

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Disclaimer

This module contains 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, you can adapt the information, statistics and photos within each slide to the particular context in which this module is being presented.

This module belongs to the Air Pollution and Health Training toolkit targeting health workers (APHT). It has been developed in collaboration with more than 30 experts from government agencies, WHO collaborating centers, non-state actors, including medical and environmental health associations, as well as academic institutions. The methodology used for development included a mapping of existing air pollution and health training opportunities targeting health workers which informed gaps and needs for a global set of materials. Experts identified through existing collaborations with WHO contributed on the definition of outline and populating the training modules with contents. Peer review and pilot test coordinated by WHO ensured the collection of feedback and input for finalization of the products.

WHO made all possible effort to ensure geographical and gender balance for the development of the training toolkit acknowledging limitations in terms of expertise, experience and overall feasibility. You can use and have access to other APHT modules where relevant.
To see the full package visit: https://www.who.int/tools/air-pollution-and-health-training-toolkit-for-health-workers

For more information on WHO's work on air quality, energy and health, please visit: https://www.who.int/teams/environment-climate-change-and-health/air-quality-and-health

Introduction to ambient air pollution

Air pollution and health training toolkit for health workers (APHT)

Email address to training:
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QR code
to toolkit