Subject Name & Code: Environmental Sciences (**NESV101)**

Sl. No.	Faculty	Topics
1	Prof S Das **(Course Instructor: Section-)**	Solid and e-Waste Management: Characteristics and Sources of Solid Waste/e-Waste, Environmental Issues related to Solid Waste, Waste Management, Basics of Solid Waste Treatment Methods, Solid Waste Transformation through Thermochemical and Biological Methods and Different Disposal Techniques for e-Waste. **Environmental Impact Assessment (EIA):** Introduction to Basic EIA Structure and Overview on Impacts of Air, Water, Biological and Socio-economical Aspects
2	Prof. Vittal H **(Course Instructor: Section-)**	**Global Atmospheric Change:** Atmospheric System, Atmospheric Circulations, Introduction to Climate and Weather, Global Energy Balance, Greenhouse Effect, and Radiative Forcing of Climate Change and Global Warming Potential. **Natural Resources:** Water resources, Mineral Resources, Land Resources, Forest Resources, Energy Resources. **Other Environmental Pollution:** Marine pollution, Nuclear Pollution, Thermal Pollution etc.
3	Prof Sheeja Jagadevan **(Course Instructor: Section-)**	**Water & Wastewater Pollution:** Introduction to Water Pollution, Characteristics/Source/Types/Analysis of Water and Wastewater, Drinking Water and Basic Treatments Process, Industrial Wastewater and Basic Treatments Process, Municipal Wastewater and Basic Treatments Process, Prevention and Control of Water Pollution and Standards for Drinking Water and Effluents. **Ecosystems:** Definition, Scope, and Importance of Ecosystems. Biogeochemical cycles, Eutrophication, Bioaccumulation and Biomagnification, ecosystem value, services and carrying capacity. **Biodiversity:** Introduction, Definition, Value of biodiversity, Threats and conservation of biodiversity, Biodiversity Indices, National Biodiversity Act.
4	**Prof. Brijesh Kumar Mishra** **(Course Instructor: Section-)**	**Air Pollution:** Types and Sources of Air Pollution, Effects of Air Pollution, Controlling Air Pollutants, Indoor Air Pollution, Ozone Depletion in the Stratosphere, Acid Deposition and **Noise Pollution.** **Environmental Policy & Legislation:** Environmental Protection act, Legal aspects Air Act, Water Act, Forest Act, Wildlife Act, Municipal Solid Waste Management and Handling Rules.

Effective Height Of Stack

1. Effective Height of Stack (He)

Concept

- The **effective stack height (He)** is the actual elevation at which the plume centerline stabilizes after leaving the stack.
- It is the **sum of physical stack height (h)** and the **plume rise (Δh)** due to:
  - **Exit momentum** (velocity of gases from the stack).
  - **Buoyancy** (temperature difference between stack gases and ambient air).

$$H_e = h + \Delta h$$

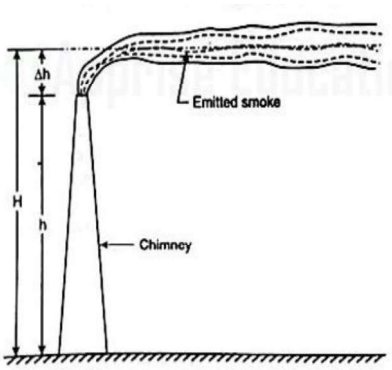


Fig. 18.9. Effective stack height.

Scientific & Technical Insights

•**Plume centerline height**: H_e is the elevation of the plume's centerline above ground.

•**Dispersion modeling**: Gaussian plume model uses H_e for ground-level concentration (GLC) prediction.

•**Meteorology role**: Wind speed, atmospheric stability (Pasquill–Gifford classes), and ambient temperature strongly influence plume rise.

•**CPCB Guideline**: Minimum stack height (for SO_2 control) is given by:

$$H = 14 \times (Q)^{0.3}$$

•where Q= SO_2 emission rate (kg/hr).

- Minimum stack height for DG sets, boilers, and thermal power plants is also prescribed (e.g., **220 m for >500 MW plants**).

Holland's Equation for calculating plume height

2. Holland's Equation for Plume Rise Equation

$$\Delta h = \frac{v_s \cdot D}{u}\left[1.5 + 2.68 \times 10^{-3} \cdot P \cdot D \cdot \frac{(T_s - T_a)}{T_a}\right]$$

where,

- Δh= plume rise (m)
- v_s =stack gas exit velocity (m/s)
- D= stack exit diameter (m)
- u= wind speed at stack height (m/s)
- P= atmospheric pressure (millibar)
- T_s =stack gas temperature (K)
- T_a =ambient air temperature (K)

Scientific Interpretation

- **First term (momentum rise):** $\frac{v_s \cdot D}{u} \times 1.5$
  - Shows effect of gas velocity & stack diameter.
  - Larger diameter + higher velocity = higher plume rise.
- **Second term (buoyancy rise):** proportional to $\frac{(T_s - T_a)}{T_a}$
  - Hotter gases compared to air rise higher due to buoyancy.
- **Wind speed (u):** inversely related. Higher wind = plume bends, reduces Δh.

Q: Using **Holland's formula**, calculate the **effective stack height** for a chimney with the following data:

- Stack height: 180 m
- Internal diameter of stack: 0.95 m
- Exit velocity of flue gas: 11.12 m/s
- Exit gas temperature: 160°C
- Ambient air temperature: 20°C
- Wind speed at stack height: 2.75 m/s
- Barometric pressure: 1000 mb

Formula (Holland)

$$\Delta h = \frac{v_s D}{u}\left[1.5 + 2.68 \times 10^{-3}\, P\, D\left(\frac{T_s - T_a}{T_s}\right)\right]$$

Notes: Temperatures must be in **Kelvin**; pressure in **millibars** for the constant in Holland's equation.

$$\Delta h = \frac{v_s \cdot D}{u}\left[1.5 + 2.68 \times 10^{-3}\, PD\left(\frac{T_s - T_a}{T_s}\right)\right]$$

$$= \frac{11.12 \times 0.95}{2.75}\left[1.5 + 2.68 \times 10^{-3} \times 1000 \times 0.95 \times \frac{433 - 293}{433}\right]$$

$$= \frac{11.12 \times 0.95}{2.75}\left[1.5 + \frac{2.68 \times 0.95 \times 140}{433}\right] = 8.92 \text{ m}$$

$\Delta h = 8.92$ m

H = Effective height of stack

$= h + \Delta h$

$= 180 + 8.92 = 188.92$ m. Ans.

Calculation of Stack Height:

Governing Formulas for Stack Height: The **effective stack height** is determined based on emissions of **particulate matter (PM)** and **sulfur dioxide (SO_2)**.

Two empirical formulas are widely used in Indian and international standards:

(1) Based on Particulate Matter Emission

$$h = 74\ (Q_p)^{0.27}$$

where,

- h= Chimney (stack) height in meters
- Q_p =Particulate matter emission in **tonnes/hour**

(2) Based on Sulphur Dioxide Emission

$$h = 14\ (Q_s)^{1/3}$$

where,

h= Chimney (stack) height in meters

Q_s =Sulphur dioxide (SO_2) emission in **kg/hour**

- For **industries with high SO_2 emissions** (e.g., coal-based thermal power plants), the SO_2-based formula generally governs stack height.
- For **industries with high particulate matter emissions** (e.g., cement plants, steel plants), the particulate matter–based formula is more critical.

3. Selection Criterion

The **maximum** of the two calculated values (from particulate matter and SO_2 emissions) is chosen as the **stack height**.

CPCB Regulatory Stack Height Norms (India)

1. Thermal Power Plants

•**For units < 210 MW:**

Use the SO_2 emission-based formula.

•**For units ≥ 210 MW:**

- **210 MW plant** → 220 m stack
- **500 MW plant** → 275 m stack
  (fixed minimum heights prescribed irrespective of SO_2 formula).

Reason: Such plants emit large SO_2 quantities; very tall stacks ensure dilution across large areas.

2. Diesel Generator (DG) Sets

Up to 75 kVA: Stack must be **3 m above the building height** housing the DG set.

75–800 kVA:

$$h = H_{building} + 0.2 \times \sqrt{kVA}$$

Above 800 kVA: Higher prescribed values or CPCB-approved designs must be followed.

➢ Ensures localized dispersion in urban areas.

3. Boilers & Small Industries

For **boilers up to 2 tonnes/hr steam capacity**: minimum 9 m stack.

For **2–5 tonnes/hr capacity**: minimum 12 m stack.

For **> 5 tonnes/hr capacity**: formula-based or regulatory-approved design.

Example: An industry utilises 0.3 Ml of oil fuel per month. It has also been estimated that for every 1 Ml of fuel oil burnt in the factory, per year, the quantities of various pollutants emitted are given as:

- Particulate matter = 2.9 t/yr
- SO_2 = 60 t/yr
- NO_x = 8 t/yr
- HC = 0.4 t/yr
- CO = 0.5 t/yr

Calculate the height of the chimney required to be provided for safe dispersion of the pollutants.

Solution. Using equation (18.26), we have

h = height of chimney

$= 74 (Q_P)^{0.27}$

where Q_P = emission of particulate matter in t/hr.

In the given case, the *particulate matter emission*

= 2.9 t/yr/Ml of fuel burnt

$= 2.9 \times (12 \times 0.3)$ t/yr

= 10.44 t/yr ($\because$ fuel burnt per yr. $= 12 \times 0.3$ Ml)

Now, $Q_P = \frac{10.44}{300 \times 24}$ t/hr (assuming 300 working days in the yr with 24 hr working)

or $Q_P = 1.45 \times 10^{-3}$ t/hr.

Using equation (18.26), we have

$h = 74 (Q_P)^{0.27}$

$= 74 \times (1.45 \times 10^{-3})^{0.27}$ m

= 12.67 m ...(i)

It means that only 12.67 m high chimney is required for effective disposal of particulate matter.

Let us now calculate the height of the chimney required for effective disposal of SO_2 by using equation (18.27) as :

$h = 14 (Q_S)^{1/3}$

where $Q_S = SO_2$ in kg/hr.

SO_2 emission = 60 t/yr/Ml of oil burnt

$= \frac{(60 \times 1000)}{(300 \times 24)}$ kg/hr/Ml of oil

$= \frac{60 \times 1000}{300 \times 24} \times (12 \times 0.3)$ kg/hr

= 30 kg/hr.

$\therefore$ $h = 14 . (30)^{1/3} = 43.45$ m ; say 43.5 m.

Since the above requirement of 43.5 m is more than the minimum requirement of 30 m, 43.5 m high chimney is required for effective disposal of pollutants. **Ans.**

Air Pollution Control

1. Natural Self-Cleansing: Air has a natural capacity to **dilute, disperse, and remove pollutants** through physical, chemical, and meteorological processes. These mechanisms reduce **ground-level concentrations (GLC)** of pollutants and protect ecosystems.
However, they do not **eliminate pollution sources**—they only help in reducing immediate exposure.

i) Dispersion

- **Definition:** The natural spreading and dilution of air pollutants due to **wind, turbulence, and atmospheric stability**.
- **Mechanism:** Pollutants released from sources (vehicles, stacks, open burning) get transported by horizontal winds and mixed vertically by turbulence.
- **Scientific Insight:**
  - Governed by **Pasquill–Gifford stability classes** (A–F).
  - More effective in **unstable atmosphere** (daytime, strong heating).
- **Example:**
  - Vehicle exhaust in a busy road corridor disperses quickly on a windy afternoon but lingers on calm winter nights (stable atmosphere).
- **Key Point:** Dispersion **reduces concentration**, but pollutants remain in the air.

ii) Gravitational Settling (with or without Flocculation)

- **Definition:** The removal of suspended particles from the air due to **gravity**.
- **Mechanism:**
  - Heavier particles (dust, ash, pollen) settle faster than fine particles.
  - **Flocculation**: Small particles collide and stick together (due to humidity or electrostatic forces), forming larger aggregates that settle faster.
- **Scientific Insight:**
  - Described by **Stokes' Law** (settling velocity $\propto$ particle diameter^2).
  - Important for **PM_{10} and coarse particles**; less effective for $PM_{2.5}$ or ultrafine particles.
- **Example:**
  - Road dust or fly ash from construction sites settling on surfaces in calm weather.
- **Key Point:** Helps remove particulates naturally, but depends on particle size and weather.

iii) Absorption (Washout and Scavenging)

- **Definition:** The removal of gaseous and particulate pollutants by **dissolving into raindrops or snow**.
- **Processes:**
  - **Washout:** Falling raindrops/snowflakes capture pollutants while moving through polluted air.
  - **Scavenging:** Pollutants (SO_2, NH_3, PM) are absorbed or trapped by cloud water droplets during precipitation.
- **Scientific Insight:**
  - Efficient in monsoon climates (India, Southeast Asia).
  - Removes water-soluble gases ($SO_2 \rightarrow H_2SO_4$, $NH_3 \rightarrow$ ammonium salts).
- **Example:**
  - "Acid rain" formation: SO_2 and NO_2 absorbed in rainwater → sulfuric and nitric acids → ground deposition.
- **Key Point:** Very effective during rainfall, reduces both gas and particulate pollution.

iv) Rainout

- **Definition:** Removal of pollutants during **cloud formation** itself, unlike washout which occurs during rainfall.
- **Mechanism:** Pollutants act as **cloud condensation nuclei (CCN)**; as vapor condenses, pollutants become embedded in droplets.
- **Scientific Insight:**
  - Occurs within the cloud before precipitation.
  - Important for **long-range transport**—pollutants incorporated in clouds can later be deposited far from the source.
- **Example:**
  - SO_2 or sea-salt particles serving as nuclei in clouds, later precipitating out as acidified rain.
- **Key Point:** Transfers pollutants from air → water cycle before raindrops even fall.

v) Adsorption

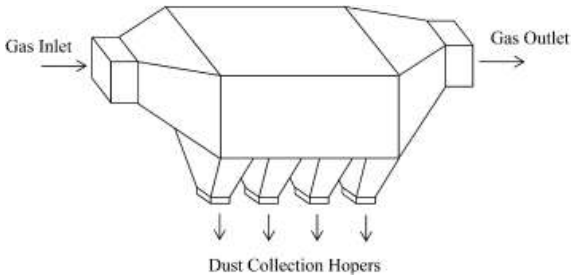
- **Definition:** Process where **pollutant molecules attach to solid surfaces** (soil, leaf surfaces, airborne particles) without penetrating the bulk material.
- **Mechanism:** Physical or chemical forces hold pollutants on the surface.
- **Scientific Insight:**
  - Important for removal of **organic vapors, heavy metals, and persistent pollutants**.
  - Natural surfaces (soils, vegetation) act as **adsorbents**.
- **Example:**
  - Ozone or volatile organic compounds (VOCs) adsorbed onto leaf wax layers.
  - Heavy metals sticking to airborne dust particles that later settle.
- **Key Point:** Surface-based process, unlike absorption which involves bulk dissolution.

Summary Table: Air Pollution Control: Natural Self-Cleansing Mechanisms

Process	Mechanism	Main Pollutants Removed	Example
Dispersion	Dilution by wind & turbulence	All pollutants (spread)	Smog dispersing on windy day
Gravitational Settling	Gravity causes particles to fall	Dust, ash, pollen	Road dust settling at night
Absorption (Washout/Scavenging)	Dissolution into raindrops/snow	SO_2, NH_3, PM	Acid rain formation
Rainout	Pollutants captured in cloud droplets	SO_2, NO_2, sea salts	Cloud condensation nuclei
Adsorption	Molecules attach to solid surfaces	VOCs, heavy metals	Ozone adsorbed on leaves

2. Controlling Air Pollution By Installing Engineering Devices :

i) Gravitational Settling Chambers

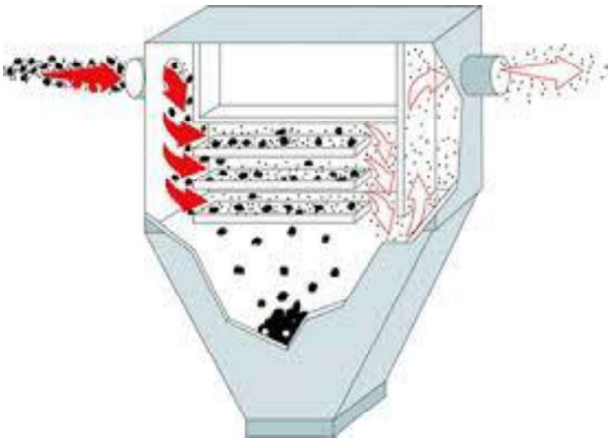


Principle:

- Operates on the principle of gravity.
- Removes large particulate matter by allowing them to settle due to their weight.
- Minimum particle size that can be removed is > 50 microns.
- Efficiency < 50%

Working:

- Polluted air enters a large horizontal chamber.
- Air velocity is reduced to allow particles to settle.
- Heavy particles fall to the bottom and are collected.
- Cleaner air exits the chamber.



Advantages:

- Simple and low-cost design.
- No moving parts → low maintenance.
- Effective for removing large, heavy particles (> 50 µm).

Limitations:

- Ineffective for fine particles (< 50 µm).
- Requires large space for installation.
- Less efficient at high airflow velocities.

ii) Centrifugal Collector (Cyclone Collectors)

Principle:

- Uses centrifugal force to separate dust particles from polluted air.
- Particles are forced outward to the cyclone wall due to rapid spinning motion.
- Minimum particle size that can be removed is 5-25 microns.
- Efficiency = 50-90%

Working:

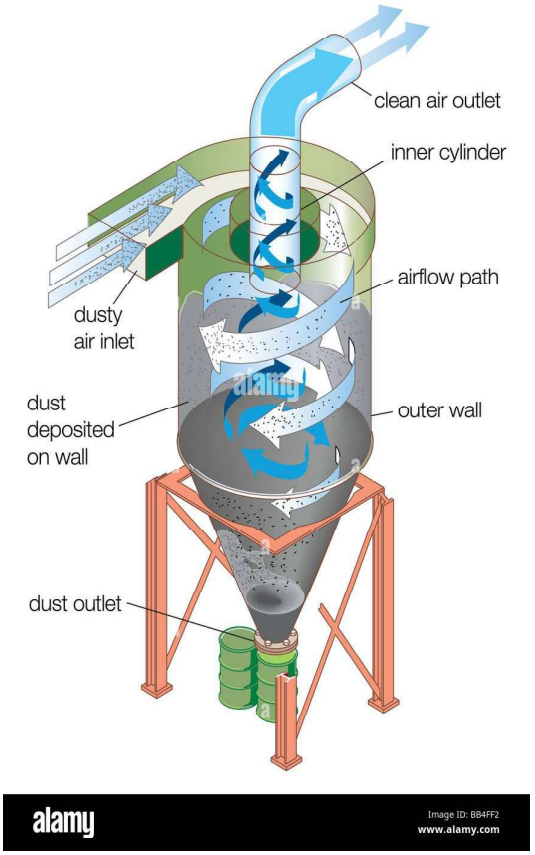
- Polluted air enters tangentially at high velocity into a cylindrical or conical chamber.
- Air spirals downward, creating a vortex.
- Heavier particles move toward the chamber walls and slide down to a collection hopper.
- Clean air spirals upward and exits through the outlet pipe.

Advantages:

- Efficient for removing medium to large particles (around 10–50 microns).
- No moving parts → low maintenance.
- Can operate under high temperature and pressure.

Limitations:

- Not very effective for fine particles (<10 microns).
- Efficiency depends on air velocity, particle size, and density.



iii) Wet Scrubbers (including spray towers, wet cyclone scrubbers and venturi-scrubbers)

Feature	Spray Tower	Wet Cyclonic Scrubber	Venturi Scrubber
Working Principle	Polluted gas contacts sprayed liquid	Uses centrifugal force + liquid spray	High-velocity gas contacts scrubbing liquid in narrow throat
Particle Size Removed	> **10 µm**	**>2.5µm**	> **0.5 µm**
Removal Efficiency	**<80%**	**<80%**	**< 99%**
Gas Absorption	Good (soluble gases)	Limited	Moderate (depends on design)
Pressure Drop	**Low**	**Moderate**	**High**
Best Use	Coarse dust, gas cooling	Medium particles, sticky dust	Fine particles, aerosols, high-efficiency needs
Limitations	Not for fine particles	Less effective < 5 µm; water maintenance	High energy cost; water treatment

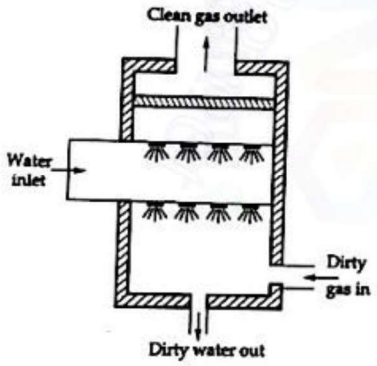


Fig. 18.13. Spray tower (Also used for removing gaseous pollutants).

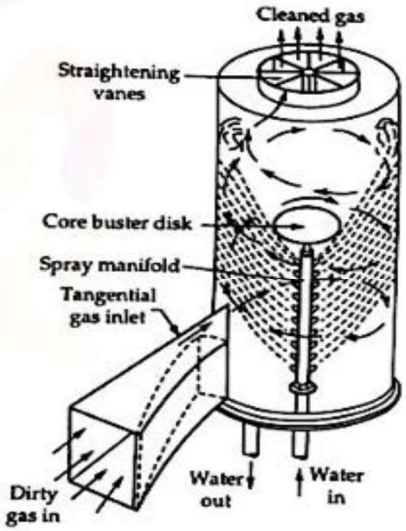


Fig. 18.14. Wet-Cyclone scrubber.

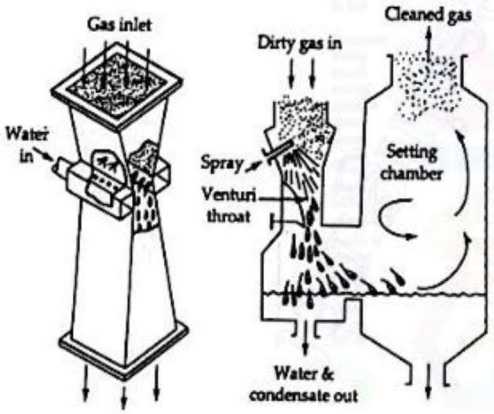


Fig. 18.15. Venturi-scrubber (also used for removing, gaseous pollutants).

iv) Electrostatic Precipitator

Feature	Electrostatic Precipitator (ESP)
Pollutants Removed	**Fine particulate matter (as small as 0.01 µm)**
Removal Efficiency	**Up to 99% or more**
Best For	Power plants, cement, steel, pulp & paper
Gas Handling	High temperatures and large volumes
Pressure Drop	**Low** (5–20 cm of water column)
Advantages	High efficiency, handles fine particles, low pressure loss
Limitations	High initial cost, sensitive to gas composition and humidity
Maintenance	Requires periodic cleaning (rapping mechanisms

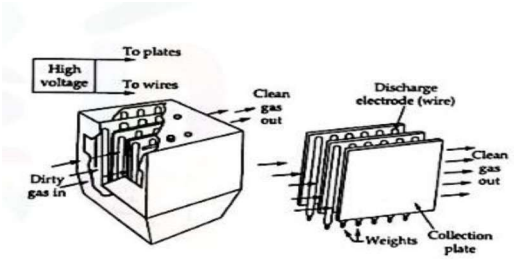
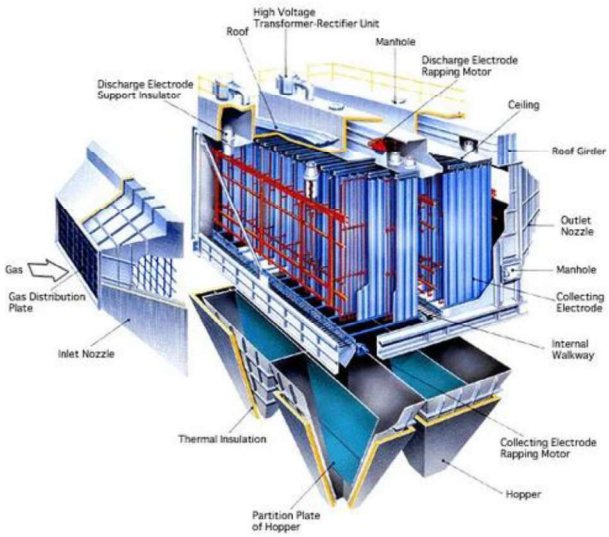


Fig. 18.16. (a) High Voltage Electrostatic Precipitator (plate type).



v. Fabric Filters

Principle:

- Works on mechanical filtration: polluted gas passes through fabric filter bags that trap dust particles.
- Clean air exits; dust stays on the bag surface and is periodically removed.

Working:

- Dust-laden gas enters the baghouse unit.
- Gas flows through fabric filter bags (usually made of synthetic or glass fibers).
- Particles are trapped on the outer surface of the bags.
- Clean gas exits through the bags.
- Accumulated dust is removed by shaking, reverse air, or pulsed air jets.
- Pollutants Removed - Fine particles (as small as 0.1 µm)
- Removal Efficiency - 99% or more

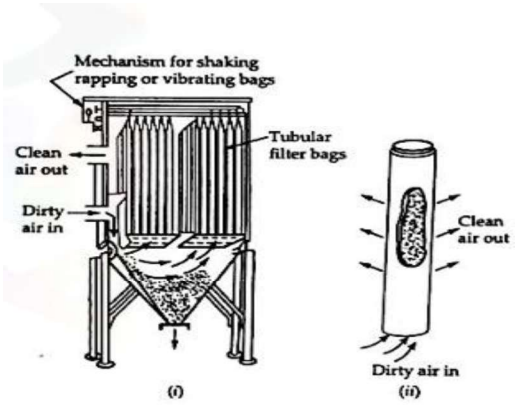
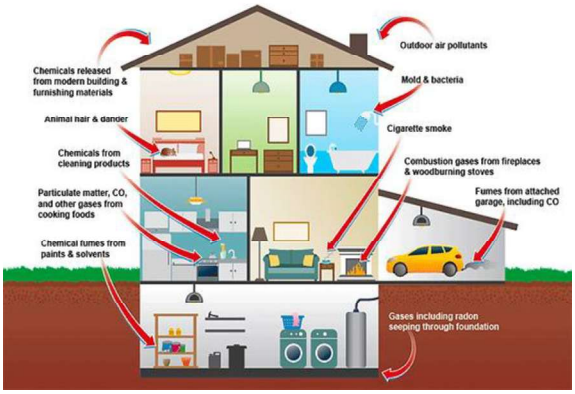


Fig. 18.17. Bag house fabric filter unit.

Indoor Air Pollution

1. Introduction

- **Indoor Air Pollution (IAP)** refers to the **contamination of indoor environments** (homes, offices, schools, hospitals, industries) by harmful pollutants that affect **human health, comfort, and productivity**.
- Unlike outdoor pollution, indoor pollution is more critical because:
  - People spend **80–90% of their time indoors**.
  - Pollutant concentrations can be **2–5 times higher indoors** compared to outdoors (WHO, 2010).
- In India, IAP is a **major cause of disease burden**, especially in rural households where biomass fuels (wood, cow dung, crop residues) are used for cooking.



2. Sources of Indoor Air Pollution

- **Poor Ventilation** – leads to accumulation of pollutants.
- **Combustion Sources** – stoves, fireplaces, kerosene heaters.
- **Household Products** – cleaners, paints, pesticides, aerosols.
- **Tobacco Smoke** – major source of PM, CO, VOCs, carcinogens.
- **Biological Sources** – mold, bacteria, pollen, pet dander.
- **Radioactive Sources** – radon gas seeping through soil.
- **Building Materials & Furnishings** – carpets, plywood, glues (formaldehyde release).

3. Classification of Indoor Air Pollutants

A. Particulate Pollutants

- **Examples:** $PM_{2.5}$, PM_{10}, dust, soot.
- **Sources:** Cooking, candles, smoking, incense burning, carpets.
- **Health Effects:** Asthma, COPD, cardiovascular diseases.

B. Gaseous Pollutants

- **Examples:**
  - Carbon Monoxide (CO) – stoves, heaters.
  - Nitrogen Dioxide (NO_2) – gas appliances, kerosene heaters.
  - Formaldehyde – plywood, glues.
  - Volatile Organic Compounds (VOCs) – paints, cleaners, sprays.
  - Ozone (O_3) – photocopiers, printers.
  - **Health Effects:** CO poisoning, lung inflammation,cancer risk from VOCs.

C. Biological Pollutants

- **Examples:** Mold, fungi, bacteria, viruses, pet dander, pollen.
- **Health Effects:** Allergies, infections, asthma.

D. Radioactive Pollutants

- **Example:** Radon (Rn).
- **Source:** Soil, rocks, cracks in basement floors.
- **Health Effect:** Lung cancer (second only to smoking).

4. Health Effects of Indoor Air Pollution

- **Short-term:** Headaches, dizziness, eye irritation, fatigue.
- **Medium-term:** Asthma, bronchitis, respiratory infections.
- **Long-term:** Lung cancer, heart disease, neurological disorders.
- **Children and elderly** are more vulnerable.
- WHO estimates **4.3 million premature deaths annually worldwide** due to indoor air pollution.

5. CPCB / WHO Guidelines for Indoor Air Quality

Pollutant	Limit (24h avg, WHO 2010)	CPCB/NAAQS 2009 Equivalent	Health Notes
$PM_{2.5}$	25 µg/m³	60 µg/m³	Deep lung penetration, cardiovascular risk
PM_{10}	50 µg/m³	100 µg/m³	Respiratory irritation, asthma
CO	10 mg/m³ (8h)	2 mg/m³ (8h)	Hypoxia, headache, dizziness
NO_2	200 µg/m³ (1h)	80 µg/m³ (24h)	Lung inflammation
SO_2	20 µg/m³	80 µg/m³	Eye irritation, bronchitis
O_3	100 µg/m³ (8h)	100 µg/m³ (8h)	Respiratory irritation
Formaldehyde	0.1 mg/m³	Not in NAAQS	Carcinogen
Radon	100 Bq/m³	Not in NAAQS	Lung cancer risk

6. Control Measures & Management

1. Engineering / Technical Controls

- **Ventilation Improvement** – cross-ventilation, exhaust fans.
- **Air Purifiers & Filters** – HEPA filters for PM, activated carbon for VOCs.
- **Low-Emission Products** – use low-VOC paints and formaldehyde-free furniture.
- **Radon Mitigation** – sealing cracks, basement ventilation.
- **Regular Maintenance** – cleaning HVAC systems, chimneys.

2. Behavioral & Preventive Measures

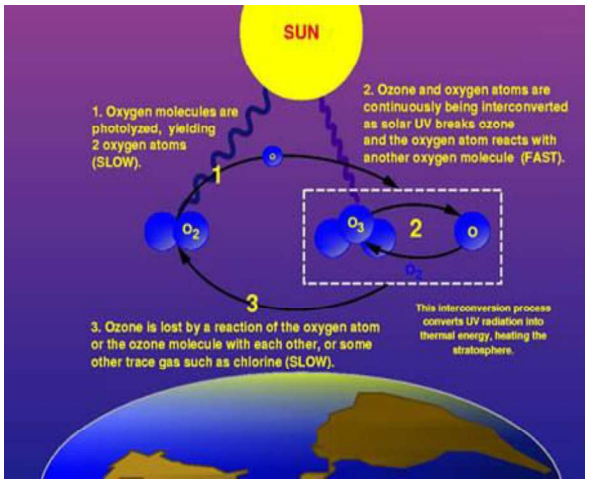
- Avoid **smoking indoors**.
- Prefer **LPG/electric stoves** instead of biomass fuels.
- Dry clothes outside to prevent dampness/mold.
- Keep indoor humidity between **30–60%**.
- Grow **indoor plants** (e.g., aloe vera, peace lily) – absorb CO_2, VOCs.

Ozone Depletion in the Stratosphere

1. Definition & Importance

- **Ozone depletion** = The **thinning of the ozone layer** in the stratosphere (≈10–50 km altitude) caused mainly by **man-made chemicals**.
- The stratospheric ozone layer **absorbs most UV-B (280–315 nm)** radiation; thinning → more UV-B reaches the surface → **greater skin cancer, cataracts, ecosystem and crop damage**.

- **Why engineers/environmental students should care:** ozone controls biological UV exposure and influences stratospheric radiative balance; its depletion required a major global policy response (Montreal Protocol).
- **Normal ozone levels:** ~300 Dobson Units (DU). "Ozone hole" = <220 DU (Antarctica).
- 1 DU = 2.69×10^{16} O_3 molecules cm^{-2}.



Main Causes:

- **CFCs** (from ACs, fridges, aerosols)
- **Halons** (fire extinguishers)
- **Carbon tetrachloride, methyl chloroform, N_2O**

How it Happens:

- CFCs → UV light → **release Cl (chlorine)**
- Cl breaks down **ozone (O_3) into oxygen (O_2)**
- One Cl atom can destroy **thousands of ozone molecules**

Effects:

- More **UV exposure** → skin cancer, cataracts
- Damage to **plants, animals, and marine life**
- Affects **climate and ecosystems**

Basic chemistry — Chapman mechanism (production & natural cycling)

1. Photolysis of molecular oxygen:

$$\mathrm{O_2} + h\nu(\lambda < 240\ \mathrm{nm}) \rightarrow 2\ \mathrm{O}$$

2. Ozone formation:

$$\mathrm{O} + \mathrm{O_2} + M \rightarrow \mathrm{O_3} + M$$

3.Ozone photolysis / loss:

$$\mathrm{O_3} + h\nu(\lambda < 320\ \mathrm{nm}) \rightarrow \mathrm{O_2} + \mathrm{O}$$

4.Recombination (natural loss):

$$\mathrm{O} + \mathrm{O_3} \rightarrow 2\ \mathrm{O_2}$$

- The Chapman cycle alone cannot explain observed losses — **catalytic cycles** (Cl, Br, NO, HO families) accelerate O_3 destruction.

Effects & Guidelines

Health Impacts:

•↑ UV-B → Skin cancer, cataracts, immune suppression.

Environmental Impacts:

•Crop damage (soybean, wheat, rice).

•Phytoplankton reduction → affects marine food webs.

•Climate feedbacks (radiative balance).

Guidelines & Limits:

•**Montreal Protocol (1987)**: Phase-out ODS (CFCs, halons, CCl_4, HCFCs).

•**Kigali Amendment (2016):** Added HFC phase-down (not ODS but high GWP).

•**WMO/UNEP assessments:** Ozone recovery to 1980 levels by **2050–2060** (if compliance continues).

Management & Precautions

Management / Control:

•**Phase-out ODS** (replace with low-ODP, low-GWP alternatives e.g., HFOs, natural refrigerants).

•**Refrigerant management:** recovery, recycling, destruction.

•**Avoid illegal ODS trade**.

•**Promote research & monitoring:** satellites, ground-based (Dobson, Brewer, ozonesondes).

Precautions:

•Engineers: design leak-proof, recovery-enabled systems.

•Policymakers: enforce Montreal Protocol compliance.

•Public: avoid old appliances with CFCs, ensure safe disposal.

Acid Deposition

•Deposition of acidic substances (wet or dry) from the atmosphere to Earth's surface.
•Occurs due to reaction of **SO_2** and **NOx** with atmospheric moisture.

Wet Deposition

- Acidic rain, snow, fog, dew.
- Transported over long distances before falling.

Dry Deposition

  - Acidic gases/particles settle on surfaces.
  - Later washed into soil/water during precipitation.

Major Pollutants:

- **Sulfur Dioxide (SO_2):**
  - From coal burning, smelters, power plants.
  - Forms **sulfuric acid** (H_2SO_4).
- **Nitrogen Oxides (NOx):**
  - From vehicles, combustion engines.
  - Forms **nitric acid** (HNO_3).

Key Chemical Reactions:

- **$SO_2 + O_2 \rightarrow SO_3$**
- **$SO_3 + H_2O \rightarrow H_2SO_4$**
- **$2NO_2 + H_2O \rightarrow HNO_3 + HNO_2$**

Human Health Effects:

- Indirect: Polluted water/soil affects food safety.
- Direct: Acidic aerosols cause **asthma**, **bronchitis**, **lung irritation**.

Control Measures:

Flue Gas Desulfurization (scrubbers).

Catalytic converters (vehicles).

Low-sulfur fuel, energy efficiency.

Environmental Impacts:

Soil:

Acid leaches essential nutrients (Ca^{2+}, Mg^{2+}, K^{+})
Releases toxic metals (Al^{3+}, Pb^{2+}) → root damage, poor growth

Vegetation:

Damaged leaf cuticles, reduced chlorophyll, impaired photosynthesis
Increased susceptibility to diseases, frost, drought

Built Environment:

Corrosion of metals, erosion of limestone/marble structures (e.g., $CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$)
Damage to monuments like **Taj Mahal (marble cancer)**

Noise Pollution

1. Introduction to Noise Pollution

- **Definition:**
  Noise pollution is characterized by unwanted, loud, or disruptive sounds that exceed permissible limits, causing discomfort, health hazards, or ecological imbalance.
- **Sources:** Traffic, industries, construction, aircrafts, loudspeakers, household appliances, etc.
- **When does sound become pollution?**
  - When it **exceeds CPCB/WHO prescribed limits**.
  - When it **interferes with human well-being, communication, or ecosystem balance**.

2. Effects of Noise Pollution

- **Noise-induced annoyance** → Stress, reduced productivity.
- **Noise-induced diseases** → Hypertension, cardiovascular issues.
- **Sleep disturbance (insomnia)** → Reduced mental performance.
- **Communication interference** → Difficulty in conversation, especially in urban areas.
- **Noise-induced hearing loss (NIHL)** → Permanent damage to auditory nerves.
- **Impact on wildlife** → Disturbs migration, breeding, and survival of birds and animals.

3. Scientific Characteristics of Sound: Sound is a **mechanical energy** generated by vibrations. It propagates as **mechanical longitudinal waves**.

•**Medium:** Requires a medium (air, water, solids). Cannot travel in a vacuum.

•**Wave Nature:** Comprised of **compressions** (high pressure) and **rarefactions** (low pressure).

4. Fundamental Parameters of Sound

(a) Frequency (Pitch)

•**Definition:** Number of wave cycles per second.

•**Unit:** Hertz (Hz).

•**Range:**

- Human hearing: **20 Hz – 20,000 Hz**
- <20 Hz → *Infrasound*; >20 kHz → *Ultrasound*.

(b) Amplitude (Loudness / Intensity)

•**Definition:** Maximum displacement of vibrating particles from equilibrium.

•**Measurement: Sound Pressure Level (SPL)** in **decibels (dB)**.

•**Formula:**

$$L_p = 20\log_{10}\left(\frac{p}{p_{ref}}\right)\ dB$$

•where p= sound pressure, $p_{ref} = 20\mu Pa$)threshold of hearing).

(c) Speed of Sound (v)

•**Formula:** $v = f \times \lambda$

•**Typical values:**

- Air (20°C) ≈ **343 m/s**
- Water ≈ **1500 m/s**
- Steel ≈ **5000 m/s**

•**Factors Affecting Speed:** Density, elasticity, humidity, and temperature of medium.

(d) Wavelength (λ)

•Distance between two consecutive crests or troughs.

•Relation: $\lambda = \frac{v}{f}$

•where v= speed of sound, f= frequency.

5. RMS (Root Mean Square) Sound Pressure

- Sound waves are **time-varying AC signals**.
- RMS represents the **effective pressure** level of fluctuating sound.
- Used in **decibel measurement instruments (Sound Level Meters)**.
- Formula:

$$P_{rms} = \sqrt{\frac{1}{T}\int_0^T [p(t)]^2 dt}$$

6. Measurement of Noise

- **Sound Level Meter (SLM):** Measures instantaneous SPL.
- **Noise Dosimeter:** Measures worker's exposure to noise over time.
- **Octave Band Analyzer:** Identifies noise frequency distribution.

Sound Level

$$L = \log_{10} \frac{Q}{Q_o} \text{ (bels)} \qquad \text{...(20.8)}$$

where Q = Measured quantity of *sound pressure*, or sound intensity

Q_0 = Reference standard quantity of sound pressure, or sound intensity, as the case may be

L = Sound level in bels (B).

$$\boxed{L \text{ in dB} = 10 \cdot \log_{10} \frac{Q}{Q_o}}$$

$$\boxed{L_p \text{ in dB} = 20 \log_{10} \left(\frac{p_{rms}}{20\ \mu\text{Pa}} \right)}$$

Sound intensity level (L_i) in dB

$$L_i \text{ in dB} = 10 \log_{10} \left(\frac{I}{10^{-12}} \right)$$

where I is in W/m^2.

Q. If you consider 50 dB noise and want to add another 50 dB noise to it. What will it make up to ?

50 decibel $= 20 \log_{10} \left(\frac{p_{rms}}{20} \right)$ where p_{rms} is in μPa

$\therefore \quad \left(\frac{p_{rms}}{20} \right) = \text{Antilog} \left(\frac{50}{20} \right) = 316.227$

or $\quad p_{rms} = 6324.55\ \mu\text{Pa}.$

$\therefore$ 50 decibel + 50 decibel in r.m.s.

$$= \sqrt{(6324.55)^2 + (6324.55)^2} = 8944.26\ \mu\text{Pa}$$

$$= 20 \log_{10} \left(\frac{8944.26}{20} \right) \text{ dB} = \textbf{53 decibel. Ans.}$$

Average Sound Pressure Level

Average pressure level

$$= \bar{L}_p = 20 \log_{10} \frac{1}{N} \sum_{n=1}^{n=N} (10)^{L_n/20} \quad \ldots(20.12)$$

where $\bar{L}_p$ = Average sound pressure level in dB *re* : 20 μPa

N = Number of measurement readings.

L_n = nth sound pressure level in dB *re*. 20 μPa.

n = 1, 2, 3 ..... N.

Equivalent Noise Level (L eq)

$$L_{eq} = 10 \log \sum_{i=1}^{i=n} (10)^{\frac{L_i}{10}} \times t_i \quad \ldots(20.13)$$

where n = Total number of sound samples

L_i = The noise level of any ith sample

t_i = Time duration of ith sample, expressed as fraction of total sample time.

Q. The average four measurements readings recorded as 40,50,62 and 72 dB is ?

$$\sum_{n=1}^{n=4} (10)^{L_n/20} = [(10)^{40/20} + (10)^{50/20} + (10)^{62/20} + (10)^{72/20}]$$

$$= [100 + 316.23 + 1258.92 + 3981.07] = 5656.22$$

and $$\bar{L}_p = 20 \log_{10} \frac{1}{4} \times 5656.22 = \mathbf{63\ dB.}\ \textbf{Ans.}$$

Q. Leq value for fluctuating noise level of 95 minutes indicated earlier (i.e. the one with 80 dB lasting for 10 minutes, followed by 60 dB for 80 minutes, followed by 100 dB for 5 minutes) will be ?

$$\sum_{1}^{3} (10)^{\frac{L_i}{10}} \times t_i = \left[(10)^{\frac{80}{10}} \times \frac{10}{95} + (10)^{\frac{60}{10}} \times \frac{80}{95} + (10)^{\frac{100}{10}} \times \frac{5}{95}\right]$$

$$= 1.053 \times 10^7 + 0.842 \times 10^6 + 0.52632 \times 10^7$$

$$= 10^6[10.53 + 0.84 + 526.32] = 537.69 \times 10^6$$

$$L_{eq} = 10 \cdot \log_{10} (537.69 \times 10^6) = \mathbf{87.3\ dB.}\ \textbf{Ans.}$$

Q. What will be the resultant of two noise levels of 81 dB and 90 dB generated by two independent sources ?

L_1=81 dB, L_2 = 90 dB

$$L_{eq} = 10log\sum_{i=1}^{i=n}(10)^{\frac{L_1}{10}} \times (t_i)$$

$$L_{eq} = 10log_{10}\left[\left(10^{\frac{L_1}{10}}\right) + \left(10^{\frac{L_2}{10}}\right)\right]$$

$$L_{eq} = 10log_{10}\left[\left(10^{\frac{81}{10}}\right) + \left(10^{\frac{90}{10}}\right)\right]$$

$$L_{eq} = 90.51 = 91dB$$

Q. The intensity of sound in a street during heavy traffic is 10^{-4} Wm^{-2}. Calculate intensity level in decibel.

Sound intensity level (β) = $10 \log_{10} [I/I_O]$

Substituting the given values, we have

$$\beta = 10 \log_{10}\left[\frac{10^{-4}}{10^{-12}}\right]$$

$$\beta = 10 \log_{10}(10^8) = 10 \times 8 = 80 \text{ dB}$$

Table 20.7. Ambient Air Quality Standards in Respect of Noise as Specified under the Indias' Environment Protection Act, 1986

Area Code	Category of Area / Zone	Limits in dB (A) Leq*	
		Day Time	Night Time
(A)	Industrial Area	75	70
(B)	Commercial Area	65	55
(C)	Residential Area	55	45
(D)	Silence Zone	50	40

Noise Abatement and Control

1. Introduction

- **Noise Abatement** and **Noise Control** are two complementary approaches:
  - **Abatement** → Policy and planning-based strategies (macro-level).
  - **Control** → Technical and engineering methods (micro-level).
- Both are essential to mitigate noise pollution and comply with regulatory standards such as **CPCB Noise Rules, 2000 (India)** and **WHO Guidelines (2018)**.

2. Noise Abatement

- **Definition:** Broad strategies aimed at reducing or eliminating noise at the **community/environment level**.
- **Focus:** Long-term prevention through regulations, zoning, and planning.
- **Examples:**
  - **Urban Planning / Zoning** – separating residential zones from industrial areas.
  - **Legislation** – CPCB Noise Rules (2000), Motor Vehicle Rules (silencers, horns).
  - **Time Restrictions** – banning loudspeakers/firecrackers during night (10 PM – 6 AM).
  - **Green Infrastructure** – tree belts, parks, green walls to absorb sound.
  - **Flight Path Management** – restricting aircraft take-offs/landings near cities at night.
- **CPCB Rule (India):** Ambient noise standards for **industrial, commercial, residential, and silence zones**.

3. Noise Control

- **Definition:** Specific engineering methods to **reduce noise levels** at source, along its path, or at the receiver.
- **Focus:** Practical and technical application of sound reduction measures.
- **Examples:**
  - **At Source (Best Solution):**
    - Quieter machine design.
    - Regular maintenance and lubrication.
    - Use of silencers in engines.
  - **Along Path:**
    - Noise barriers (concrete/metal/acoustic panels).
    - Green belts as buffers.
    - Enclosures for noisy equipment.
  - **At Receiver:**
    - Soundproof rooms (double glazing, acoustic insulation).
    - Personal Protective Equipment (PPE) → earplugs, earmuffs.
- Limiting exposure time

a) OSHA (Occupational Safety and Health Administration, USA) : 8 hrs @ 90 dB permissible)
b) NIOSH (National Institute for Occupational Safety and Health, USA) : 85 dB(A) for 8 hours

4. CPCB and WHO Guidelines

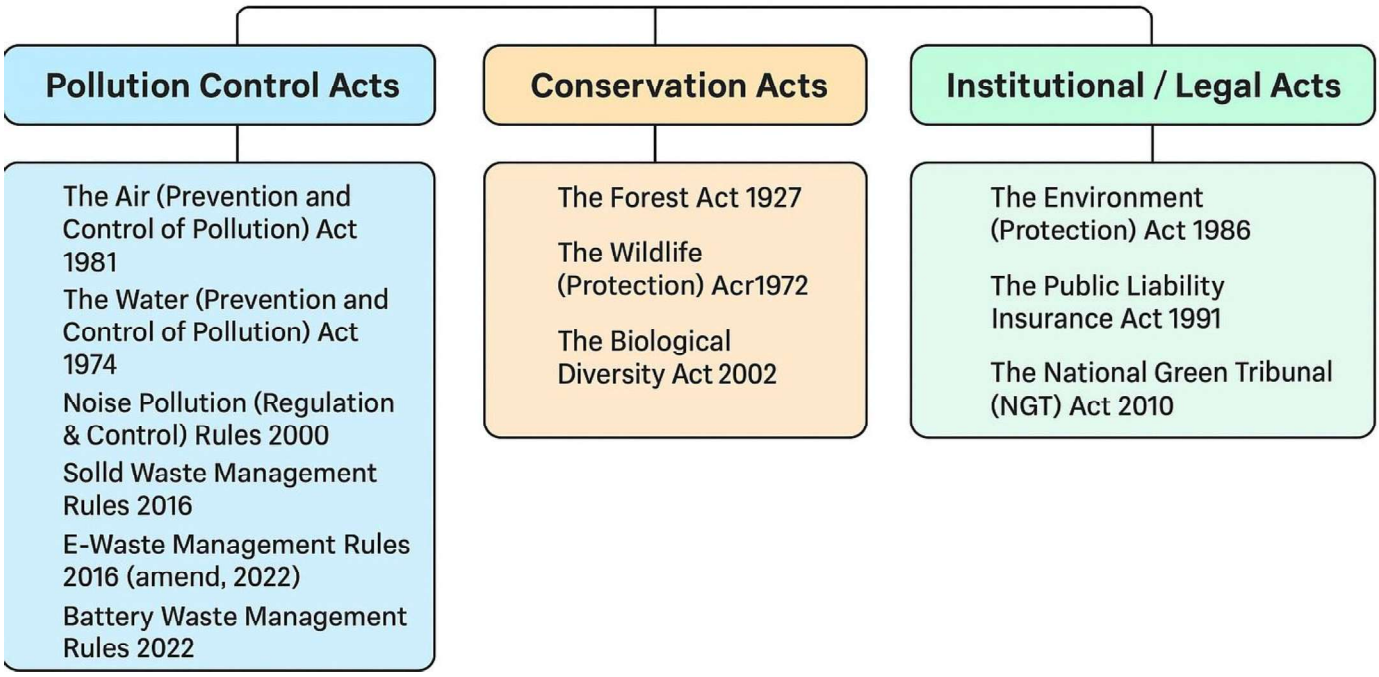
(a) CPCB Ambient Noise Standards (2000):

Area Category	**Day Time** (6 AM – 10 PM)	**Night Time** (10 PM – 6 AM)
Industrial area	75 dB(A)	70 dB(A)
Commercial area	65 dB(A)	55 dB(A)
Residential area	55 dB(A)	45 dB(A)
Silence zone*	50 dB(A)	40 dB(A)

(b) WHO Environmental Noise Guidelines (2018):

- Long-term exposure above **55 dB (day)** or **40 dB (night)** linked to cardiovascular and sleep disorders.

Environmental Acts & Rules in India



1. The Environment (Protection) Act, 1986:

1. Background and Introduction

Enacted: 23rd May 1986
Came into Force: 19th November 1986
Context: Passed after the **Bhopal Gas Tragedy (1984)** to provide a stronger legal framework for environmental protection.
Nature: An **umbrella legislation** covering all aspects of environment (air, water, land, noise, hazardous waste).
Chapters & Sections: 4 chapters and 26 sections

2. Objectives

To **protect and improve** the quality of the environment.
To implement decisions of the **1972 Stockholm Conference** on the human environment.
To empower the **Central Government** for nationwide control of pollution.

3. Key Definitions

- **Environment:** Includes air, water, land, and their interactions with living beings.
- **Pollution:** Presence of harmful environmental pollutants.
- **Hazardous Substance:** Substances harmful due to chemical or physical properties.

4. Powers of Central Government

Set **environmental quality standards** (e.g., air quality standards).
Restrict or prohibit industries in **ecologically sensitive areas**.
Regulate **handling of hazardous substances**.
Conduct **inspections** and order closure of polluting industries.

5. Key Provisions

No discharge/emission of pollutants beyond prescribed limits.
Mandatory safeguards for **hazardous waste handling**.
Power to issue **directions and take samples**.
Penalties: Up to **5 years imprisonment or ₹1 lakh fine** (can extend to 7 years for continued violations).

6. Relation with Other Acts & Rules

The Act provides legal support for framing of several rules:
EIA Notification, 2006
Solid Waste Management Rules, 2016
Plastic Waste Management Rules, 2016
Noise Pollution (Regulation and Control) Rules, 2000

7. Institutions Empowered

MoEFCC (Ministry of Environment, Forest and Climate Change) → policy making.
CPCB (Central Pollution Control Board) → national monitoring & enforcement.
SPCBs (State Pollution Control Boards) → state-level implementation.

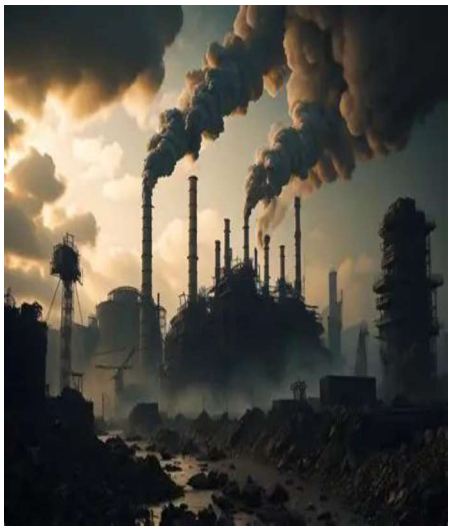
8. Examples (Practical Relevance)

Closure of polluting tanneries near the Ganga under this Act.
Ban on single-use plastics (2022) framed under this Act.
Air quality management in Delhi NCR (GRAP) implemented under this Act.

9. Importance for Students & Engineers

Provides **legal framework** for industries and projects.
Ensures compliance with **Environmental Impact Assessment (EIA)**.
Engineers must design **pollution control systems** keeping standards of this Act in mind.

2.The Air (Prevention and Control of Pollution) Act, 1981:



Enacted: 29 March 1981
Came into Force: 16th May 1981
Comprises: 7 chapters and 54 sections

Purpose:
- ✓ Enacted to prevent, control, and abate air pollution in India.
- ✓ Implements decisions from the 1972 UN Conference on Human Environment (Stockholm).

Scope:
- ✓ Applicable throughout India.
- ✓ Provides for the establishment of **Central** and **State Pollution Control Boards**.

Key Definitions:
Air Pollutant: Harmful solid, liquid, or gaseous substances (including noise).
Air Pollution: Presence of air pollutants in the atmosphere.
Control Equipment: Devices for managing emissions from industrial sources.

Structure and Powers under the Act:

Boards Established:

- **Central Pollution Control Board (CPCB):** Coordinates nationwide air quality programs, sets air quality standards, and advises the central government, as well as coordinates with State Boards.
- **State Pollution Control Boards (SPCBs):** Implement policies and pollution control programs, monitor emission standards for industries and vehicles, inspect pollution control areas and equipment, approve fuel appliances, and advise state governments.

Key Functions:

✓ Lay down emission standards.
✓ Inspect industrial plants.
✓ Restrict operations without prior consent in pollution control areas.
✓ Establish air quality monitoring labs.

Enforcement & Penalties:

- Declaration of air pollution control areas.
- Restrictions on industrial plant operations without consent.
- Penalties for violations: imprisonment & fines.
- Power to inspect, seize, and issue directions.

3. The Water (Prevention and Control of Pollution) Act, 1974:

Enacted: March 23, 1974
Comprises: 8 chapters and 64 Sections
Purpose:

- Prevent and control water pollution.
- Maintain or restore the wholesomeness of water.
- Establish Central, State Pollution Control Boards and Joint Board.

Applicability:

- Initially applied to select states and Union Territories.
- Other states can adopt via resolution under Article 252 of the Constitution.

Key Definitions:
Pollution: Contamination that renders water harmful.
Board: Central or State Pollution Control Board.
Stream: Includes rivers, watercourses, inland waters, and other bodies of water.

Powers and Functions of the Boards:

Central Pollution Control Board (CPCB):

- Advises Central Government.
- Coordinates among State Boards.
- Develops nationwide programs.
- Lays down standards for water quality.

State Pollution Control Boards (SPCBs):

- Advise State Governments.
- Grant/deny consent for industrial discharges.
- Inspect, sample, and analyze effluents.
- Lay down effluent and water quality standards.

Penalties for Violations:

- Imprisonment (1.5–6 years) and fines for illegal discharges.
- Additional penalties for continued non-compliance.

4. Noise Pollution (Regulation and Control) Rules, 2000

Enacted: **Year-** 2000
Under: Environment (Protection) Act, 1986

Objectives / Purpose:

To **regulate and control noise pollution** in India.
To maintain **ambient air quality standards in respect of noise**.
To **safeguard public health and well-being** from harmful effects of noise.

Scope:

Applicable **throughout India**.
Covers **industrial, commercial, residential, and silence zones**.

Key Definitions:

Ambient Noise: The sound level of a total environment (background + specific sources).
Silence Zone: Areas up to **100 m around hospitals, schools, courts, religious places**.
Authority: District Magistrate/Police Commissioner responsible for enforcement.

Provisions under the Rules:

Restriction on loudspeakers / public address systems:

Not allowed between **10:00 PM to 6:00 AM** (except in emergencies & specific cultural/religious exemptions).

Firecrackers and construction activity:

Time restrictions to limit public nuisance.

Silence Zones:

Special restrictions near **hospitals, schools, religious institutions, and courts**.

State Governments' Role:

May permit use of loudspeakers during **festivals** (up to midnight, max 15 days/year).

Enforcement & Penalties:

Authorities: District Magistrate / Police Commissioner.

Penalties (as per EPA, 1986):

Imprisonment up to **5 years** or fine up to **₹1 lakh** (extendable to 7 years for continued violation).

5.The Forest Act, 1927:

Enacted: **25th October, 1927**
Comprises: 13 chapters and 133 sections
Purpose of the Act:

- ❖ Consolidate forest laws.
- ❖ Regulate forest-produce & transit.
- ❖ Impose duties on timber.
- ❖ Define forest-related offenses.

Types of Forests under the Act:

- ❑ **Reserved Forests** (Chapter II):
  - Maximum control, the state government owns rights.
  - Forest Settlement Officer resolves local claims.
- ❑ **Village Forests** (Chapter III):
  - Rights given to village communities.
  - The State defines rules for usage and protection.
- ❑ **Protected Forests** (Chapter IV):
  - Lesser control than reserved forests.
  - Government regulates land use and vegetation clearance.

Drawbacks of the 1927 Act:

- Focused on **revenue generation** rather than conservation
- **Forest dwellers & tribes deprived** of traditional rights
- Over-empowerment of forest officials

Post-Independence Reforms:

- **Forest Conservation Act, 1980**: Restricted deforestation, emphasized sustainable use
- **National Forest Policy, 1988**: Shift from commercial use to ecological conservation
- **Forest Rights Act, 2006**: Restored rights of tribal and traditional forest dwellers.

6.The Wild Life (Protection) Act, 1972:

Enacted: **9th September, 1972**
Comprises: 8 Chapters and 60 Sections

- Extends to the whole of India, except Jammu and Kashmir.
- It has six schedules which give varying degrees of protection.

Purpose of the act:
- Landmark legislation for the conservation of wildlife in India.
- Aims to ensure ecological and environmental security.

Objectives:
- ✓ Protection of wild animals, birds & plants.
- ✓ Regulate & control hunting and poaching.
- ✓ Manage wildlife habitats and conserve biodiversity.
- ✓ Control illegal trade in wildlife & derivatives.
- ✓ Conserve endangered species.

Six Schedules of the Act

Schedule	Description	Level of Protection / Penalty	Examples
Schedule I	**Provides absolute protection to the listed species. Hunting and trade are strictly prohibited.**	**Highest level of protection. Harsh penalties for violation.**	**Bengal Tiger, Indian Elephant, Snow Leopard**
Schedule II	**Also provides high protection, though slightly lower than Schedule I.**	**High level of protection. Penalties similar to Schedule I.**	**Indian Cobra, Gaur (Indian Bison)**
Schedule III	**Animals protected, but with lesser degree of protection than Schedules I & II.**	**Moderate protection. Lower penalties compared to Schedule I & II.**	**Hyena, Nilgai (Blue Bull)**
Schedule IV	**Includes animals that are not endangered.**	**Protection is provided but with minimal penalties for violations.**	**Porcupine, Flying Fox**
Schedule V	**Lists animals that can be hunted. These are considered vermin.**	**No protection. Hunting permitted.**	**Common Crow, Fruit Bat, Rat, Mice**
Schedule VI	**Pertains to the protection of specified endangered plant species.**	**Prohibits cultivation and planting of listed species without permission.**	**Pitcher Plant, Red Vanda (an orchid species)**

Key Provisions:

1. Protected Areas:
- **Sanctuaries (Sec. 18):** Protected from hunting/grazing.
- **National Parks (Sec. 35):** Higher protection level.
- **Reserves (Sec. 36A & 36C):** Community involvement.

2. Regulation of Hunting (Sec. 9–12):
➢ Prohibits hunting endangered species.
➢ Permits hunting in special circumstances.

3. Trade & Commerce (Sec. 39–49):
✓ Wildlife property belongs to the government.
✓ Ban on ivory trade.

Implementation, Challenges & Amendments

Implementation & Authorities:
Central: Director of Wildlife Preservation.
State: Chief Wildlife Warden, Wildlife Wardens.

Challenges:
Poaching & Illegal Trade.
Human-Wildlife Conflict.
Habitat Destruction.
Resource Constraints.

Key Amendments:
2002: National Board for Wildlife, stricter penalties.
2006: National Tiger Conservation Authority.
2013: Stronger anti-poaching laws.

Importance:
The Act provides a strong legal framework for wildlife protection, but success depends on robust enforcement, public participation, and continuous judicial oversight.

7. Solid Waste Management and Handling Rules, 2016:

Established: 25th September, 2000
Revised: 8th April, 2016
Issued by: Ministry of Environment, Forest and Climate Change
Applies to:

- ❑ Urban local bodies, census towns, notified areas, industrial townships, airpc SEZs, government bodies, places of pilgrimage, etc.
- ❑ All domestic, institutional, commercial, and non-residential waste generator

Key Definitions:

- **Solid Waste:** Includes domestic, sanitary, commercial, horticulture, street sweepings, etc.
- **Segregation:** Sorting into biodegradable, recyclable, hazardous, etc.
- **Waste Generator:** Any person or entity that generates solid waste.
- **Waste Hierarchy:** Prioritizes prevention → reduction → reuse → recycle - recovery → disposal.

Responsibilities & Implementation Framework:

Responsibilities:
Waste Generators: Segregate waste, pay user fees, and avoid littering/burning.
Local Bodies: Door-to-door collection; processing; landfill management; awareness.
State/UT Departments: Policy creation; land allocation; monitoring compliance.
Central Agencies (MoEFCC, CPCB, MoHUA): National policy, funding, monitoring, setting standards.

Implementation Timeline:
Site identification: **1 year**
Processing facilities for >1L population: **2 years**
Landfills, composting units, RDF plants: **2–3 years**
Bio-mining/capping of dumpsites: **5 years**

Monitoring & Reporting:
Annual reports by local bodies, SPCBs, CPCB.
Accident reporting protocols.
Central/State Monitoring Committees.

8. E-Waste Management Rules, 2016 (Amended 2022)

Introduction

E-waste = Waste electrical and electronic equipment (EEE) that has reached its end of life.
Includes: Computers, mobiles, TVs, refrigerators, washing machines, CFLs, LEDs, etc.
India is the **3rd largest e-waste generator** in the world (after China & USA).
Rules notified under the **Environment (Protection) Act, 1986**.

Objectives

Ensure **scientific collection, segregation, recycling, and disposal** of e-waste.
Promote **Extended Producer Responsibility (EPR)**.
Reduce environmental and health risks from **toxic substances** (lead, mercury, cadmium, brominated flame retardants).
Encourage **recycling industry and circular economy**.

Scope

Applies to:

- **Producers** (manufacturers, importers, brand owners)
- **Consumers** (bulk & individual)
- **Dismantlers & Recyclers**

Covers **all electrical and electronic equipment (EEE)** listed in Schedule I.

Key Provisions (2016 Rules)

1.Extended Producer Responsibility (EPR):

1. Producers responsible for **collection and channelization** of e-waste.
2. Must set up **take-back systems** or partner with authorized recyclers.

2.Collection Targets:

1. Initially **30% of EEE sold** (first 2 years).
2. Increased **10% every 2 years** up to **70%**.

3.Role of Consumers:

1. Bulk consumers must **maintain records** of e-waste generated.
2. Deposit e-waste only with authorized recyclers/dismantlers.

4.Dismantlers/Recyclers:

1. Must obtain authorization from SPCB.
2. Ensure **environmentally sound recycling**.

Amendments (2022)

Introduced **Online Portal for EPR Registration & Monitoring**.
EPR targets linked to **weight of EEE** produced/sold.
Producers can meet targets by purchasing **EPR Certificates** from registered recyclers.
Pan-India system of collection & tracking via CPCB.
Provisions for **refurbishers** added to extend product life.

E-Waste Generation in India

•India generated **1.7 million tonnes (2021-22)** of e-waste.
•**70% from 21 major EEE categories** (computers, telecom equipment, consumer electronics).
•Only **~20% recycled** formally; rest handled by informal sector.

Enforcement & Penalties

Regulatory Authority: CPCB & SPCBs.
Penalty: Non-compliance may attract fines under EPA, 1986.
Producers failing to meet targets → liable for **environmental compensation**.

Environmental & Health Impacts

Improper recycling (informal sector): open burning, acid leaching → soil, water, air pollution.
Toxics: lead (neurological damage), mercury (brain/kidney damage), cadmium (cancer), brominated flame retardants (endocrine disruption).
Benefits of Recycling: recovery of **precious metals** (gold, silver, palladium, copper).

9. Plastic Waste Management Rules, 2016 (Amended 2022)

Introduction

Plastic = synthetic polymer, versatile but **non-biodegradable**.
India generates **3.4 million tonnes/year (CPCB 2019 report)**, with only ~60% recycled.
Major concern: **single-use plastics (SUPs)** → littering, clogging drains, harming animals, microplastics in soil & water.
Rules notified under the **Environment (Protection) Act, 1986**.

Objectives

Promote **scientific management of plastic waste**.
Eliminate **single-use plastics (SUPs)**.
Strengthen **Extended Producer Responsibility (EPR)**.
Encourage **recycling, reuse, and alternatives** (biodegradable plastics, cloth/jute bags).

Scope

Applies to:

- **Producers, Importers & Brand Owners (PIBOs)**
- **Waste Generators (consumers, institutions, shops, street vendors)**
- **Local Bodies (Municipalities, Panchayats)**
- **Plastic Waste Processors (recyclers, co-processors, waste-to-energy units)**

Key Provisions (2016 Rules)

1.Ban on Plastic Carry Bags < 50 microns:

1. To increase recyclability and collection efficiency.

2.Extended Producer Responsibility (EPR):

1. PIBOs responsible for collection and environmentally sound disposal of plastic waste.
2. Must submit EPR plan to CPCB/SPCB.

3.Segregation & Collection:

1. Local bodies must ensure door-to-door collection, segregation into wet, dry & domestic hazardous waste.

4.User Responsibility:

1. Shops/street vendors must not provide plastic carry bags free of cost.
2. Consumers encouraged to reduce & reuse.

Enforcement & Penalties

Regulatory Authority: CPCB & SPCBs.
Non-compliance: Environmental compensation under EPA, 1986.
Penalties include fines, cancellation of licenses for PIBOs.

Amendments (2022)

1.Ban on Single-Use Plastics (from 1 July 2022):

1. Banned items include: plastic straws, cutlery, plates, cups, wrapping films, earbuds, balloons sticks, cigarette packets.

2.EPR Guidelines Strengthened:

1. Producers/Importers/Brand Owners must meet annual EPR targets for collection & recycling.
2. Categories defined:
    1. **Category I:** Rigid plastics (bottles, containers)
    2. **Category II:** Flexible plastics (wrappers, pouches)
    3. **Category III:** Multilayered packaging
    4. **Category IV:** Compostable/biodegradable plastics

3.Plastic Waste Processing:

1. Allowed methods: recycling, co-processing in cement kilns, road construction (per IRC guidelines).

4.Phasing Out SUP:

1. Timeline for eliminating specific plastic items.

Environmental & Health Impacts

- **Improper disposal** → clogging of drains, urban flooding.
- **Wildlife impact**: animals ingest plastic → starvation, death.
- **Microplastics** in soil, rivers, oceans → enter food chain.
- **Burning plastics** → releases dioxins & furans (carcinogenic).

Management & Precautions

Promote **3R principle: Reduce – Reuse – Recycle**.
Develop **biodegradable alternatives** (PLA, starch-based plastics).
Use **Plastic Waste in Road Construction** (as per IRC guidelines).
Extended use of **deposit refund schemes** for PET bottles.
Awareness drives in schools, colleges, and industries.

10. The National Green Tribunal (NGT) Act, 2010

Introduction

Enacted: **2nd June 2010**
Came into Force: **18th October 2010**
Purpose: Establishment of a **specialized judicial body** for the effective and expeditious disposal of cases relating to environmental protection and conservation of forests and natural resources.
Legal Basis: Implemented under **Article 21 of the Constitution (Right to Life)** and principles of **sustainable development, precautionary principle, polluter-pays principle**.

Objectives of NGT

Provide a **fast-track mechanism** for environmental disputes.
Ensure **effective enforcement** of environmental laws.
Reduce the burden on regular courts.
Promote **environmental justice** and uphold citizens' rights to a healthy environment.

Jurisdiction & Scope

Deals with all civil cases relating to environment protection and conservation of forests & biodiversity.
Jurisdiction over matters under: The Water (Prevention and Control of Pollution) Act, 1974, The Air (Prevention and Control of Pollution) Act, 1981, The Environment (Protection) Act, 1986, The Forest (Conservation) Act, 1980, and The Biological Diversity Act, 2002
Excludes: Wildlife (Protection) Act, 1972 and Scheduled Tribes & Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006.

Structure of the Tribunal

•**Chairperson**: Retired Judge of the Supreme Court or Chief Justice of High Court.
•**Judicial Members**: Retired Judges of High Courts.
•**Expert Members**: Professionals with expertise in environmental management, science, or related fields.
•**Benches**: Principal Bench at **New Delhi**, with regional benches in **Chennai, Pune, Bhopal, and Kolkata**.

Powers & Functions

Adjudicatory Powers

Pass orders, awards, and relief for environmental damage.
Impose penalties on violators (polluter-pays principle).

Appellate Powers

Hears appeals against orders/decisions of regulatory authorities (e.g., CPCB, MoEF&CC).

Compensation

Grant relief & compensation to victims of pollution, accidents, or environmental harm.

Time-bound Justice

Aim to dispose of cases within **6 months**.

Penalties

Non-compliance with NGT orders = **up to 3 years imprisonment and/or fine up to ₹10 crore**.
For companies: fine may extend to **₹25 crore or more**.

Significance of NGT

- Provides **specialized expertise** compared to normal courts.
- Promotes **speedy justice** (reduces years-long delays).
- Implements **environmental governance** by integrating law, science, and policy.
- Ensures **public participation** in environmental protection (locus standi broadened).

Case Studies (Examples)

Sterlite Copper Plant, Tamil Nadu (2018):

NGT ordered reopening after closure by TN Govt, citing compliance.
Later Supreme Court upheld closure citing public health.

Yamuna Pollution Case:

NGT directed Delhi Govt. and agencies to stop direct sewage discharge.

Volkswagen Emissions (2019):

NGT fined Volkswagen ₹500 crore for environmental damage due to excess NOx emissions.