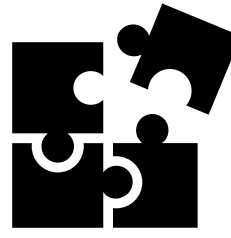


# Environmental medicine

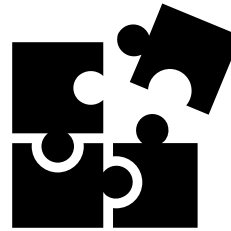




# Impact of air pollution on human health

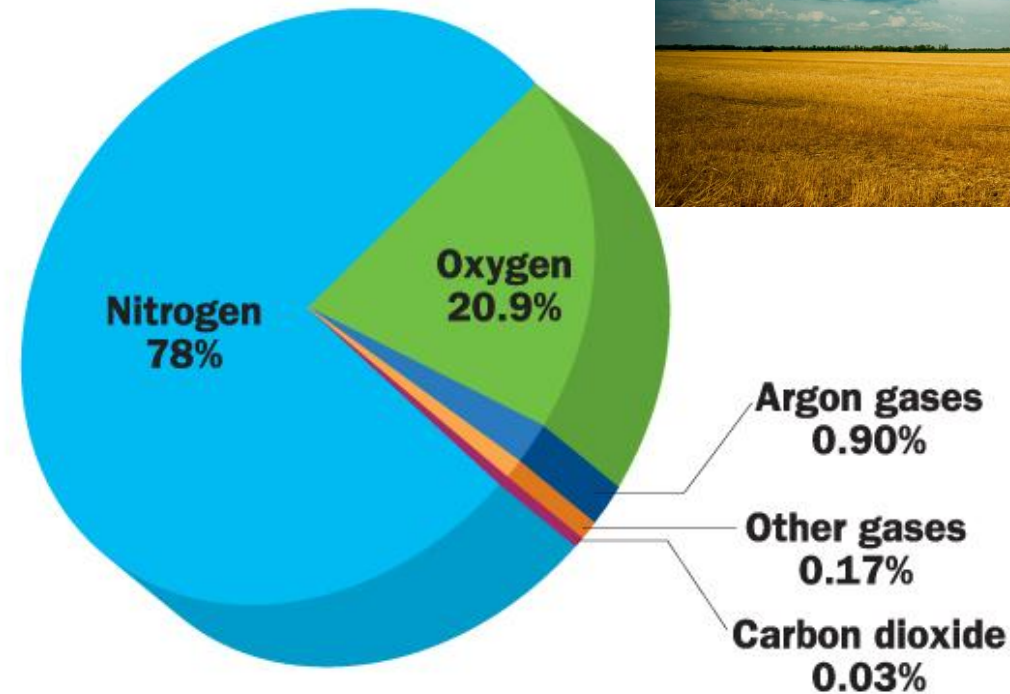


# Air composition



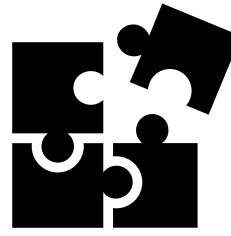
Air contains:

- 78% nitrogen,
- 20.9% oxygen,
- 0.93% argon,
- 0.03% carbon dioxide,
- and small amounts of other trace gases .



# Impact of air pollution on human health

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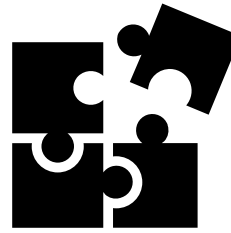


- Air pollution is **contamination** of the indoor or outdoor environment by any chemical, physical or biological agent that modifies the natural characteristics of the atmosphere.



# Sources of air pollution

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## London 1952 – The Great SMOG

A deadly air pollution event in which a thick smog overtook the city for **five days in December 1952**.

**The smog**, which was caused by a **combination of emissions from burning coal and natural weather patterns** that **trapped the pollution in place**

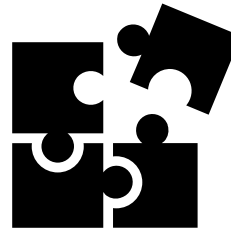
➤ Aprox. 12.000 people died.



↓  
Legislation

# Sources of air pollution

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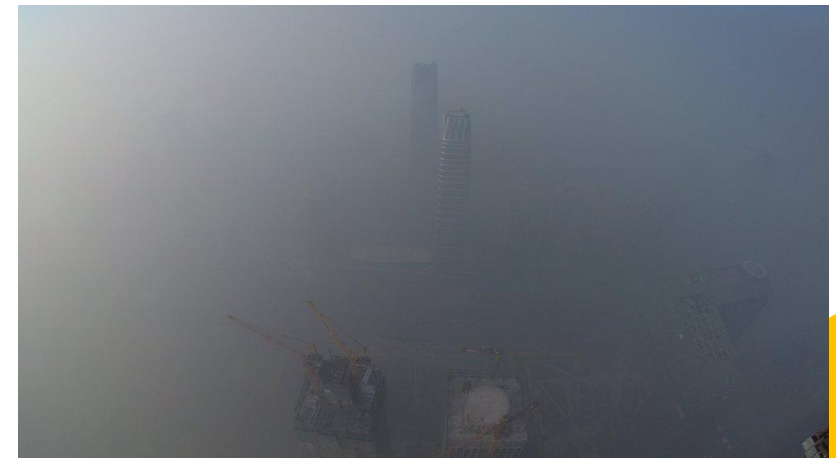


## Beijing, China

Particle pollution in China's capital **has fallen by 60% in 10 years**, but it **remains six times higher** than WHO guidelines.



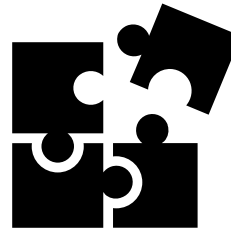
Beijing, China





# Sources of air pollution

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## New Delhi, India

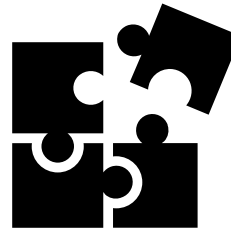
India battles air pollution **every winter** as **cold, heavy air traps dust, emissions, and smoke from farm fires** started illegally in the farming states of Punjab and Haryana.



New Delhi, India

# Sources of air pollution

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Sources of air pollution:

➤ Stationary:

- household combustion devices,
- industrial facilities
- forest fires

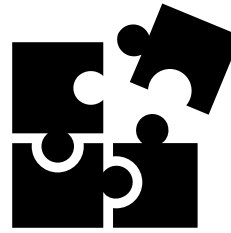
➤ Mobile

- motor vehicles





# Sources of air pollution



## Outdoor air pollution sources



**Car  
Emissions**



**Factory  
Pollution**



**Wildfire  
Smoke**



**Wood  
Smoke**



Volcanic eruption, a natural source



Aircraft, a mobile source



A mobile source of pollution



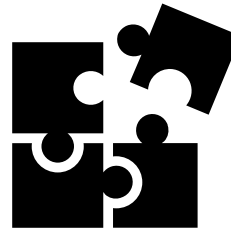
Smokestack, a stationary source

Natural sources

Anthropogenic sources

# Sources of air pollution

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## Indoor air pollution sources



**Dust**



**Secondhand  
Smoke**

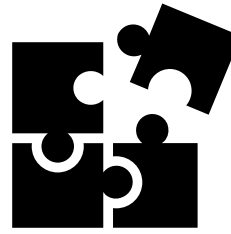


**Chemical  
Irritants**



# Sources of air pollution

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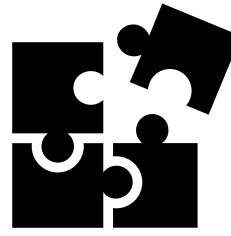
- Outdoor and indoor air pollution cause respiratory and cardiovascular diseases and cancer and can be important sources of morbidity and mortality.



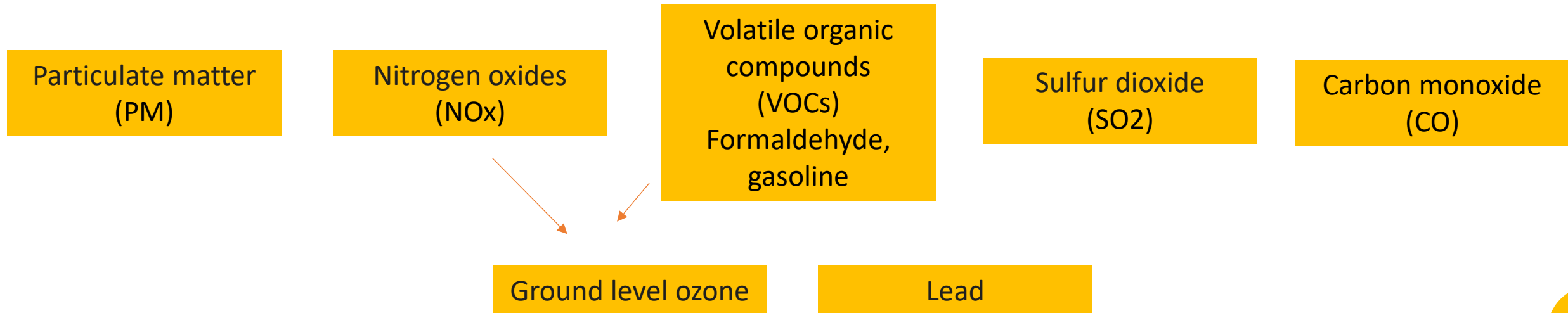
- Lung disease
- Heart disease
- Cancer

# Sources of air pollution

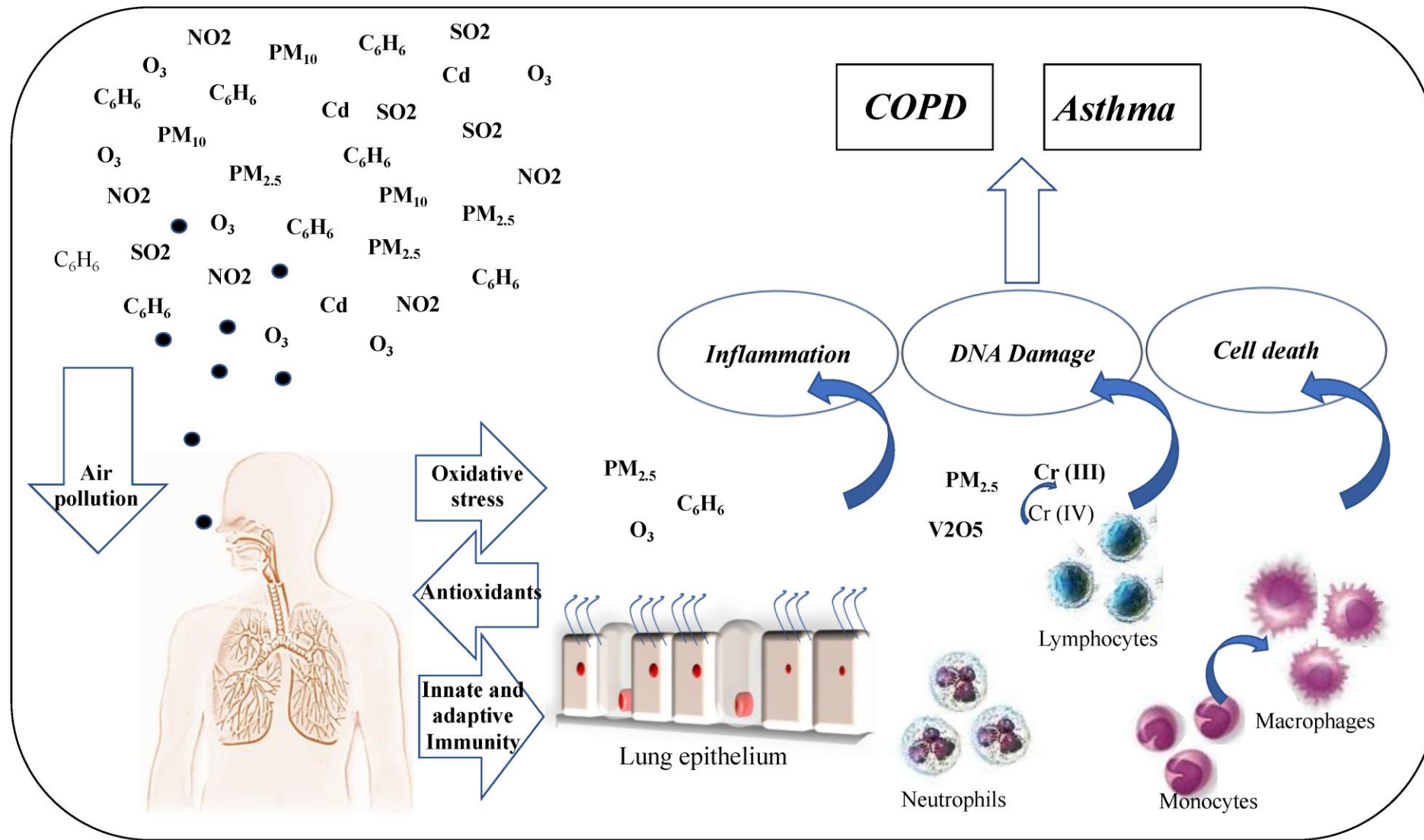
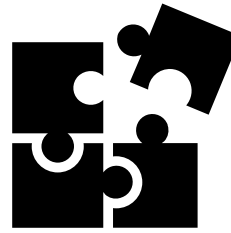
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- Pollutants of major public health concern include:

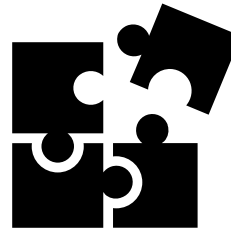


# Air Quality and Respiratory Health



# Impact of air pollution on human health

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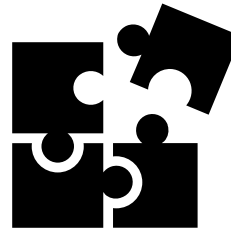
- World Health Organization (WHO) data show that **almost all of the global population (99%) breathe air that exceeds WHO guideline limits** and contains high levels of pollutants.
- **Low- and middle-income** countries suffering from the **highest exposures**.





# Impact of air pollution on human health

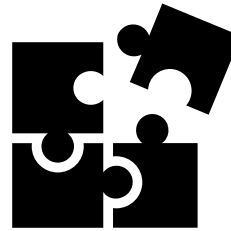
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- In 2015, the World Health Assembly adopted a landmark resolution on air quality and health, recognizing air pollution as a risk factor for ischaemic heart disease, stroke, chronic obstructive pulmonary disease, asthma and cancer, and the economic toll they take.
- The global nature of the challenge calls for an enhanced global response.



[https://www.who.int/health-topics/air-pollution#tab=tab\\_1](https://www.who.int/health-topics/air-pollution#tab=tab_1)



# Impact of air pollution on human health

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- **Air quality** is closely linked to the **earth's climate** and ecosystems globally.
- Many of the drivers of air pollution (i.e. combustion of fossil fuels) are also **sources of greenhouse gas emissions**.
- Policies to reduce air pollution, therefore, offer a **win-win strategy** for both **climate and health**, lowering the burden of disease attributable to air pollution, as well as contributing to the near- and long-term mitigation of climate change.

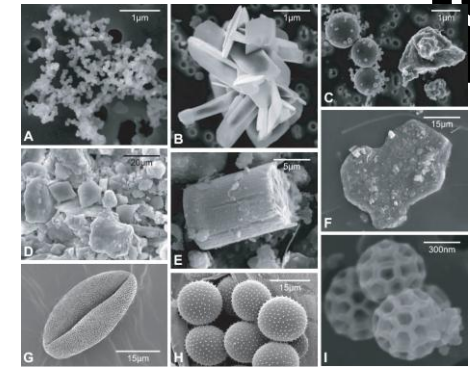


# Air Quality and Respiratory Health



## Particulate Matter (PM):

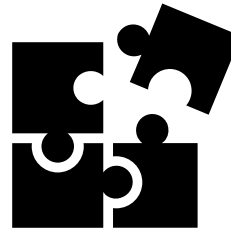
- PM stands for **particulate matter** (also called particle pollution): a **mixture of solid particles** and **liquid droplets** found in the **air**.
- Some particles, such as **dust, dirt, soot, or smoke**, are **large or dark** enough to be seen with the **naked eye**.
- Others are so **small** they can only be detected using an **electron microscope**.



	Solid-vapor-particle-pathway		Solid-particle-pathway
PM	0.1 µm	2.5 µm	10 µm
gaseous/ aerosol	<div>↑ condensation chemical surface reactions coagulation nucleation</div>		<div>↑ coagulation</div>
	<div>surface interaction ZnO, PbO, CdO → KCl, K<sub>2</sub>SO<sub>4</sub>, Na<sub>2</sub>SO<sub>4</sub>, Na<sub>2</sub>CO<sub>3</sub>, NaCl</div>		<div>CaO, CaCO<sub>3</sub>, MgO, SiO<sub>2</sub></div>
biomass	Zn, Pb, Cd	K, Na, S, Cl	Ca, Mg, Si

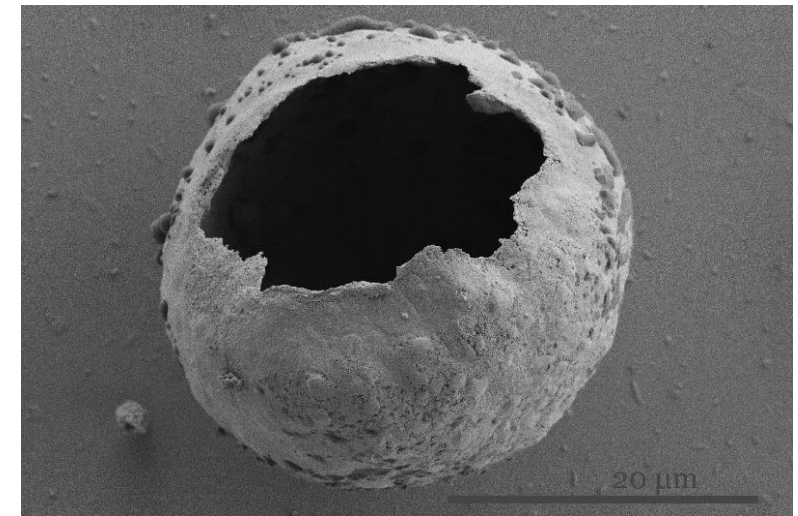
# Air Quality and Respiratory Health

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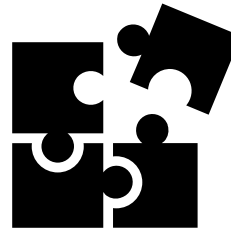


## Particulate Matter (PM):

- Airborne particulate matter (PM) is not a single pollutant, but rather is a **mixture of many chemical species**.
- It is a complex **mixture of solids and aerosols** composed of small droplets of liquid, dry solid fragments, and **solid cores with liquid coatings**.

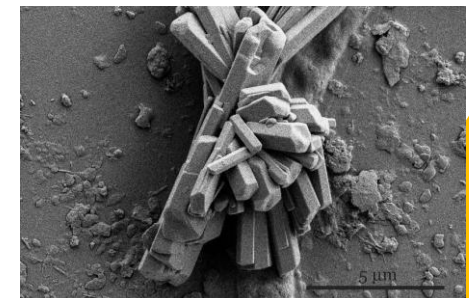
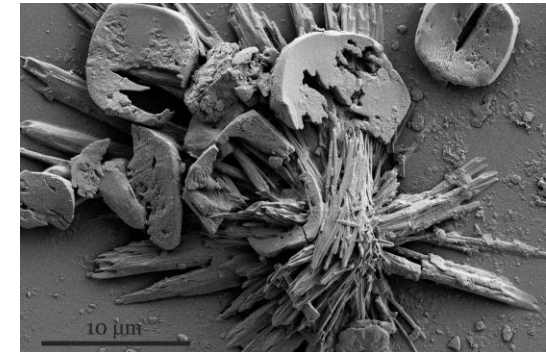
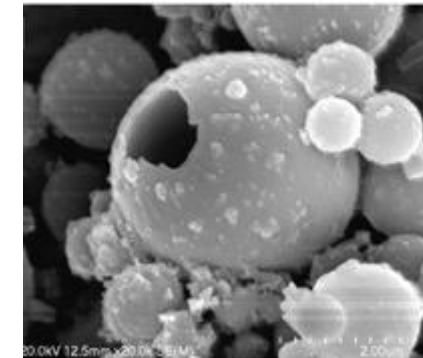
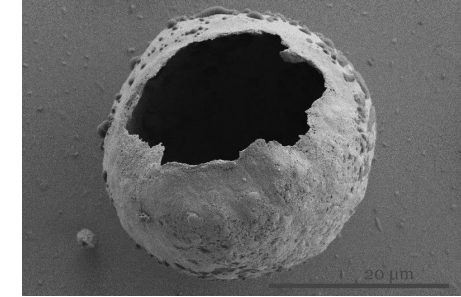


# Air Quality and Respiratory Health



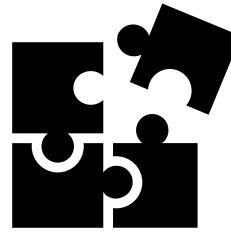
## Particulate Matter (PM):

- Particles vary widely in size, shape and chemical composition, and may contain inorganic ions, metallic compounds, elemental carbon, organic compounds, and compounds from the earth's crust.



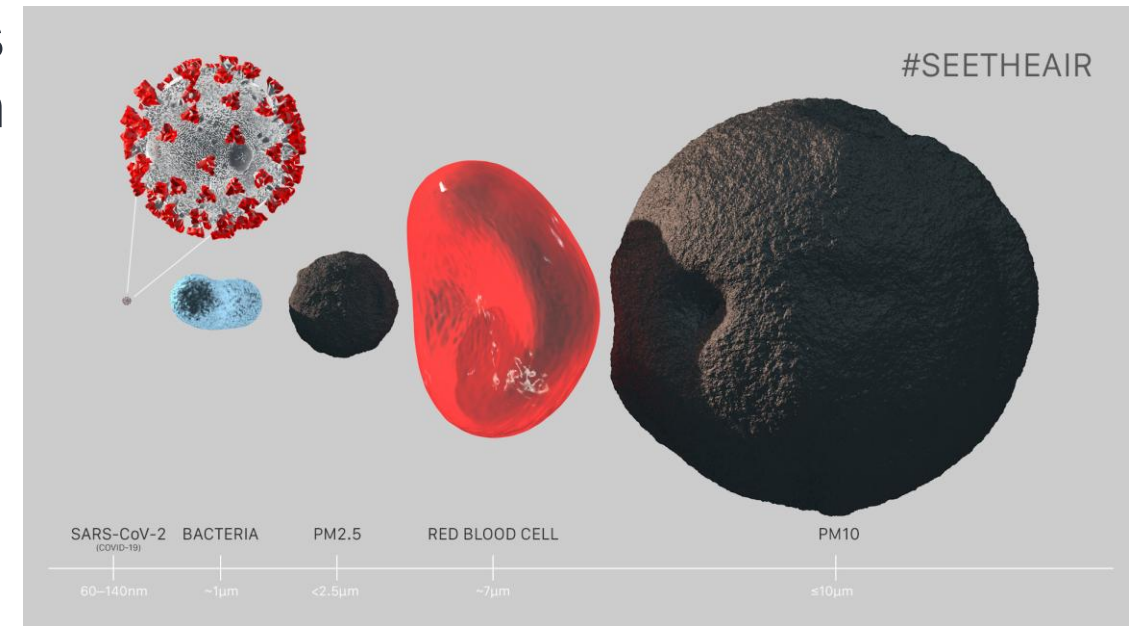


# Air Quality and Respiratory Health



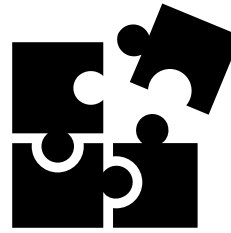
## Particulate Matter (PM):

- Those with a diameter of **10 microns** or less (PM10) are **inhalable into the lungs** and can induce adverse health effects.
- **PM10**: inhalable particles, with diameters that are generally 10 micrometers and smaller;



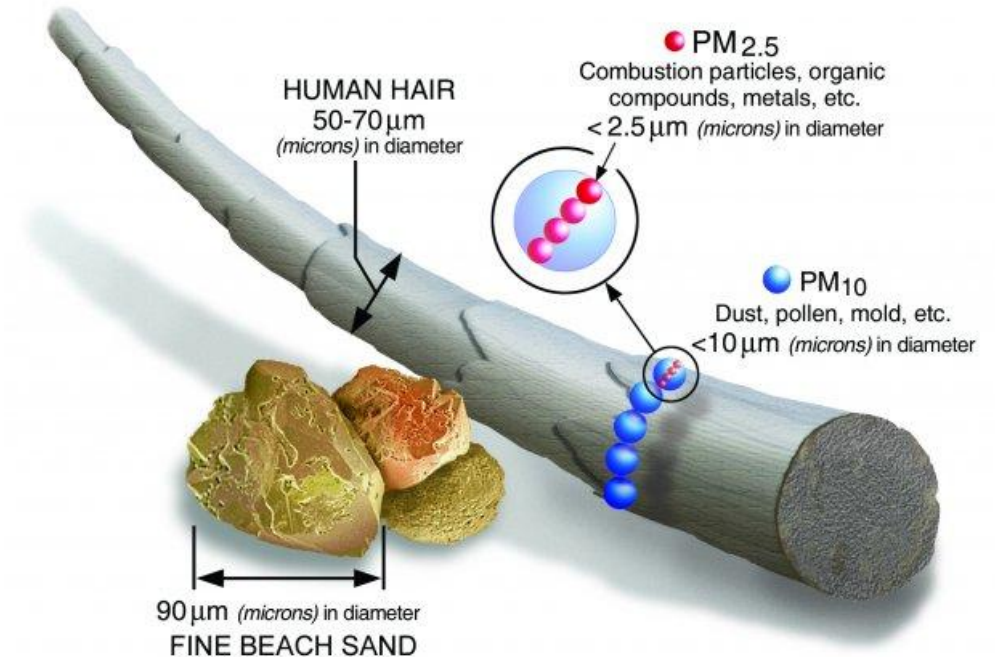


# Air Quality and Respiratory Health



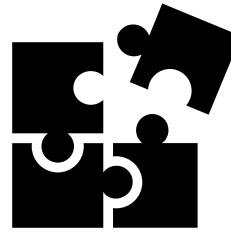
## Particulate Matter (PM):

- **PM<sub>2.5</sub>** : fine inhalable particles, with diameters that are generally **2.5 micrometers and smaller**.
- PM<sub>2.5</sub> comprises a portion of PM<sub>10</sub>.
- How small is 2.5 micrometers?
- Think about a single hair from your head. The average **human hair is about 70 micrometers** in diameter – making it **30 times larger** than the **largest fine particle**.



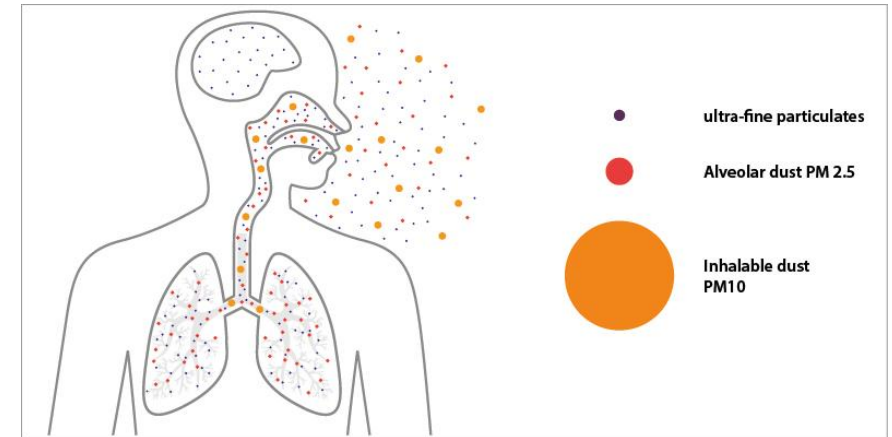
# Air Quality and Respiratory Health

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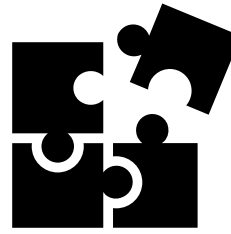


## Ultrafine particle

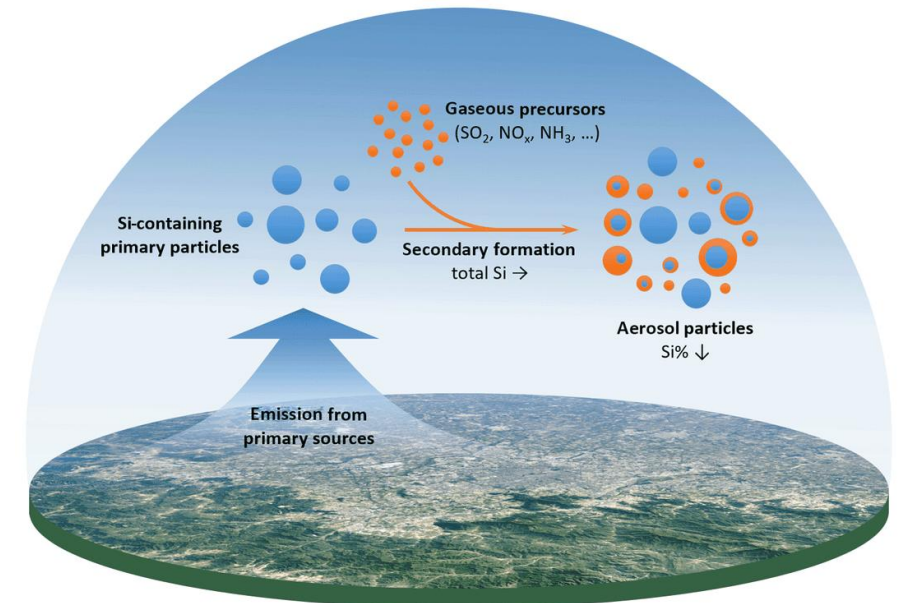
- Particles of an **aerodynamic diameter** less than or equal to **0.1  $\mu\text{m}$**  (that is, 100 nm).



# Air Quality and Respiratory Health

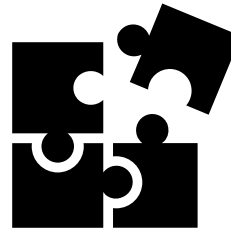


- PM may be either directly **emitted from sources** (**primary particles**)
- or **formed in the atmosphere through chemical reactions** of gases (**secondary particles**) such as **sulfur dioxide** (SO<sub>2</sub>), **nitrogen oxides** (NO<sub>x</sub>), and certain **organic compounds**.



# Air Quality and Respiratory Health

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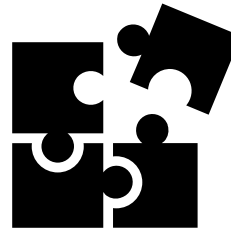


- These organic compounds can be emitted by:
  - both **natural sources**, such as trees and vegetation,
  - from **man-made (anthropogenic)** sources, such as industrial processes and motor vehicle exhaust.



# Air Quality and Respiratory Health

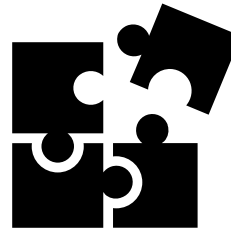
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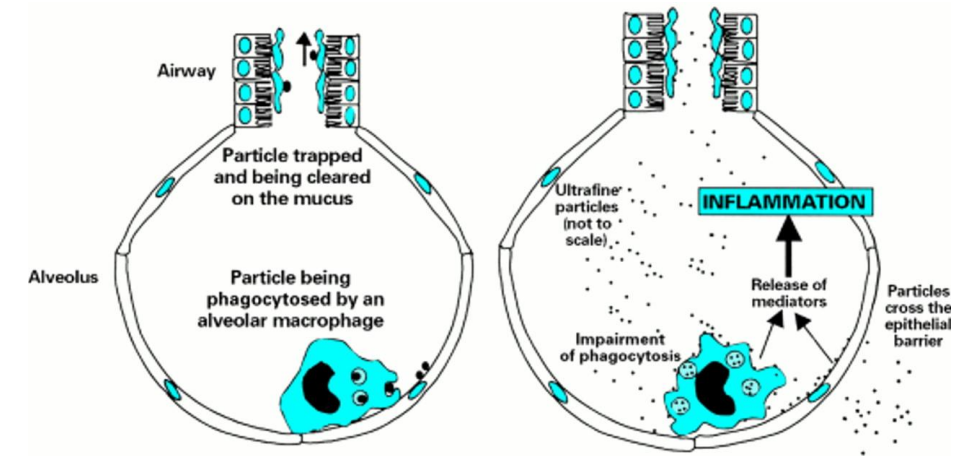
- Emissions from combustion of gasoline, oil, diesel fuel or wood produce much of the PM<sub>2.5</sub> pollution found in outdoor air, as well as a significant proportion of PM<sub>10</sub>.
- PM<sub>10</sub> also includes dust from construction sites, landfills and agriculture, wildfires and brush/waste burning, industrial sources, wind-blown dust from open lands, pollen and fragments of bacteria.



# Air Quality and Respiratory Health



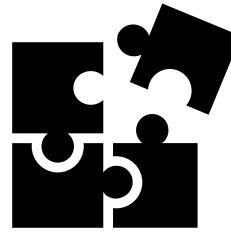
- Both **PM2.5** and **PM10** can be inhaled, with some **depositing** throughout the **airways**, though the locations of particle deposition in the lung depend on particle size.
- **PM2.5** is more likely to travel into and **deposit on the surface of the deeper parts of the lung**, while
- **PM10** is more likely to **deposit on the surfaces of the larger airways** of the **upper region of the lung**.



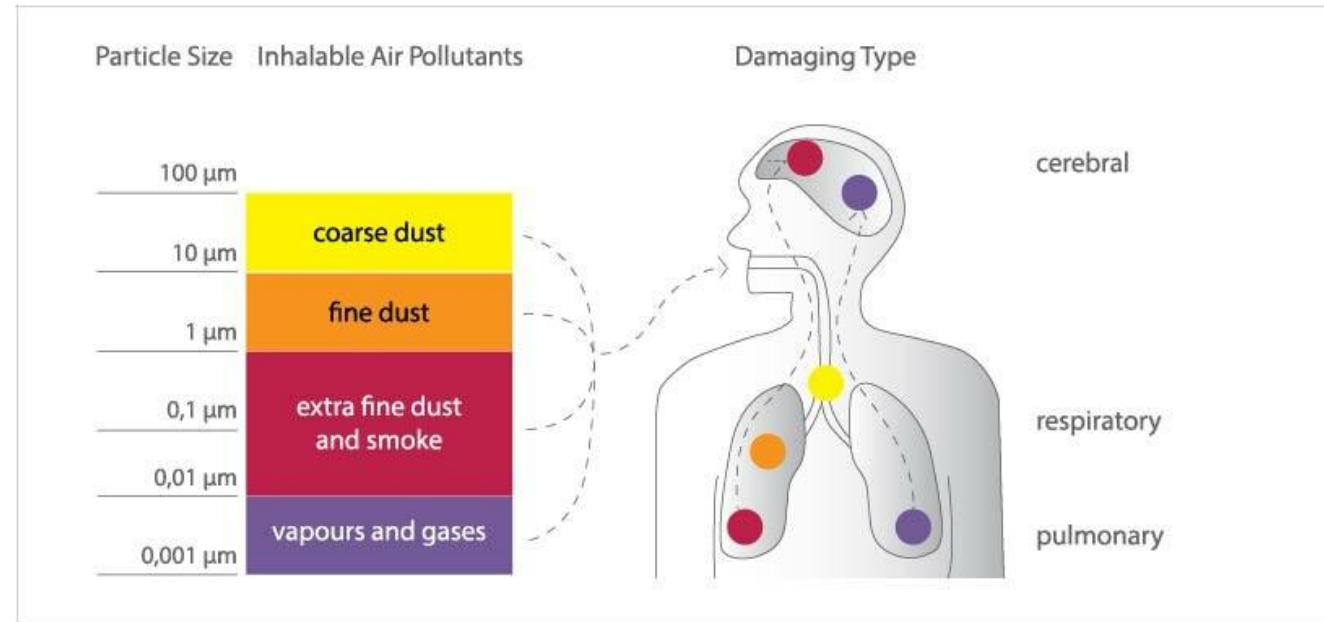
Particles deposited on the lung surface can induce **tissue damage**, and **lung inflammation**.



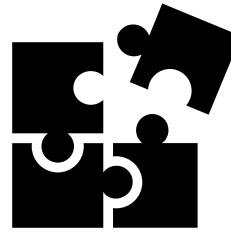
# Air Quality and Respiratory Health



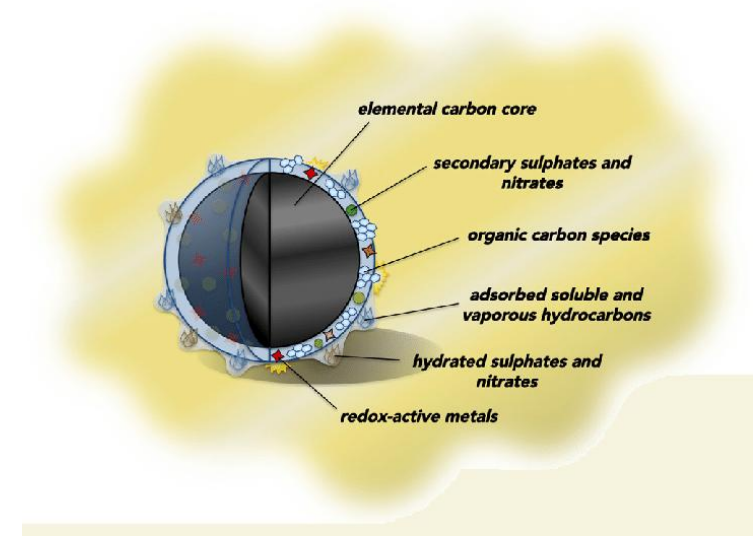
- Epidemiological and toxicological studies worldwide have suggested a strong link between exposure to fine particles and adverse health effects (e.g., respiratory disease, lung cancer, cardiovascular disease, and premature mortality).



# Air Quality and Respiratory Health

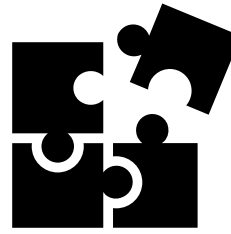


- The **World Health Organization** (WHO) established **guidelines for particulate matter** based on mass concentration of particulate matter less than  $2.5\text{ }\mu\text{m}$  (PM<sub>2.5</sub>).
- However, **health risks of PM<sub>2.5</sub> are not fully taken into account** with the PM<sub>2.5</sub> mass, and **all fine particles may not be equally toxic**.

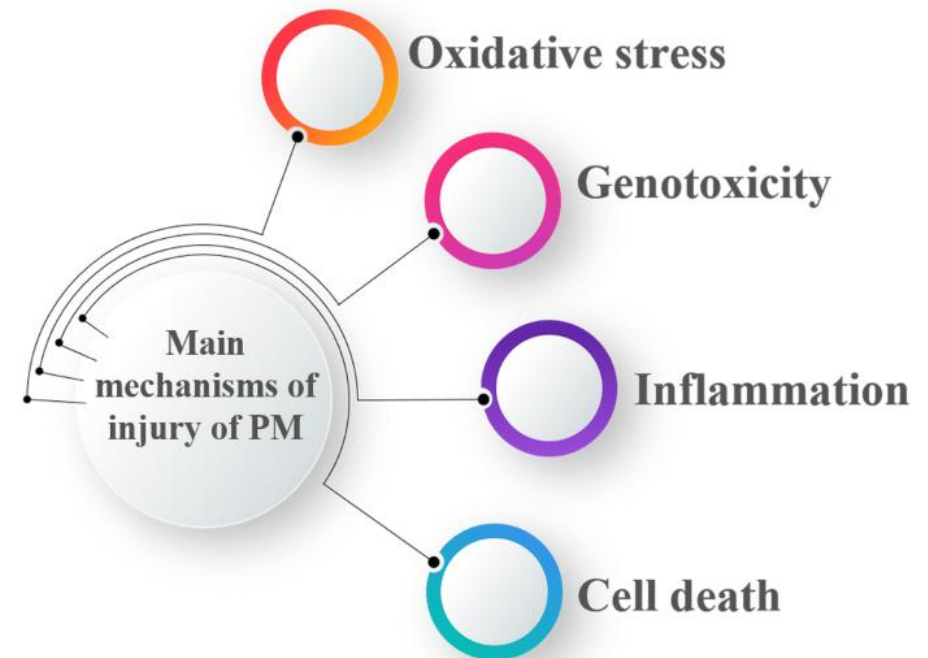


# Air Quality and Respiratory Health

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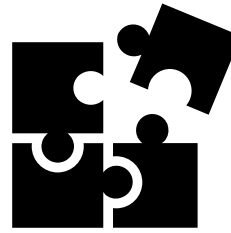


- Due to multiple sources and formation pathways, ambient PM<sub>2.5</sub> have **diverse sizes, shapes, surface charges, surface chemistry and chemical compositions**, leading to **differential health effects** among particle types.



# Air Quality and Respiratory Health

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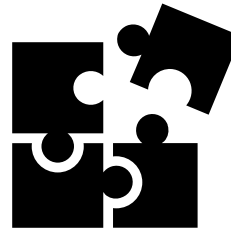


- **Short-term exposures** to PM10 have been associated primarily with worsening of **respiratory diseases, including asthma and chronic obstructive pulmonary disease (COPD)**, leading to hospitalization and emergency department visits.



# Air Quality and Respiratory Health

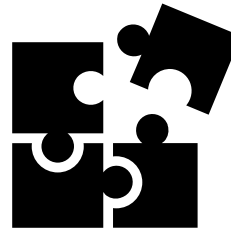
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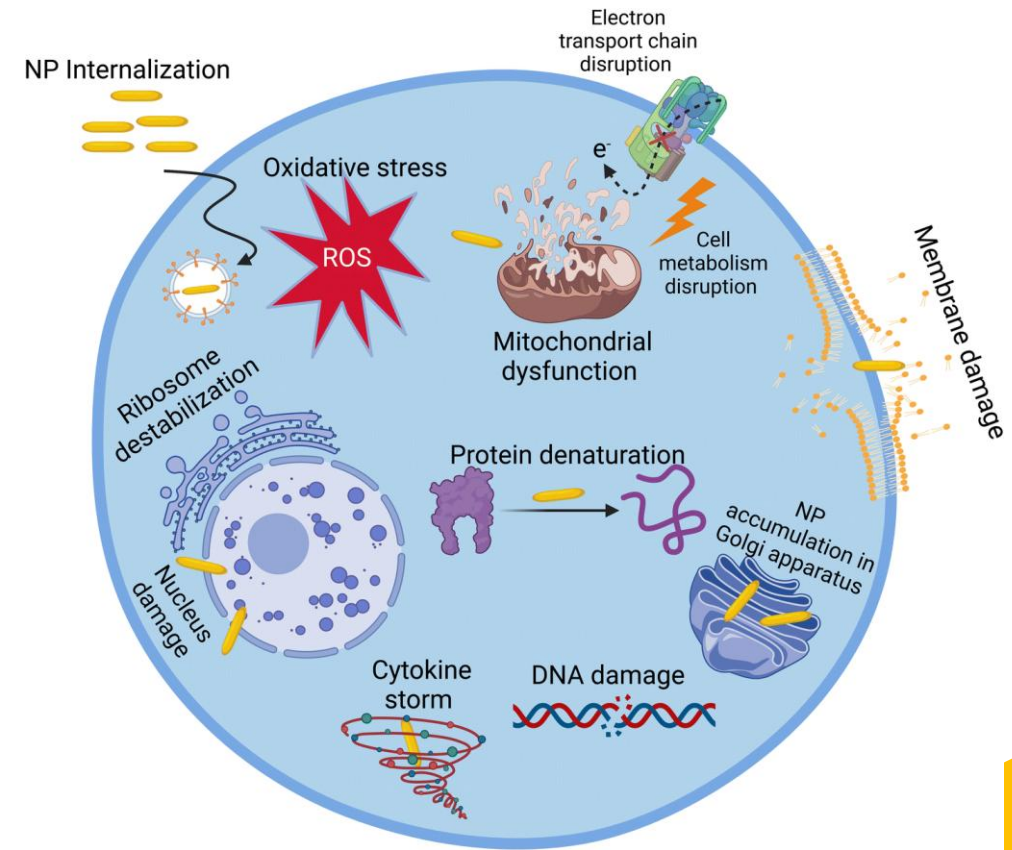
- Long-term (months to years) exposure to PM<sub>2.5</sub> has been linked to premature death, particularly in people who have chronic heart or lung diseases, and reduced lung function growth in children.
- The effects of long-term exposure to PM<sub>10</sub> are less clear, although several studies suggest a link between long-term PM<sub>10</sub> exposure and respiratory mortality.



# Air Quality and Respiratory Health



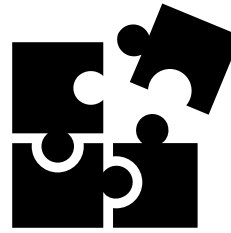
- Exposure to PM2.5 induces **oxidative stress, inflammation, and immune responses** in humans.
- **PM2.5-bound chemical components** exhibit greater **toxicity and immunotoxicological effects**





# Air Quality and Respiratory Health

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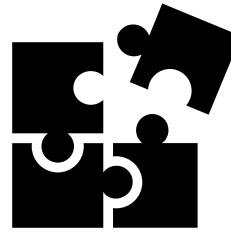


- Some of the particulate matter found **indoors originates from the outdoors**, especially PM2.5.
- These particles enter indoor spaces through doors, windows, and **“leakiness” in building structures**.
- Particles can also originate from indoor sources.



# Air Quality and Respiratory Health

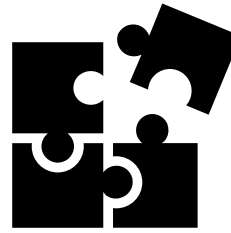
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- **Particles of indoor origin** include components derived from **biological sources**, many of which are **known allergens**, such as **pollens**, **mold spores**, **dust mites** and **cockroaches**.
- Indoor activities generate particles, as well, including **smoking tobacco**, **cooking** and **burning wood**, **candles** or **incense**.



# Air Quality and Respiratory Health

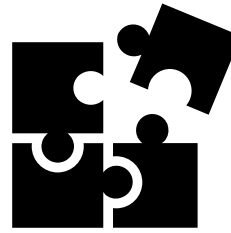


- Particles also can form indoors from complex reactions of gaseous pollutants emitted from such sources as household cleaning products and air fresheners.



# Air Quality and Respiratory Health

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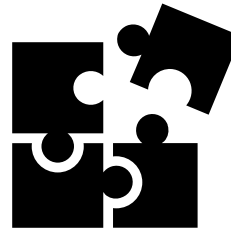


- **Atmospheric nitrogen (N<sub>2</sub>)** makes up 78% of our atmosphere.
- However, over the past 100 years, humans have converted N<sub>2</sub> into many reactive nitrogen forms, through **fertilizer and munitions manufacturing and burning of fossil fuels**.
- This has caused **unprecedented changes** to the **global nitrogen cycle**, leading to a **doubling of the flow of nitrogen compounds** around the world in the past **100 years**.

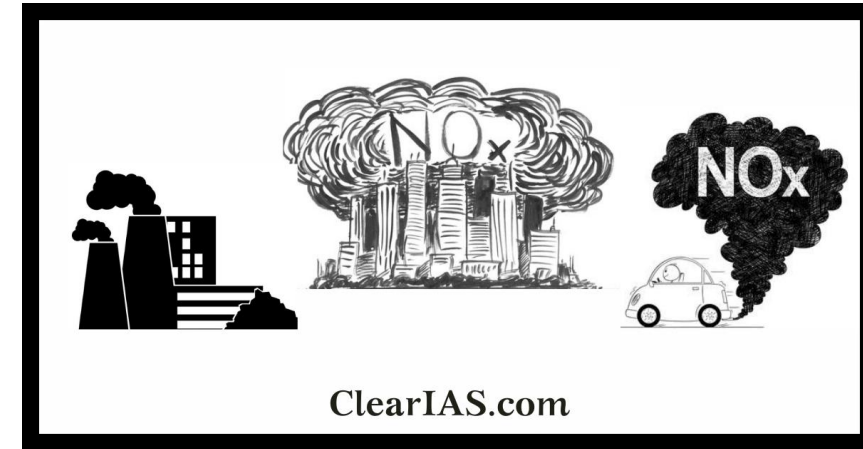


# Air Quality and Respiratory Health

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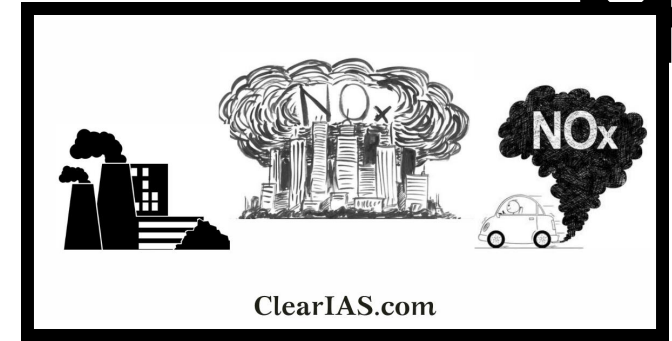


- The main nitrogen oxides are **nitric oxide (NO)** and **nitrogen dioxide (NO<sub>2</sub>)**, although there are other less common compounds.
- These compounds are **produced primarily by high-temperature combustion processes**, such as those seen in **internal combustion vehicle engines, power plants, and industrial plants.**





# Air Quality and Respiratory Health

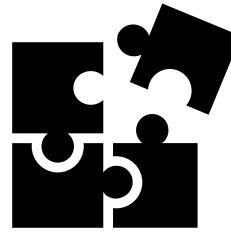


- The **main sources of nitrogen oxide** emissions are therefore:
  - road transport,
  - thermal power plants,
  - the manufacturing industry
  - **agriculture** (use of nitrogen fertilizers).

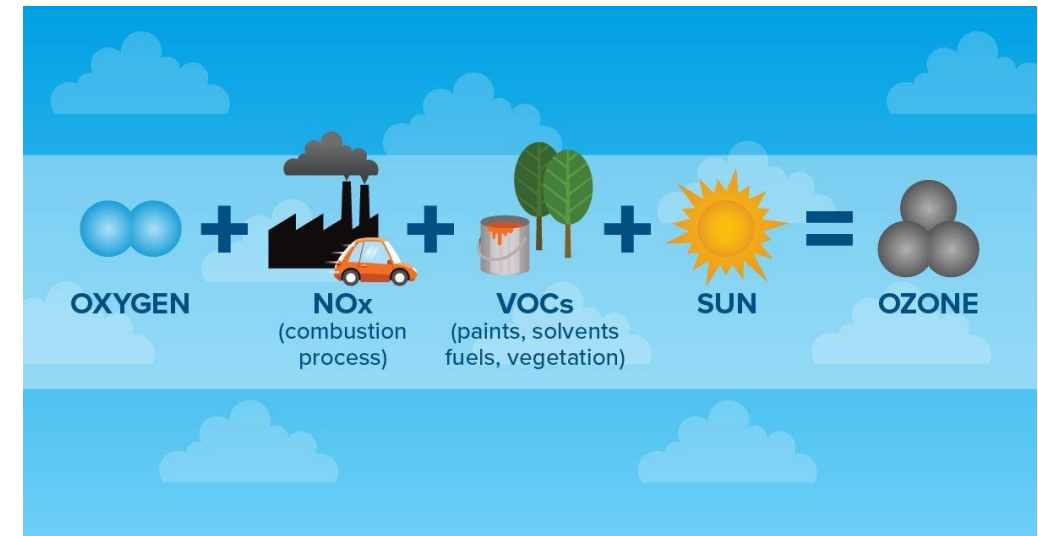




# Air Quality and Respiratory Health

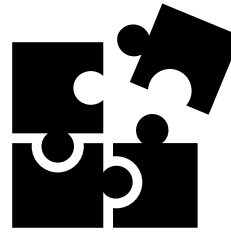


- In the presence of **sunlight**, **nitrogen oxides** **react with volatile organic compounds (VOCs)** to form **ozone**, a major air pollutant and constituent of **smog**.



# Air Quality and Respiratory Health

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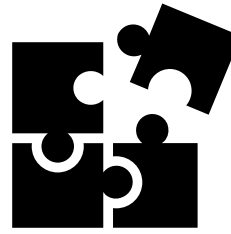


## Ozone (O<sub>3</sub>):

- Ozone is a gas composed of three atoms of oxygen.
- Ozone occurs both in the Earth's upper atmosphere and at ground level.
- Ozone at ground level is a harmful air pollutant, because of its effects on people and the environment, and it is the main ingredient in "smog."

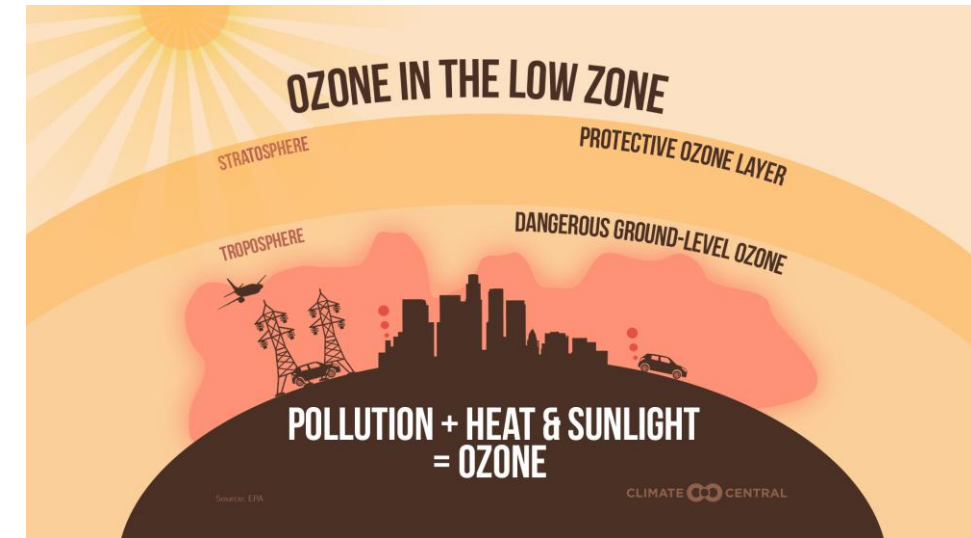


# Air Quality and Respiratory Health

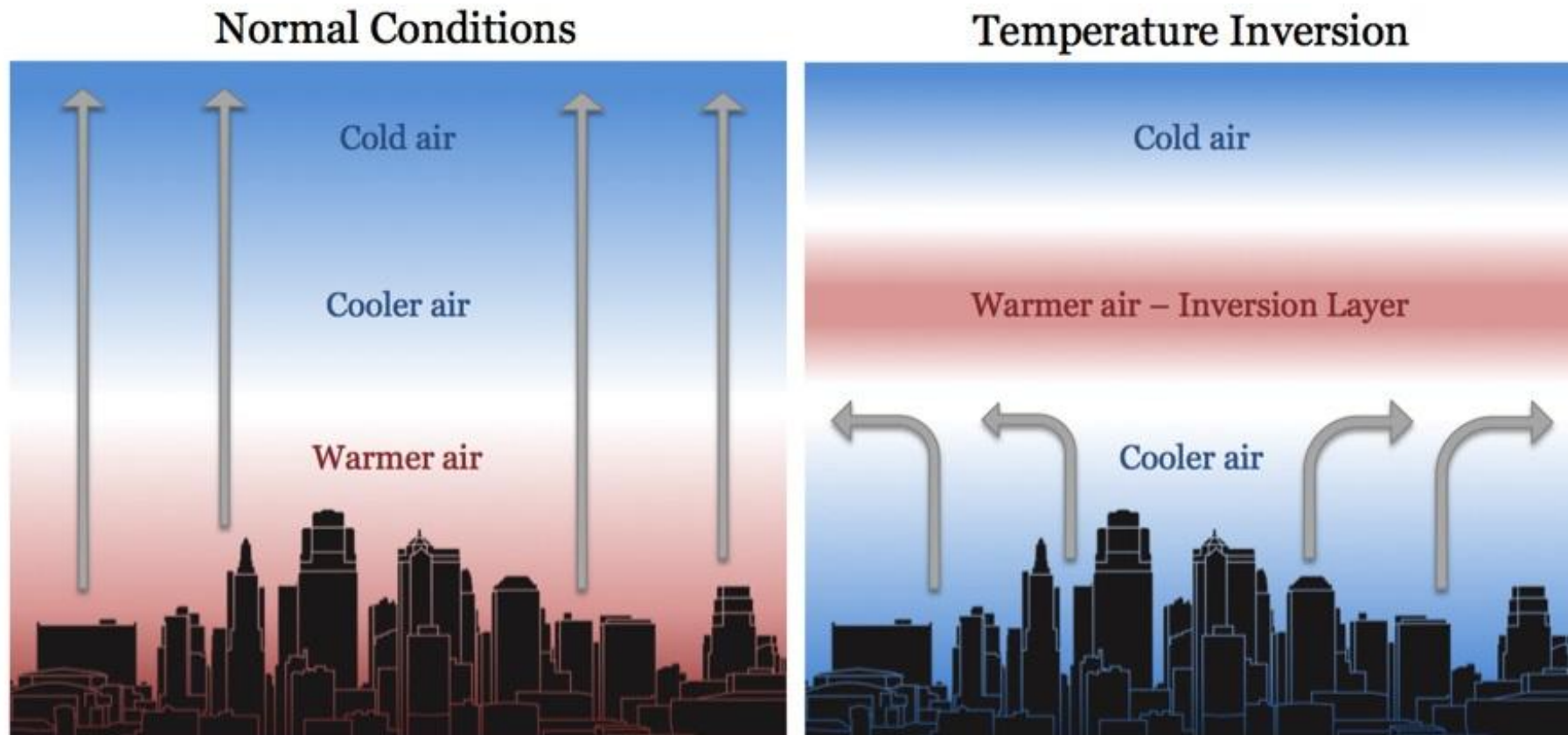
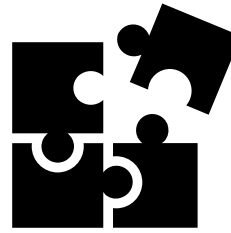


## Ozone (O<sub>3</sub>):

- Ground-level ozone forms when **nitrogen oxides and volatile organic compounds** react with each other in **sunlight and hot temperatures**.
- Ozone can **irritate the respiratory system, causing coughing, throat irritation, and exacerbating** asthma and other **respiratory conditions**.



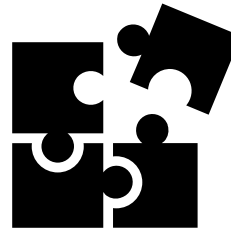
# Air Quality and Respiratory Health



Arrows show air flow in normal conditions on the left and during temperature inversion on the right. In normal conditions, warm air rises and normal convective patterns persist. During temperature inversion, the warm air acts as a cap, effectively shutting down convection and trapping smog over the city.

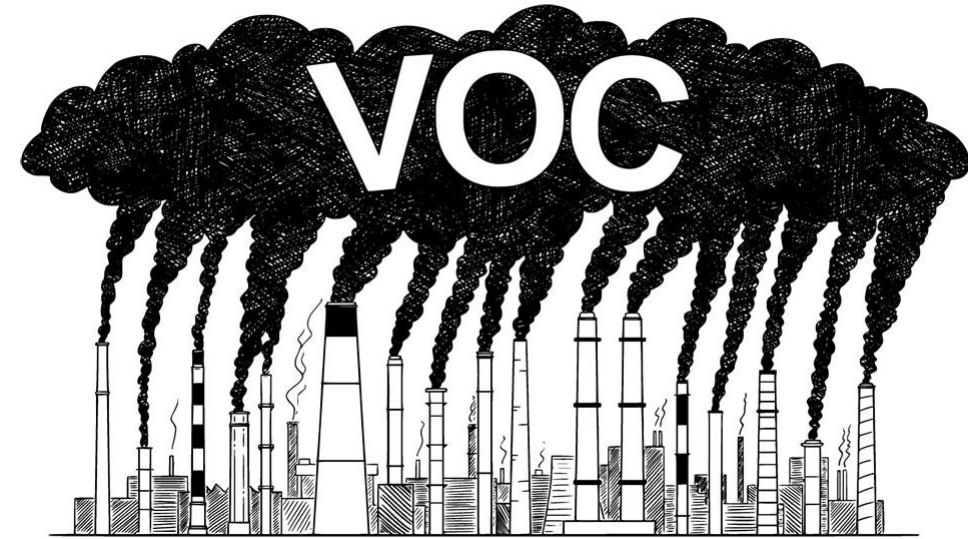
# Air Quality and Respiratory Health

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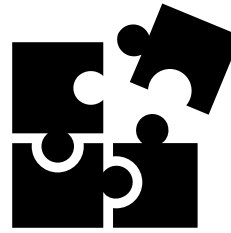
## Volatile organic compounds (VOCs):

- VOCs are emitted as **gases** from certain **solids or liquids**.
- VOCs typically are **industrial solvents**, or **by-products** produced by **chlorination** in **water treatment**, such as chloroform.
- VOCs include a variety of chemicals, some of which may have **short- and long-term adverse health effects**.





# Air Quality and Respiratory Health



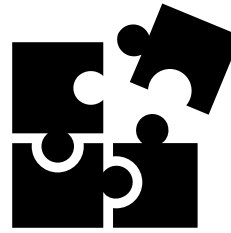
## Volatile organic compounds (VOCs):

- Volatile Organic Compounds in Commonly Used Products
- Gasoline, fuels, and solvents.
- Paints, stains, strippers, and finishes.
- Pesticides.
- Aerosol sprays.
- Cleaners and room deodorizers.
- New carpets, rugs, and wood floors



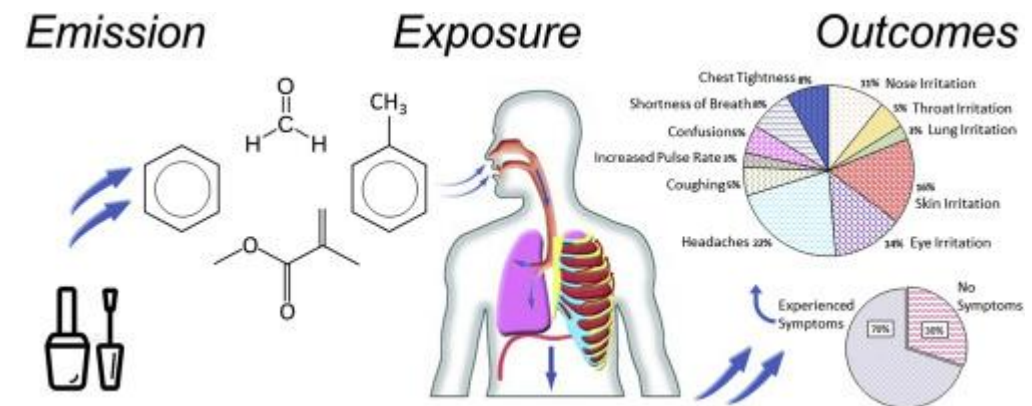


# Air Quality and Respiratory Health

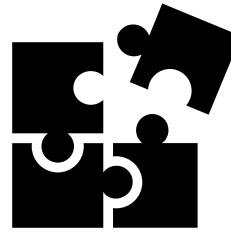


## Volatile organic compounds (VOCs):

- Short-term exposure to high levels of some VOCs can cause **headaches, dizziness, light-headedness, drowsiness, nausea, and eye and respiratory irritation.**
- These effects usually go away after the exposure stops.
- In laboratory animals, long-term exposure to high levels of some VOCs has caused **cancer** and affected the **liver, kidney and nervous system.**

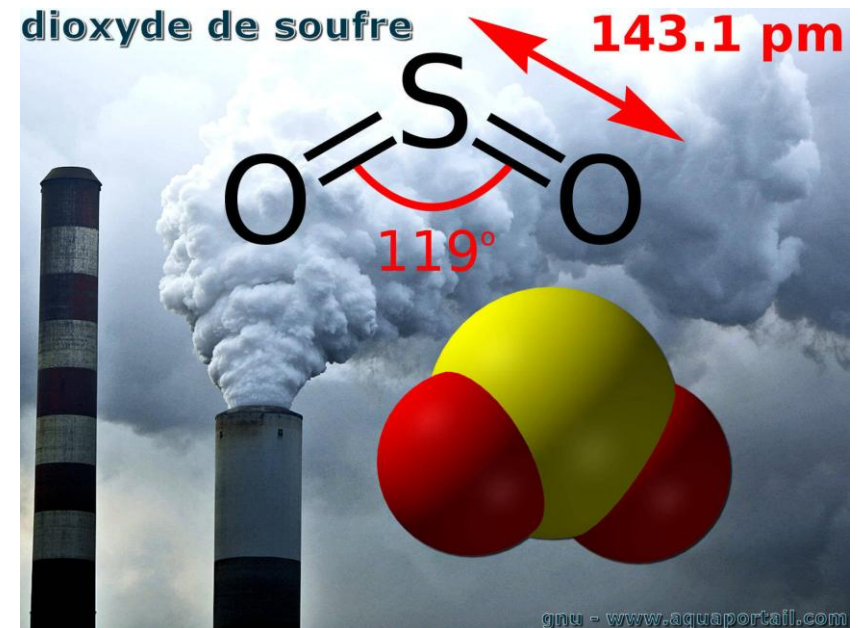


# Air Quality and Respiratory Health



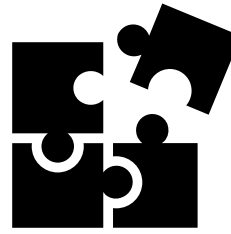
## Sulfur Dioxide (SO<sub>2</sub>):

- Sulfur dioxide is a gas by the **combustion of fossil fuels, such as coal and oil**, during which sulfur impurities in the fuels are oxidized by air oxygen O<sub>2</sub> to **sulfur dioxide** SO<sub>2</sub>.
- Inhalation of SO<sub>2</sub> can irritate the **respiratory tract, exacerbate asthma**, and increase the risk of respiratory infections.



# Air Quality and Respiratory Health

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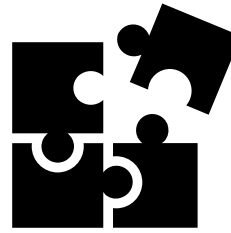
## Sulfur Dioxide (SO<sub>2</sub>):

- Coal burning is the largest synthetic source of sulfur dioxide accounting for around 50% of annual global emissions, with oil burning accounting for another 25-30%.
- Volcanoes are the most common natural source of sulfur dioxide.



# Air Quality and Respiratory Health

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**Acidification:** Sulfur dioxide can react with atmospheric moisture to form sulfuric acid, contributing to the acidification of soils and waters, which can have adverse effects on terrestrial and aquatic ecosystems.

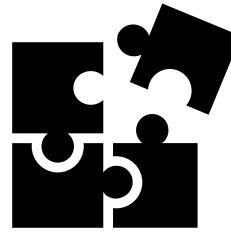
**Particulate formation:** SO<sub>2</sub> can react in the atmosphere to form fine particles, contributing to air pollution and deterioration of air quality.





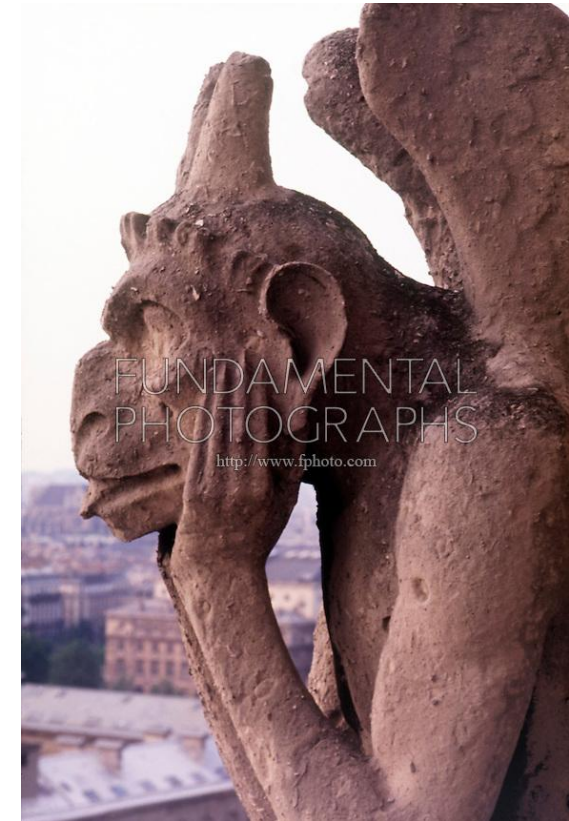
# Air Quality and Respiratory Health

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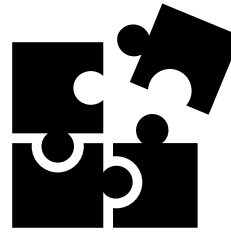
**Effect on materials:** from the acidic substances it generates (**sulfuric acid**), sulfur dioxide contributes to the **degradation processes of materials**.

The sulfuric acid formed in the presence of water reacts with the calcium contained in the particles and gives rise to gypsum crystals which play an important role in the degradation of monuments both through their mechanical and chemical action.



# Air Quality and Respiratory Health

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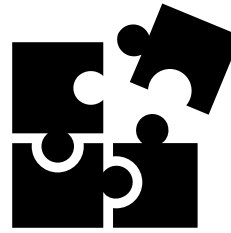
The ecological effects of acid rain are most clearly seen in **aquatic environments**, such as **streams, lakes, and marshes** where it can be **harmful to fish and other wildlife**.

As it flows through the soil, **acidic rain water can leach aluminum** from soil clay particles and then flow into streams and lakes.



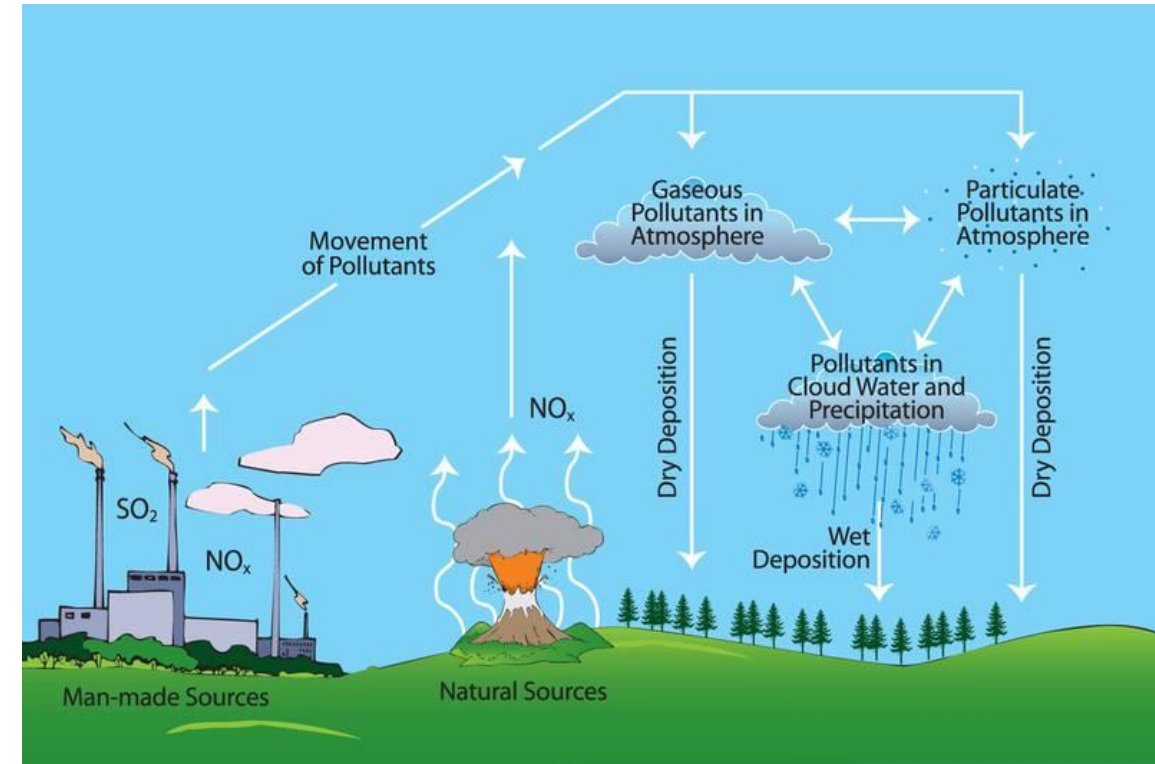


# Air Quality and Respiratory Health

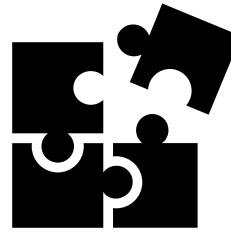


Sulphur dioxide deposition can affect vegetation around industrial discharges and in cities.

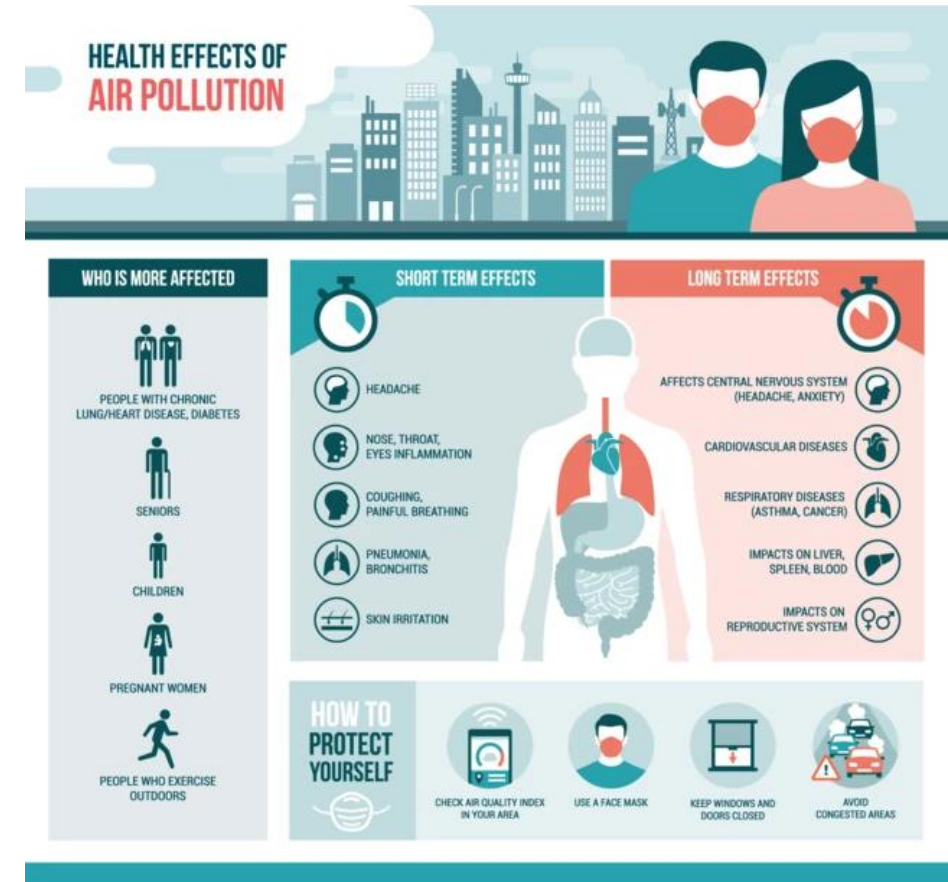
Lichens are good **bio-indicators** of pollution as they **do not like to grow where there is sulphur dioxide in the air.**

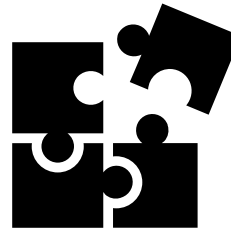


# Air Quality and Respiratory Health



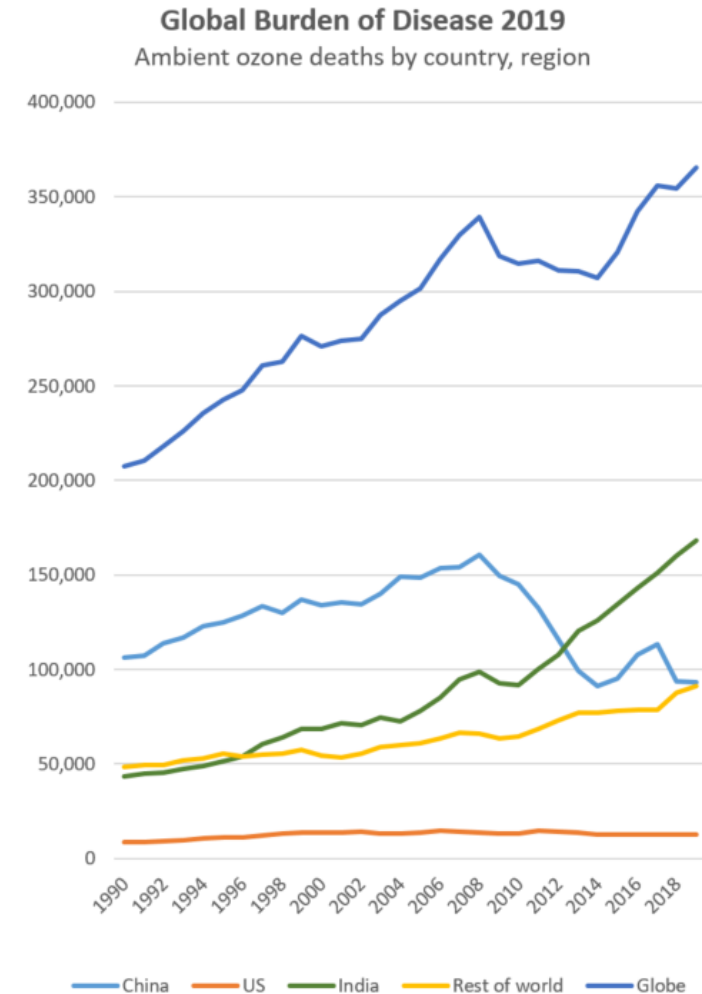
- Sulphur dioxide can cause **respiratory problems** such as **bronchitis**, and **can irritate your nose, throat and lungs**. It may cause coughing, wheezing, phlegm and asthma attacks.
- The effects are worse when you are exercising.
- Sulphur dioxide has been linked to **cardiovascular disease**.



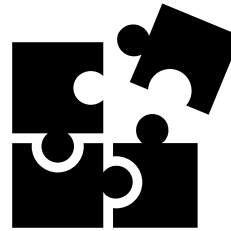


# Air Quality and Respiratory Health

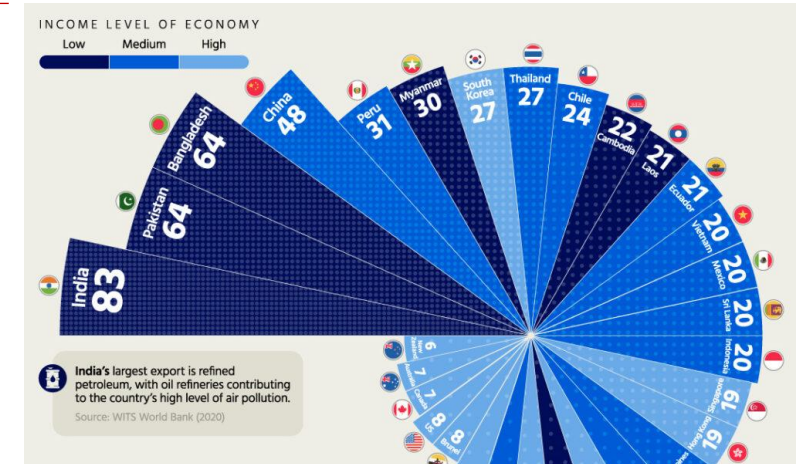
- **The disease burden** caused by **air pollution** is now considered **comparable to other major global health risks**, such as an unhealthy diet and tobacco smoking.
- Furthermore, air pollution is recognized as **one of the most significant environmental threat** to human health.



# Air Quality and Respiratory Health



- While air quality has **markedly improved in high-income countries** over this period,
- it **has generally deteriorated in most low- and middle-income** countries, in step with large-scale urbanization and economic development.





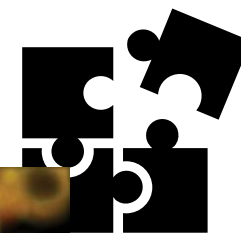
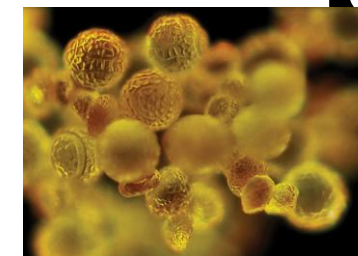
# Air Quality and Respiratory Health

Table 0.1. Recommended AQG levels and interim targets

Pollutant	Averaging time	Interim target				AQG level
		1	2	3	4	
PM <sub>2.5</sub> , µg/m <sup>3</sup>	Annual	35	25	15	10	5
	24-hour <sup>a</sup>	75	50	37.5	25	15
PM <sub>10</sub> , µg/m <sup>3</sup>	Annual	70	50	30	20	15
	24-hour <sup>a</sup>	150	100	75	50	45
O <sub>3</sub> , µg/m <sup>3</sup>	Peak season <sup>b</sup>	100	70	–	–	60
	8-hour <sup>a</sup>	160	120	–	–	100
NO <sub>2</sub> , µg/m <sup>3</sup>	Annual	40	30	20	–	10
	24-hour <sup>a</sup>	120	50	–	–	25
SO <sub>2</sub> , µg/m <sup>3</sup>	24-hour <sup>a</sup>	125	50	–	–	40
CO, mg/m <sup>3</sup>	24-hour <sup>a</sup>	7	–	–	–	4

<sup>a</sup> 99th percentile (i.e. 3–4 exceedance days per year).

<sup>b</sup> Average of daily maximum 8-hour mean O<sub>3</sub> concentration in the six consecutive months with the highest six-month running-average O<sub>3</sub> concentration.



"AQG" stands **for "Air Quality Guidelines."**

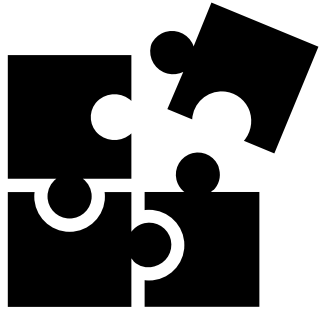
World Health  
Organization (WHO)

Consecutive interim targets" refers to specific goals or objectives set to be achieved sequentially or successively over a period of time.

Meeting these **guidelines helps ensure that air quality is maintained at levels that minimize adverse health effects** on populations exposed to air pollution.

# The Clean Air Act

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- **Landmark legislations** that have reshaped industries
- 1990 **Clean Air Act Amendments**, which introduced Title VI focusing on **stratospheric ozone protection**
- A direct response to the growing scientific consensus on the detrimental impact of **ozone-depleting substances** (*chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)*).

## The Clean Air Act of 1963

