

APPLIED CHEMISTRY AND ENVIRONMENTAL SCIENCE

UNIT-1: Air and Noise Pollution

Definition of Pollution and Pollutant

1. Pollution:

Pollution is the **undesirable change in the physical, chemical, or biological characteristics of the environment** caused by harmful substances or activities, which adversely affects living organisms and the environment.

2. Pollutant:

A pollutant is any **substance or agent that causes pollution** and produces harmful or undesirable changes in the environment.

Examples of pollutants: Smoke, dust, sewage, plastics, pesticides, harmful gases, industrial waste, and excessive noise.

Classification of Pollutants

Pollutants are mainly classified into **Primary Pollutants** and **Secondary Pollutants** based on how they are formed.

1. Primary Pollutants

Definition:

Primary pollutants are pollutants that are **released directly into the environment from a source** in harmful or undesirable form.

Examples:

- Carbon monoxide (CO) – from automobile exhaust
- Sulphur dioxide (SO₂) – from burning coal and petroleum
- Nitrogen oxides (NO_x) – from vehicles and industries
- Smoke and dust – from industries and construction
- Particulate matter (PM) – from combustion and industrial activities

Example:

Coal burning → SO₂ released directly into the atmosphere

2. Secondary Pollutants

Definition:

Secondary pollutants are pollutants that are **not emitted directly** but are **formed in the environment by chemical reactions** between primary pollutants and other substances, often in the presence of sunlight.

Examples:

- Ozone (O₃) at ground level
- Peroxyacetyl nitrate (PAN)
- Sulphuric acid (H₂SO₄)
- Nitric acid (HNO₃)
- Photochemical smog

Example:

NO_x + hydrocarbons + sunlight → **Photochemical smog and ground-level ozone**

Difference Between Primary and Secondary Pollutants

Primary Pollutants	Secondary Pollutants
Emitted directly from a source.	Formed by chemical reactions in the environment.
Present in the emitted form.	Usually not present in the original emission.
Examples: CO, SO ₂ , NO _x , smoke, dust.	Examples: O ₃ , PAN, H ₂ SO ₄ , HNO ₃ .
Mainly produced by combustion, industries and vehicles.	Formed from reactions involving primary pollutants.

Natural and Man-Made Sources of Air Pollution

Air pollution can be caused by both **natural sources** and **man-made (anthropogenic) sources**.

1. Natural Sources

Natural sources are sources of air pollution that occur **naturally without direct human activity**.

Major natural sources:

1. **Volcanic eruptions** – release ash, smoke, SO₂ and other gases.
2. **Forest fires** – produce smoke, carbon monoxide and particulate matter.
3. **Dust storms** – release large quantities of dust and suspended particles.
4. **Sea spray** – adds salt particles and aerosols to the atmosphere.
5. **Pollen and spores** – released by plants and may cause allergies.
6. **Decomposition of organic matter** – releases gases such as methane (CH₄) and hydrogen sulphide (H₂S).
7. **Lightning** – produces nitrogen oxides (NO_x).
8. **Natural radioactive gases** – radon may be released from soil and rocks.

2. Man-Made Sources

Man-made sources are sources of air pollution that result from **human activities**.

Major man-made sources:

1. **Industries and factories** – release smoke, dust, SO₂, NO_x and other pollutants.
2. **Automobiles** – emit CO, NO_x, hydrocarbons and particulate matter.

3. **Thermal power plants** – burning coal produces smoke, fly ash and SO₂.
4. **Mining activities** – generate dust and particulate matter during drilling, blasting and transportation.
5. **Construction activities** – produce dust and suspended particles.
6. **Burning of waste** – releases smoke, toxic gases and particulate matter.
7. **Agricultural activities** – fertilizers, pesticides and crop-residue burning contribute to air pollution.
8. **Domestic fuel burning** – burning coal, wood, kerosene and other fuels produces smoke and harmful gases.

Difference at a Glance

Natural Sources	Man-Made Sources
Occur naturally.	Result from human activities.
Generally difficult to control.	Can be reduced through proper control measures.
Examples: volcanoes, forest fires, dust storms.	Examples: industries, vehicles, power plants, mining.

Air Pollutants: Types

Air pollutants are harmful substances present in the atmosphere in concentrations that may adversely affect **human health, plants, animals, property, or the environment.**

Air pollutants are broadly classified into:

1. **Particulate Pollutants**
2. **Gaseous Pollutants**

Particulate Pollutants

Definition

Particulate pollutants are very small **solid or liquid particles suspended in the air.** They may remain suspended in the atmosphere for a considerable period and can enter the human respiratory system.

Examples

- Dust
- Smoke
- Soot
- Fly ash
- Fumes
- Mist
- Aerosols
- Pollen
- Ash particles

Sources of Particulate Pollutants

1. **Industries** – cement, steel, mining and chemical industries.
2. **Thermal power plants** – release fly ash and fine particles.
3. **Automobiles** – produce smoke and fine particles.
4. **Mining and quarrying** – drilling, blasting and material handling generate dust.
5. **Construction activities** – produce large amounts of dust.
6. **Road traffic** – causes resuspension of road dust.
7. **Burning of coal, wood and waste** – produces smoke and soot.
8. **Agricultural activities** – ploughing and crop-residue burning generate particles.

Effects of Particulate Pollutants

- Cause **respiratory problems**.
- Reduce visibility and may contribute to **smog**.
- Fine particles can penetrate deep into the lungs.
- Cause irritation of the **eyes, nose and throat**.
- Settle on buildings, machinery and vegetation.
- Reduce the efficiency of industrial equipment.
- May affect plant growth by depositing on leaves.

Particulate Matter (PM) refers to a mixture of **very small solid particles and liquid droplets suspended in the air**. PM is one of the most important air pollutants because smaller particles can penetrate deeper into the respiratory system.

1. Classification of PM Based on Particle Size

The **number after PM** indicates the **approximate maximum aerodynamic diameter of the particles in micrometres (μm)**.

Type	Particle size	Description
PM₁₀	$\leq 10 \mu\text{m}$	Inhalable particles; can enter the nose and upper respiratory tract
PM_{2.5}	$\leq 2.5 \mu\text{m}$	Fine particles; can penetrate deep into the lungs
PM₁	$\leq 1 \mu\text{m}$	Very fine particles
PM_{0.1}	$\leq 0.1 \mu\text{m}$	Ultrafine particles

2. PM₁₀

PM₁₀ = Particulate Matter with aerodynamic diameter $\leq 10 \mu\text{m}$.

Sources include:

- Road and construction dust
- Mining activities
- Crushing and grinding
- Cement industries
- Fly ash
- Vehicle emissions

PM₁₀ can be inhaled and can cause irritation and respiratory problems.

3. PM_{2.5}

PM_{2.5} = Particulate Matter with aerodynamic diameter $\leq 2.5 \mu\text{m}$.

These are called **fine particulate matter**.

Major sources:

- Diesel and petrol combustion
- Coal combustion
- Industrial processes
- Biomass and waste burning
- Secondary formation from gaseous pollutants

Because of their small size, PM_{2.5} can penetrate **deep into the lungs**.

4. PM₁

PM₁ = particles with aerodynamic diameter $\leq 1 \mu\text{m}$.

They are smaller than PM_{2.5} and can penetrate further into the respiratory system.

5. PM_{0.1}

PM_{0.1} = particles with aerodynamic diameter $\leq 0.1 \mu\text{m}$.

These are known as **ultrafine particles (UFPs)**.

They are mainly produced by:

- Combustion processes
- Vehicle engines
- Industrial combustion
- High-temperature processes

Effects and Control of Particulate Air Pollution

Particulate matter such as **dust, smoke, soot, fly ash and fumes** can adversely affect human health, vegetation, buildings and the environment. Industrial particulate emissions can be controlled using devices such as **cyclone separators, bag filters and electrostatic precipitators (ESP)**.

1. Effects of Particulate Pollutants

A. Effects on Human Health

1. **Respiratory problems** – Dust and fine particles can irritate the respiratory tract.
2. **Coughing and breathing difficulty** – Exposure to high concentrations can cause irritation.
3. **Reduced lung function** – Long-term exposure to fine particulate matter may affect lung function.
4. **Cardiovascular effects** – Fine particles such as $PM_{2.5}$ are associated with cardiovascular health risks.
5. **Eye, nose and throat irritation** – Suspended particles can cause irritation.
6. **Occupational diseases** – Long-term exposure to certain industrial dusts can cause diseases such as **silicosis and pneumoconiosis**.

B. Effects on Plants

- Dust deposited on leaves can reduce **photosynthesis**.
- It may block leaf pores and interfere with plant respiration.
- Heavy deposition can affect plant growth.

C. Effects on Environment and Property

- Reduces **visibility**.
 - Contributes to **haze and smog**.
 - Dust deposition makes buildings and monuments dirty.
 - Some particulate pollutants can cause **corrosion and deterioration of materials**.
 - Fly ash and industrial dust can contaminate soil and water when deposited.
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2. Control of Particulate Pollution

The three important particulate-control devices are:

1. **Cyclone Separator**
 2. **Bag Filter**
 3. **Electrostatic Precipitator (ESP)**
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A. Cyclone Separator

Principle

A cyclone separator works on the principle of **centrifugal force**.

When dust-laden gas enters the cyclone **tangentially**, it rotates at high speed. The heavier particles are thrown towards the wall by centrifugal force and move downward into the dust collection hopper.

Working

Dusty gas → Tangential entry → Spiral motion → Particles move to wall → Dust falls into hopper → Clean gas exits

Main Parts

- Gas inlet
- Cylindrical body
- Conical section
- Dust collection hopper
- Gas outlet

Advantages

- Simple construction
- No moving parts
- Low maintenance
- Suitable for high-temperature gases
- Low operating cost
- Useful for removing relatively large/coarse particles

Limitations

- Less efficient for very fine particles.
- Efficiency depends on particle size and operating conditions.
- Not generally sufficient alone when very high removal efficiency for fine PM is required.

Applications

Used in:

- Cement industries
- Foundries
- Wood-processing industries
- Boilers
- Mining and mineral-processing plants

B. Bag Filter

Principle

A bag filter works on the principle of **filtration**.

Dust-laden gas passes through porous filter bags. The gas passes through the fabric, while particulate matter is retained on the surface of the bags.

Working

Dusty gas → Filter bags → Dust retained on bags → Clean gas exits

As dust accumulates, a **dust cake** forms on the bag surface. This cake itself helps improve filtration. Periodically, the bags are cleaned by methods such as **shaking, reverse air or pulse-jet cleaning**.

Main Parts

- Filter bags
- Bag house/chamber
- Tube sheet
- Dust hopper
- Cleaning system
- Clean-gas outlet

Advantages

- Very high efficiency for particulate removal.
- Effective for fine particles.
- Suitable for many industrial dust-control applications.
- Collected dust can often be recovered or reused.

Limitations

- Filter bags can be damaged by excessive temperature.
- Moisture and sticky dust can cause problems.
- Bags require periodic cleaning and replacement.
- Pressure drop increases as dust accumulates.

Applications

Commonly used in:

- Cement plants
- Steel industries
- Foundries
- Thermal power plants
- Mineral-processing industries
- Pharmaceutical industries

C. Electrostatic Precipitator (ESP)

Principle

An electrostatic precipitator works on the principle of **electrostatic attraction**.

Dust particles are electrically charged and then attracted towards oppositely charged **collecting plates**.

Working

- 1. Dust-laden gas enters the ESP.
- 2. High-voltage discharge electrodes produce an electrical field.
- 3. Particles become electrically charged.
- 4. Charged particles move towards the collecting plates.
- 5. Particles accumulate on the plates.
- 6. The plates are periodically **rapped or vibrated** to remove the collected dust.
- 7. Dust falls into the hopper.
- 8. Clean gas leaves the ESP.

Simple Flow Diagram

Dusty Gas → Charging Zone → Charged Particles → Collecting Plates → Dust Hopper → Clean Gas

Advantages

- Very high particulate-removal efficiency.
- Can handle large volumes of gas.
- Suitable for fine particles.
- Low pressure drop compared with many fabric filtration systems.
- Widely used in large industrial plants.

Limitations

- High initial cost.
- Requires high-voltage electrical equipment.
- Performance depends on particle characteristics.
- Requires skilled operation and maintenance.
- Not suitable for every type of dust or gas without proper design.

Applications

ESP is widely used in:

- **Thermal power plants**
- Cement plants
- Steel plants
- Metallurgical industries
- Large industrial boilers

Comparison of Particulate Control Devices

Feature	Cyclone Separator	Bag Filter	ESP
Basic principle	Centrifugal force	Filtration	Electrostatic attraction
Best suited for	Coarse particles	Fine and coarse particles	Fine particles
Moving parts	Very few/none	Cleaning mechanism	Rapping/collection system

Initial cost	Low	Moderate	High
Maintenance	Low	Moderate	Moderate
Fine-particle removal	Relatively low	Very high	Very high
Pressure drop	Moderate	Moderate	Generally low
Common application	Dust pre-cleaning	Industrial dust collection	Large power/industrial plants

Gaseous Pollution Control and Effects of Air Pollution

Gaseous pollutants include **carbon monoxide (CO)**, **sulphur dioxide (SO₂)**, **nitrogen oxides (NO_x)**, **hydrocarbons and other harmful gases**. They are released from automobiles, industries, boilers, I.C. engines and other combustion processes.

1. Catalytic Converter

A **catalytic converter** is an emission-control device fitted in the exhaust system of automobiles. It converts harmful gaseous pollutants into **less harmful substances** through chemical reactions over a catalyst.

Main Components

A catalytic converter generally contains catalysts such as:

- **Platinum (Pt)**
- **Palladium (Pd)**
- **Rhodium (Rh)**

These catalysts are deposited on a honeycomb-type substrate to provide a large surface area.

Working

The commonly used **three-way catalytic converter** controls three major pollutants:

CO → CO₂

Unburnt hydrocarbons → CO₂ + H₂O

NO_x → N₂ + O₂

Thus, the converter significantly reduces **CO, hydrocarbons and NO_x** in automobile exhaust.

Simple Flow

Engine exhaust → Catalytic converter → Chemical reactions → Cleaner exhaust gases

Advantages

- Reduces harmful automobile emissions.
- Controls CO, hydrocarbons and NO_x.
- Helps improve urban air quality.
- Works continuously when the engine and converter reach suitable operating conditions.

Limitations

- Requires suitable operating temperature.
 - Catalyst can be poisoned by certain contaminants.
 - Adds cost to the vehicle.
 - Does not remove all pollutants from exhaust.
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2. Effects of Air Pollution Due to Refrigerants

Refrigerants are substances used in **refrigerators, air conditioners and heat-pump systems**. Some older refrigerants, particularly **CFCs**, have caused serious environmental problems.

A. Ozone Layer Depletion

CFCs (chlorofluorocarbons) can reach the stratosphere. Under ultraviolet radiation, they release chlorine radicals that participate in reactions that destroy ozone.

CFC → UV radiation → Chlorine radicals → Ozone destruction

The ozone layer protects Earth from harmful **ultraviolet (UV) radiation**.

Effects of Ozone Depletion

- Increased exposure to harmful UV-B radiation.
- Increased risk of **skin damage and skin cancer**.
- Eye damage such as cataracts.
- Adverse effects on some plants and aquatic organisms.
- Disturbance of ecosystems.

B. Global Warming

Some refrigerants, including many **CFCs, HCFCs and HFCs**, are greenhouse gases with varying global-warming potentials.

Therefore, leakage and improper disposal of refrigerants can contribute to **climate change**.

C. Control Measures

- Prevent leakage from refrigeration and air-conditioning systems.

- Recover refrigerants during servicing and disposal.
- Use environmentally preferable refrigerants where technically appropriate.
- Avoid releasing refrigerants directly into the atmosphere.
- Properly maintain refrigeration equipment.

Important: CFCs are associated with both **ozone depletion and climate impacts**; HFCs generally have **zero ozone-depleting potential but some have high global-warming potential**.

3. Air Pollution from I.C. Engines

I.C. (Internal Combustion) engines burn petrol, diesel or other fuels inside the engine cylinder. Their exhaust can contain several pollutants.

Major Pollutants

Pollutant	Main reason/source
CO	Incomplete combustion
CO ₂	Combustion of carbon-containing fuels
NO _x	High-temperature combustion
Unburnt hydrocarbons (HC)	Incomplete combustion
Particulate matter	Particularly important in diesel engines
SO ₂	Sulphur present in fuel

Effects

- **CO** reduces the blood's ability to carry oxygen.
- **NO_x** contributes to smog and acid deposition.
- **HC** contributes to photochemical smog.
- **PM** can cause respiratory and cardiovascular health effects.
- **CO₂** contributes to global warming.
- **SO₂** contributes to acid rain and respiratory irritation.

Control Measures

1. Use cleaner and low-sulphur fuels.
2. Maintain engines properly.
3. Use **catalytic converters** in suitable vehicles.
4. Use particulate filters where applicable.
5. Improve combustion efficiency.
6. Promote public transport and electric vehicles.
7. Conduct regular emission testing.

4. Air Pollution from Boilers

A **boiler** burns fuel to produce heat and steam. Boilers using coal, oil or other fuels can release particulate and gaseous pollutants.

Major Pollutants

- **Particulate matter**
- **SO₂**
- **NO_x**
- **CO**
- **CO₂**
- **Smoke and fly ash**

Effects

- **PM/fly ash:** respiratory problems and reduced visibility.
- **SO₂:** respiratory irritation and acid rain.
- **NO_x:** smog, acid deposition and respiratory effects.
- **CO:** toxic gas that interferes with oxygen transport in the body.
- **CO₂:** contributes to climate change.

Control Measures

1. Use cleaner fuel

Use low-sulphur fuel or cleaner alternatives.

2. Proper combustion

Maintain the correct air-fuel ratio to reduce incomplete combustion and CO formation.

3. Cyclone separator

Removes relatively coarse particulate matter.

4. Bag filter

Removes fine particulate matter by filtration.

5. Electrostatic precipitator (ESP)

Removes fine particles such as fly ash from large-volume flue gas.

6. Flue-gas treatment

Appropriate systems can be used to control SO₂ and NO_x emissions.

7. Regular maintenance

Proper maintenance improves combustion efficiency and reduces emissions.

NOISE POLLUTION

1. Definition of Noise Pollution

Noise pollution is the presence of **unwanted, unpleasant, or excessive sound** in the environment that causes discomfort, disturbance, or harmful effects on human beings, animals, and the environment.

Noise

Noise is generally defined as **unwanted sound**. The intensity of sound is commonly measured in **decibels (dB)**.

Important: The decibel (dB) scale is logarithmic, not a simple linear scale.

2. Sources of Noise Pollution

Noise pollution may originate from **transportation, industries, construction, domestic activities and social activities**.

A. Transportation Sources

1. **Road traffic** – cars, buses, trucks, motorcycles and horns.
2. **Railways** – trains, engines, whistles and braking.
3. **Aircraft** – aircraft engines during take-off and landing.
4. **Ships and boats** – engines and machinery.

B. Industrial Sources

- Heavy machinery
- Compressors
- Generators
- Turbines
- Pumps
- Presses
- Welding and cutting equipment
- Mining and quarrying machinery

C. Construction Sources

- Drilling machines
- Concrete mixers
- Excavators
- Bulldozers
- Pile-driving equipment
- Demolition activities

D. Domestic Sources

- Television and music systems
- Kitchen appliances
- Washing machines
- Air conditioners
- Water pumps
- Generators

E. Social and Other Sources

- Loudspeakers
 - Firecrackers
 - Public gatherings
 - Festivals and processions
 - Markets
 - Political and religious events
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3. Effects of Noise Pollution

Noise pollution can affect **human health, communication, work efficiency and animals.**

A. Effects on Human Health

1. Hearing Problems

Long-term exposure to high noise levels can cause:

- Temporary hearing impairment
- Permanent hearing loss
- Ringing or buzzing in the ears (**tinnitus**)

2. Sleep Disturbance

Excessive noise can:

- Disturb sleep
- Reduce sleep quality
- Cause daytime tiredness

3. Stress and Mental Effects

Continuous noise may cause:

- Stress
- Irritation

- Anxiety
- Reduced concentration
- Mental fatigue

4. Cardiovascular Effects

Long-term exposure to excessive environmental noise has been associated with increased risks of:

- High blood pressure
- Cardiovascular stress

5. Reduced Work Efficiency

Noise can:

- Reduce concentration
- Increase mistakes
- Reduce productivity
- Interfere with learning and communication

B. Effects on Animals

- Disturbs communication between animals.
- Interferes with feeding and breeding behaviour.
- Can cause stress and avoidance of noisy areas.
- Excessive underwater noise can affect aquatic organisms.

4. Control of Noise Pollution

Noise pollution can be controlled at the **source**, **along the transmission path**, and **at the receiver**.

A. Control at Source

1. Use **low-noise machinery**.
2. Maintain machines regularly.
3. Lubricate moving parts properly.
4. Use silencers on engines and exhaust systems.
5. Reduce unnecessary use of horns.
6. Replace noisy equipment with quieter alternatives.

B. Control Along the Transmission Path

1. Construct **sound barriers** around noisy equipment.
2. Use acoustic enclosures.
3. Use sound-absorbing materials on walls and ceilings.
4. Develop **green belts** and vegetation around industrial areas.

5. Maintain adequate distance between noisy industries and residential areas.

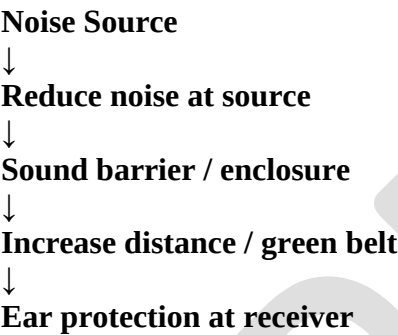
C. Control at the Receiver

- 1. Use **earplugs or earmuffs** in high-noise workplaces.
- 2. Limit the duration of exposure.
- 3. Provide workers with proper hearing protection.
- 4. Conduct periodic hearing examinations for workers exposed to occupational noise.

D. Administrative Measures

- Restrict unnecessary use of loudspeakers.
- Control vehicle horns.
- Establish **silent zones** around hospitals, schools and other sensitive locations.
- Restrict noisy construction activities during sensitive hours.
- Enforce applicable noise-control regulations.

5. Simple Noise Pollution Control Flow



Aspect	Important Points
Definition	Unwanted or excessive sound causing disturbance or harmful effects
Unit	Decibel (dB)
Major sources	Vehicles, industries, construction, loudspeakers, domestic appliances
Major effects	Hearing loss, sleep disturbance, stress, reduced concentration
Source control	Silencers, maintenance, low-noise machines
Path control	Barriers, enclosures, sound-absorbing materials, green belts
Receiver control	Earplugs, earmuffs, exposure-time reduction
Administrative control	Silent zones, regulation of loudspeakers and horns