

Kingdom of Saudi Arabia

Ministry of Education

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Physics



Type Of Air pollution

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Introduction

Air pollution is considered the world's most significant environmental threat to human health and one of the leading preventable causes of illness and premature death. According to the World Health Organization (WHO), both outdoor (ambient) and indoor air pollution are responsible for nearly seven million premature deaths each year—surpassing the combined global deaths from malaria, tuberculosis, and AIDS. Approximately 4.2 million people die annually due to outdoor air pollution alone, mainly from heart disease, stroke, chronic obstructive pulmonary disease (COPD), lung cancer, and respiratory infections. Women, children, and the elderly in developing countries are especially vulnerable.

The issue of air pollution began with the Industrial Revolution, when industrial expansion relied heavily on fossil fuels such as coal and oil. Burning these fuels released large quantities of harmful gases and particulate matter into the atmosphere. With rapid urbanization and technological advancement throughout the twentieth century, air pollutants have evolved into a global environmental challenge, contributing to major problems such as global warming, acid rain, and depletion of the ozone layer.

Air pollutants differ in their sources, chemical composition, and physical properties, but they are generally categorized into gaseous pollutants and particulate matter. Their danger lies in their ability to spread rapidly, resist control, and cause direct harm to both human health and ecological systems.

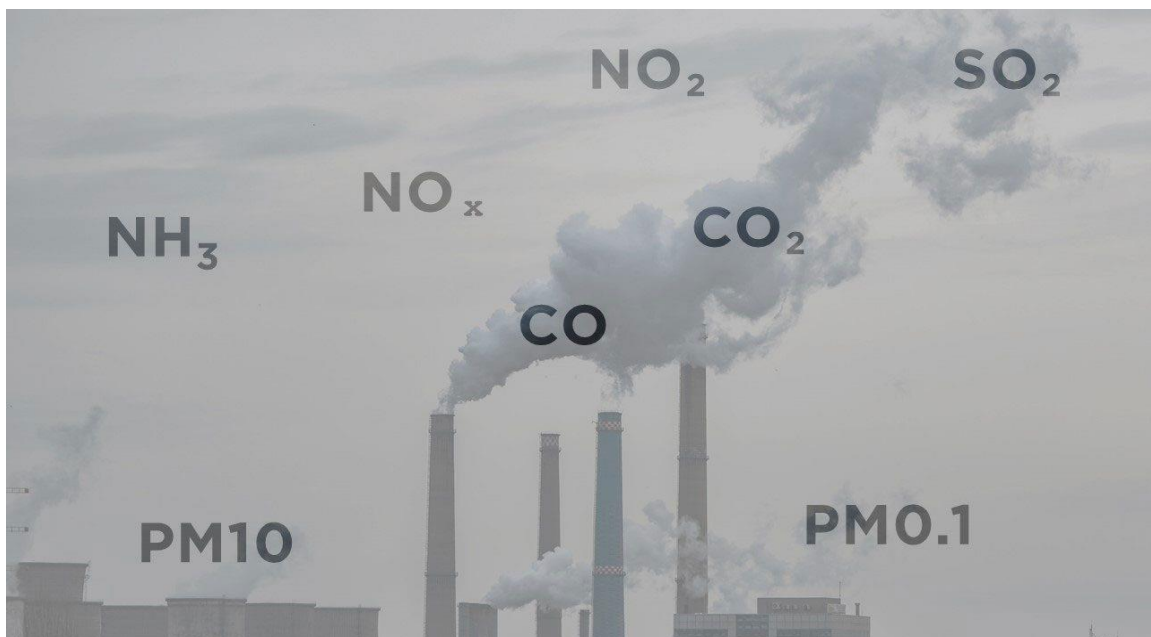


Figure 1. picture of air pollution sources. MANN+HUMMEL. (n.d.). *Air Pollutants: Types, Sources, and Impact*. Retrieved from <https://www.mann-hummel.com/en/insights/air-pollutants-typesources-impact.html>.retrieved at November '12 '2025

Types of Air Pollutants

Air pollutants are typically categorized into two major groups: **primary pollutants** and **secondary pollutants**.

Primary pollutants are substances emitted directly into the atmosphere from clearly identifiable sources. These sources may be **natural**, such as volcanic eruptions, wildfires, and dust storms, or **human-made**, including industrial processes, vehicle exhaust emissions, and the combustion of fossil fuels.

In contrast, **secondary pollutants** are not emitted in their final harmful form. Instead, they develop in the atmosphere when primary pollutants react with other atmospheric components—often influenced by sunlight, oxygen, or moisture—forming new, more hazardous pollutants.

Primary Pollutants

1. Carbon Oxides (CO and CO₂)

Carbon oxides are mainly produced by the burning of fossil fuels such as coal, oil, and natural gas.

- **Carbon monoxide (CO)** is a colorless, odorless, and extremely toxic gas that disrupts the body's ability to transport oxygen, potentially leading to severe health complications and even death at high exposure levels.
- **Carbon dioxide (CO₂)** is a major greenhouse gas responsible for trapping heat in the atmosphere, significantly contributing to global warming and climate change.

2. Nitrogen Oxides (NO_x)

Nitrogen oxides—including nitric oxide (NO) and nitrogen dioxide (NO₂)—form under high-temperature conditions when nitrogen and oxygen interact, particularly in vehicle engines, power plants, and industrial furnaces.

These gases are key precursors in the formation of **photochemical smog** and **acid rain**, and they irritate the respiratory system, resulting in inflammation and reduced lung function.

3. Sulfur Oxides (SO_x)

Sulfur oxides, mainly sulfur dioxide (SO₂), are generated when sulfur-rich fuels such as coal and oil are burned.

After entering the atmosphere, these gases may react with moisture to produce **sulfuric acid (H₂SO₄)**, leading to **acid rain**, which harms vegetation, corrodes buildings, and alters the chemical balance of soil and water bodies.

4. Toxic Heavy Metals (Lead and Mercury)

Heavy metals like **lead (Pb)** and **mercury (Hg)** are released through industrial activities, metal smelting operations, and coal-fired power plants.

- **Lead** exposure is especially dangerous for children, as it affects the nervous system and can impair cognitive and developmental processes.
- **Mercury**, often emitted from industrial smokestacks, accumulates in the food chain and can cause severe neurological and reproductive disorders in humans and wildlife.

5. Volatile Organic Compounds (VOCs)

VOCs are a diverse group of carbon-based chemicals that evaporate easily into the atmosphere. Examples include methane (CH₄), benzene, and formaldehyde.

They originate from fuel combustion, industrial solvents, paints, cleaning agents, and agricultural activities. Livestock farming, for example, emits large quantities of methane—a powerful greenhouse gas.

VOCs contribute significantly to the formation of **ground-level ozone** and **photochemical smog**, posing risks to human health and deteriorating air quality.

6. Particulate Matter (PM)

Particulate matter consists of extremely small solid or liquid particles suspended in the air, including dust, ash, soot, smoke, and organic residues.

The most hazardous types are **PM₁₀** (particles smaller than 10 micrometers) and **PM_{2.5}** (particles smaller than 2.5 micrometers). Due to their microscopic size, these particles can penetrate deep into the respiratory system and even enter the bloodstream, leading to serious respiratory and cardiovascular diseases.

Examples of primary air pollutants:

Carbon monoxide (CO) is produced by the incomplete combustion of carbon containing fuels such as wood, gasoline, and coal, particularly in motor vehicles and heating appliances like stoves.

Sulfur dioxide (SO₂) is predominantly generated in industrial processes and electricity production, arising from the combustion of fossil fuels that contain sulfur. Particulate matter (PM) serves as a key indicator for air pollution, encompassing various tiny particles, including those resulting from brake and tire wear, among other pollutants.

2. Secondary Pollutants

Secondary pollutants form when primary pollutants react chemically in the atmosphere. These reactions often occur under sunlight, leading to the formation of new and more complex substances that can be even more harmful than their original components. One of the most well-known examples is photochemical smog, a brownish haze often observed over large cities, especially during sunny and dry weather conditions.

Photochemical smog results from the reaction between nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight, producing ozone (O₃) as a major component.

While ozone in the stratosphere is beneficial because it protects the Earth from harmful ultraviolet (UV) radiation, ground-level ozone is a dangerous pollutant. It can cause eye irritation, coughing, throat inflammation, and lung damage, and it also harms crops and natural vegetation. Other examples of secondary pollutants include acid rain, peroxyacetyl nitrate (PAN), and secondary particulate matter, all of which have wideranging effects on human health, ecosystems, and infrastructure.

Examples of secondary air pollutants:

Ground-level ozone (O₃) is created in the atmosphere through the reaction of nitrogen oxides (NO_x) and volatile organic compounds (VOCs) under the influence of strong sunlight.

Nitrogen dioxide (NO₂) forms when nitrogen and oxygen gases react, typically during high-temperature combustion processes, such as those found in automobile engines and industrial operations. Acid rain results from the chemical reaction between sulfur dioxide (SO₂) or nitrogen oxides (NO_x) and water in the atmosphere, leading to precipitation that is acidic in nature. This acidification of rain is especially damaging to plant life and trees.

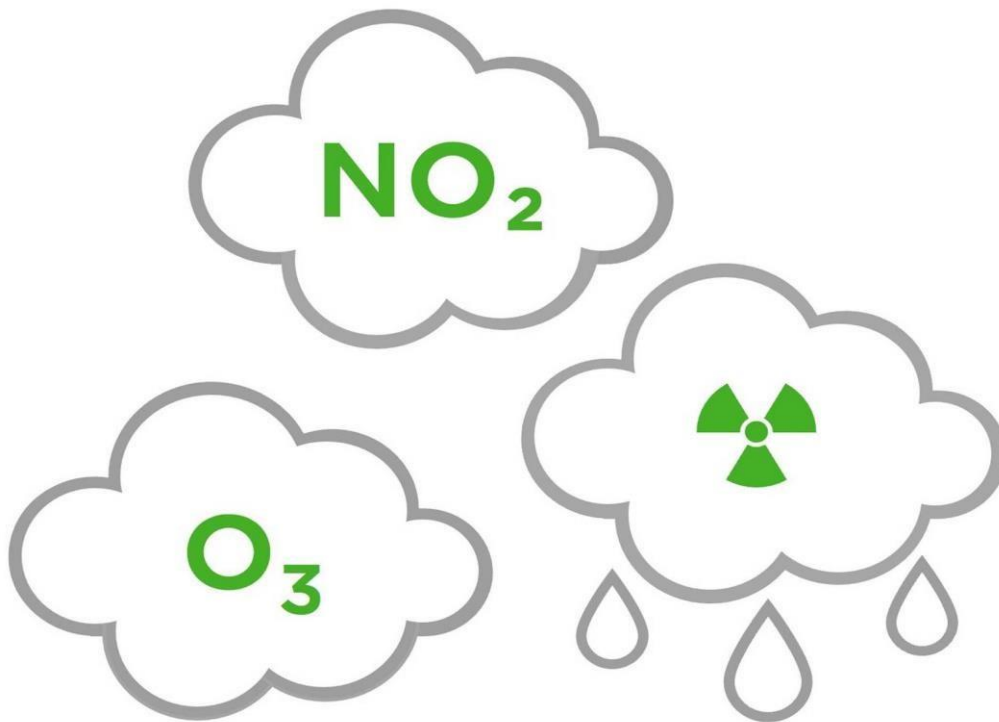


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Other air pollutants:

Polycyclic aromatic hydrocarbons (PAHs) are generated from the incomplete burning of organic materials and substances. Ammonia (NH₃) is a noxious gas primarily found in agricultural fertilizers. When released, it reacts with other air pollutants to create particulate matter.

Nitrogen oxides (NO_x) emerge from the combustion of fuels, wood, oil, and other materials, occurring in engines or combustion facilities.

Formaldehyde is another pollutant generated during the combustion of organic materials, including wood, similar to polycyclic aromatic hydrocarbons (PAHs).

Radon is a pollutant resulting from the natural radioactive decay of uranium found in soils and rocks.

Conclusion

Air pollution, with its complex mixture of particulates and gaseous pollutants, poses one of the most pressing challenges of our time. The health and ecological effects of pollutants such as sulfur oxides, nitrogen oxides, carbon monoxide, and fine particulate matter highlight the urgent need for global action.

Mitigation requires adopting clean energy technologies, improving fuel efficiency, enforcing strict emission regulations, and expanding green spaces to naturally absorb pollutants.

Protecting the purity of our air means safeguarding life itself — for the atmosphere is not an infinite resource, but a fragile shield upon which all living beings depend.

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