Air Pollution

Module 2

- **ENVIRONMENTAL POLLUTION (10 hours)**

- Water, air, soil, noise, thermal and radioactive, marine pollution: sources, effects and engineering control strategies. Drinking water quality and standards, Ambient air and noise quality standards

Content

- Air pollution definition
- Composition of air
- Sources
- Primary & Secondary air pollutant
- Criteria & Non criteria air pollutant
- Primary and secondary standards
- Health impacts of major pollutants
- Air quality monitoring
  - Manual
- Air Pollution Control

Definition

- Excessive concentration of foreign matters which adversely affects the well being of human/animals/ properties

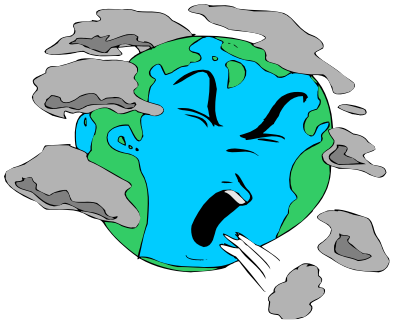
- Air pollution means the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odour, smoke or vapour in quantities with characteristics, and of durations such as to be injurious to human, plant or animal life or to property or which unreasonably interfere with the comfortable enjoyment of life and property- (**Engineers Joint Council)**

- Air pollution is the presence in ambient atmosphere of substances generally resulting from the activity of man, in sufficient concentration present for a sufficient time and under circumstances which interfere significantly with the comfort, health or welfare of persons or with the full use or enjoyment of property- **Indian Standards Institution IS-4167 (1996)**

- Air pollution is the excessive concentration of forigen matter in the air which adversely affects the well being of the individual or causes damage property-**American Medical Association**

COMPOSITIONS OF DRY ATMOSPHERIC AIR

Chemical compound	Concentration (ppm)[a]	Concentration ($\mu g/m^3$)[b]
Nitrogen (N_2)	780,000	8.95×10^8
Oxygen (O_2)	209,400	2.74×10^8
Argon (Ar)	9,300	1.52×10^7
Carbon dioxide (CO_2)	415	5.67×10^5
Neon (Ne)	18	1.49×10^4
Helium (He)	5.2	8.50×10^2
Methane (CH_4)	1.2	7.87×10^2
Krypton (Kr)	1.0	3.43×10^3
Hydrogen (H_2)	0.5	4.13×10^1
Xenon (Xe)	0.08	4.29×10^2
Nitrous oxide (N_2O)	0.5	9.00×10^2
Ozone (O_3)	0.01-0.04	$1.96 \times 10^1 - 7.84 \times 10^1$



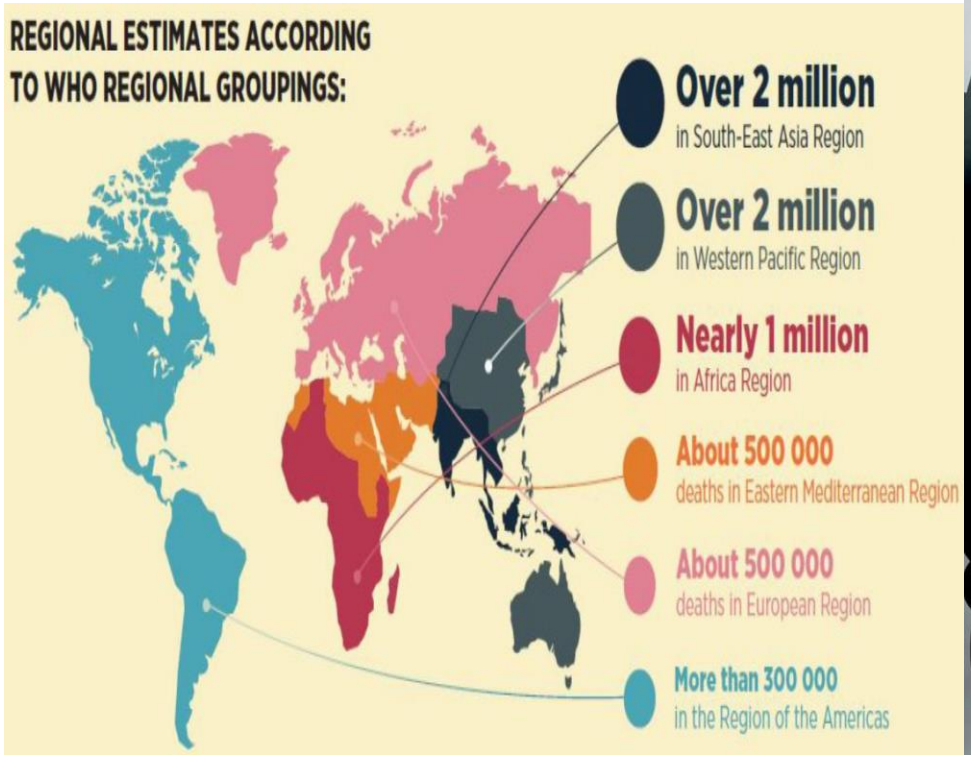
[a] parts per million; [b] micrograms per cubic meter

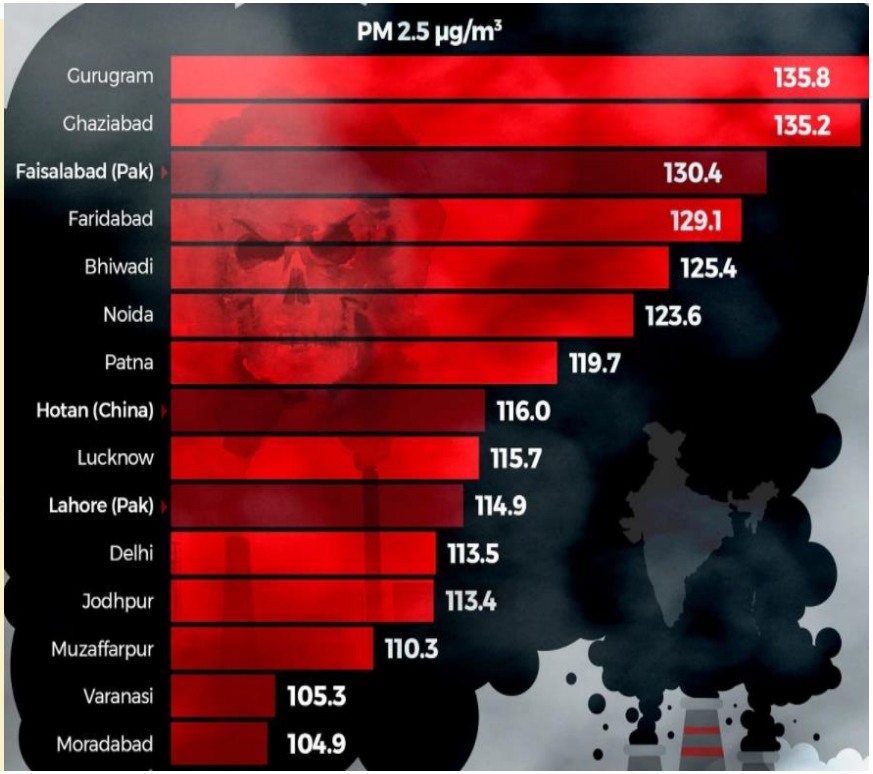
Impact of Air Pollution

- The World Health Organization states that 7 million people die each year from causes directly attributable to outdoor air pollution.
- Many of these mortalities are attributable to indoor air pollution.
- Worldwide more deaths per year are linked to air pollution than to automobile accidents.
- World Health Organization: The European Union could save up to 161 billion euros a year by reducing deaths caused by air pollution.
- Over 80% of lung getting damaged by particulate matter.

Impact of Air Pollution

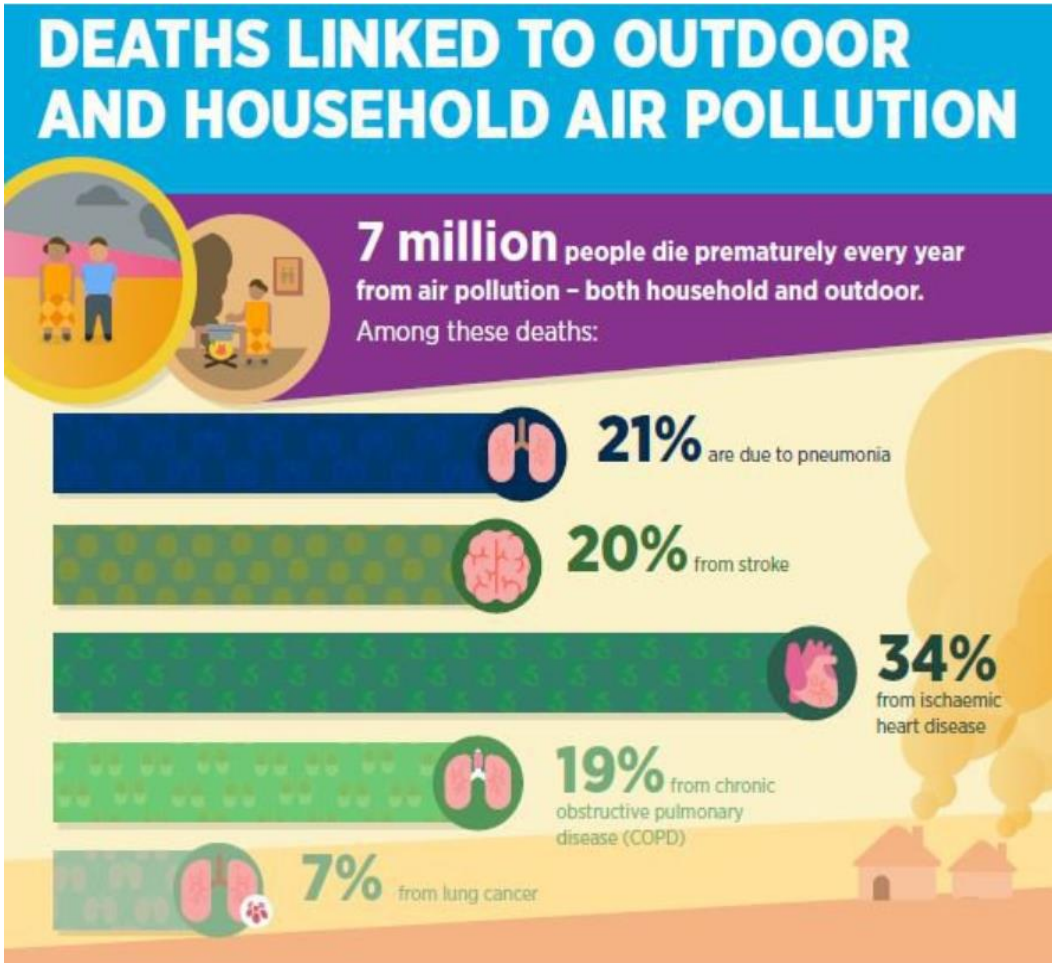
- Air Pollution: World's Biggest Environmental Killer (WHO, 2014).
- 9 out of 10 people worldwide breathe polluted air
- 12 out of 15 cities worst polluted cities across the world is from India





Source : WHO

Impact of Air Pollution

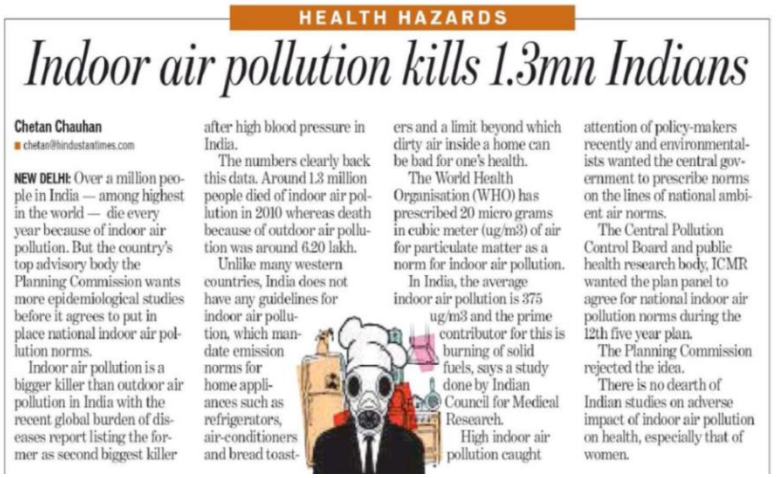


Source : WHO

Ambient air pollution alone caused some **4.2 million deaths in 2016**

Indoor air pollution estimated **3.8 million deaths** in the same period.

More than 90% of air pollution-related deaths occur in low- and middle-income countries, mainly in Asia and Africa



HEALTH HAZARDS

Indoor air pollution kills 1.3mn Indians

Chetan Chauhan
chetan@hindustantimes.com

NEW DELHI: Over a million people in India — among highest in the world — die every year because of indoor air pollution. But the country's top advisory body the Planning Commission wants more epidemiological studies before it agrees to put in place national indoor air pollution norms.

Indoor air pollution is a bigger killer than outdoor air pollution in India with the recent global burden of diseases report listing the former as second biggest killer after high blood pressure in India.

The numbers clearly back this data. Around 1.3 million people died of indoor air pollution in 2010 whereas death because of outdoor air pollution was around 6.20 lakh.

Unlike many western countries, India does not have any guidelines for indoor air pollution, which mandate emission norms for home appliances such as refrigerators, air-conditioners and bread toasters and a limit beyond which dirty air inside a home can be bad for one's health.

The World Health Organisation (WHO) has prescribed 20 micro grams in cubic meter (ug/m3) of air for particulate matter as a norm for indoor air pollution.

In India, the average indoor air pollution is 375 ug/m3 and the prime contributor for this is burning of solid fuels, says a study done by Indian Council for Medical Research.

High indoor air pollution caught attention of policy-makers recently and environmentalists wanted the central government to prescribe norms on the lines of national ambient air norms.

The Central Pollution Control Board and public health research body, ICMR wanted the plan panel to agree for national indoor air pollution norms during the 12th five year plan.

The Planning Commission rejected the idea.

There is no dearth of Indian studies on adverse impact of indoor air pollution on health, especially that of women.

Source of Pollutants

- Natural sources
  - sand/dust storms
  - volcanoes
  - forest fires
  - gases produced by decaying organisms
- Human activity

Sandstorm

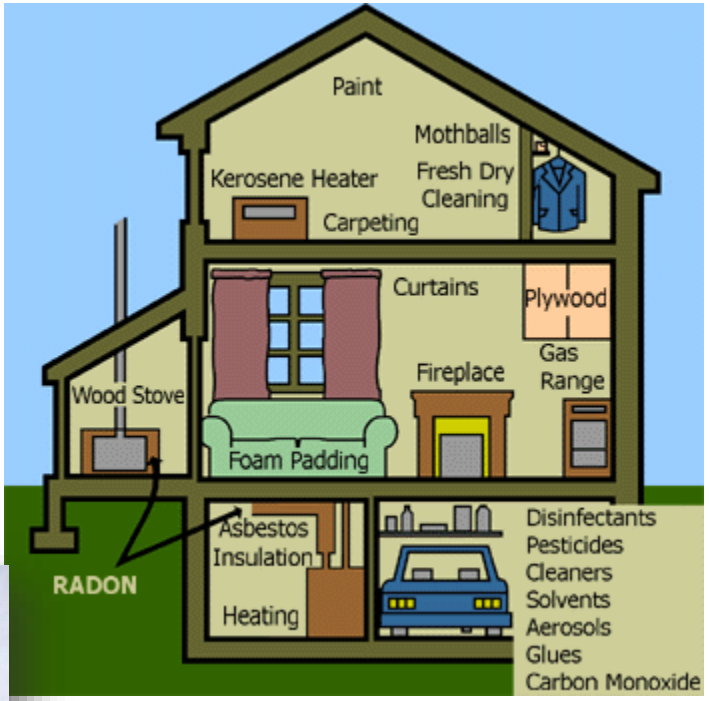
Anthropogenic Source of Pollutants

Human activity

- "Stationary Sources" as smoke stacks of power plants, manufacturing facilities, municipal waste incinerators
- "Mobile Sources" as motor vehicles, aircraft etc.
- Combustion-fired power plants
- Controlled burn practices used in agriculture and forestry management
- Motor vehicles generating air pollution emissions.
- Burning wood, fireplaces, stoves, furnaces and incinerators
- Fumes from paint, hair spray, varnish, aerosol sprays and other solvents.

Human Activity

Indoor pollutants



Classification of Pollutants

Primary Pollutant:

- Primary pollutants are substances directly emitted from source; such as ash from a volcanic eruption or the carbon monoxide gas from a motor vehicle exhaust.

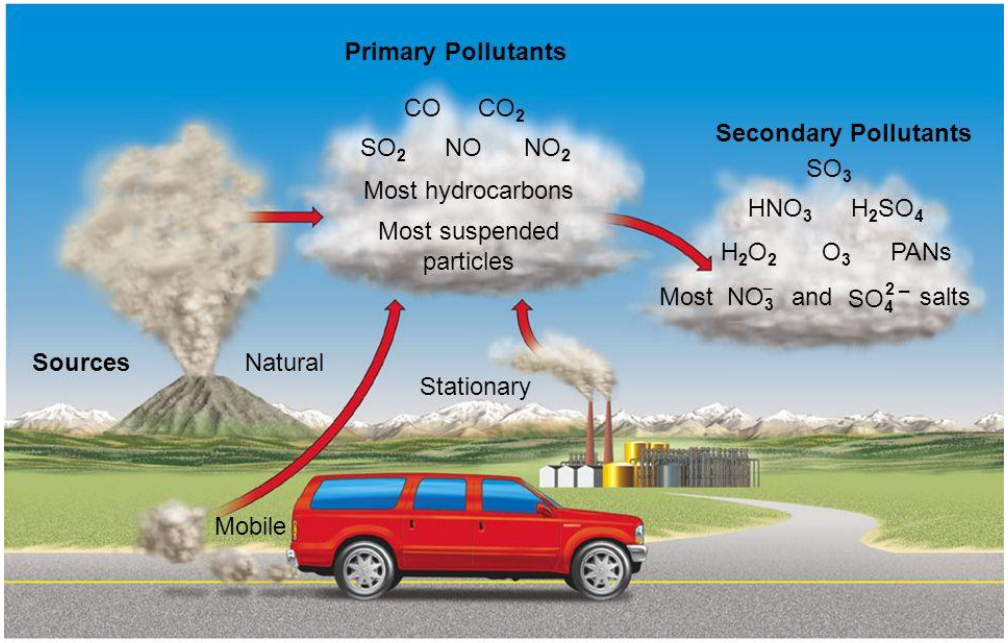
Materials that when released pose health risks in their unmodified forms or those emitted directly from identifiable sources.

Five major materials released directly into the atmosphere in unmodified forms.
-Carbon monoxide
-Sulfur dioxide
-Nitrogen oxides
-Hydrocarbons
-Particulate matter

Classification of Pollutants

Secondary Pollutant:

- Secondary pollutants not emitted directly.
- Rather, they form in the air when primary pollutants react or interact.
- An important example of a secondary pollutant is ground level ozone - one of the many secondary pollutants that make up photochemical smog.



Primary vs. Secondary

Criteria Air Pollutants

Environmental Protection Agency calls 6 pollutants "criteria" air pollutants because it regulates them by developing human health-based and/or environmentally-based criteria (**science-based guidelines**) for **setting permissible levels**.

Based on health effects with measured air quality levels that violate the National Ambient Air Quality Standards (NAAQS)

1. Carbon monoxide (CO)
2. Lead (Pb)
3. Ground level ozone
4. Particulate matter
5. Nitrogen oxides (Nox)
6. Sulfur oxides (Sox)

Criteria pollutants

Pollutant	Description	Sources	Health Effects
Carbon Monoxide (CO)	Colorless, odorless gas	Motor vehicle exhaust, indoor sources include kerosene or wood burning stoves.	Headaches, reduced mental alertness, heart attack, cardiovascular diseases, impaired fetal development, death, Contribute to the formation of smog.
Sulfur Dioxide (SO_2)	Colorless gas that dissolves in water vapor to form acid, and interact with other gases and particles in the air.	Coal-fired power plants, petroleum refineries, manufacture of sulfuric acid and smelting of ores containing sulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage, contribute to formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.

Pollutant	Description	Sources	Health Effects
Nitrogen Dioxide (NO_2)	Reddish brown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing),contribute to formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O_3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage, plant and ecosystem damage.

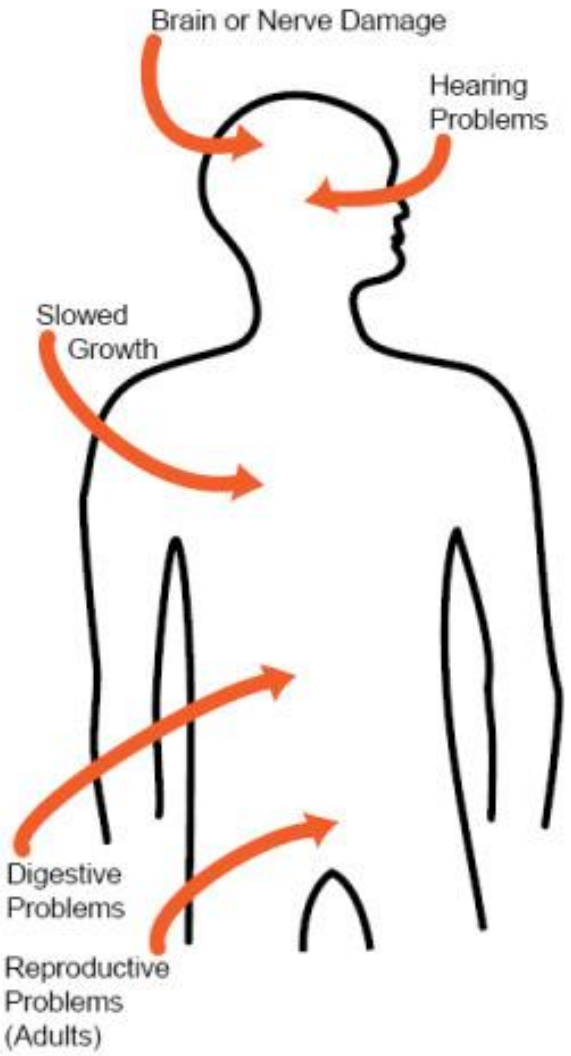
Pollutant	Description	Sources	Health Effects
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ, affects animals and plants, aquatic ecosystem
Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning, cardiovascular effects, Visibility impairment, atmospheric deposition, aesthetic damage

Lead

- As a result of EPA's regulatory efforts including the removal of lead from motor vehicle gasoline, levels of lead in the air decreased by **98** percent between 1980 and 2014.

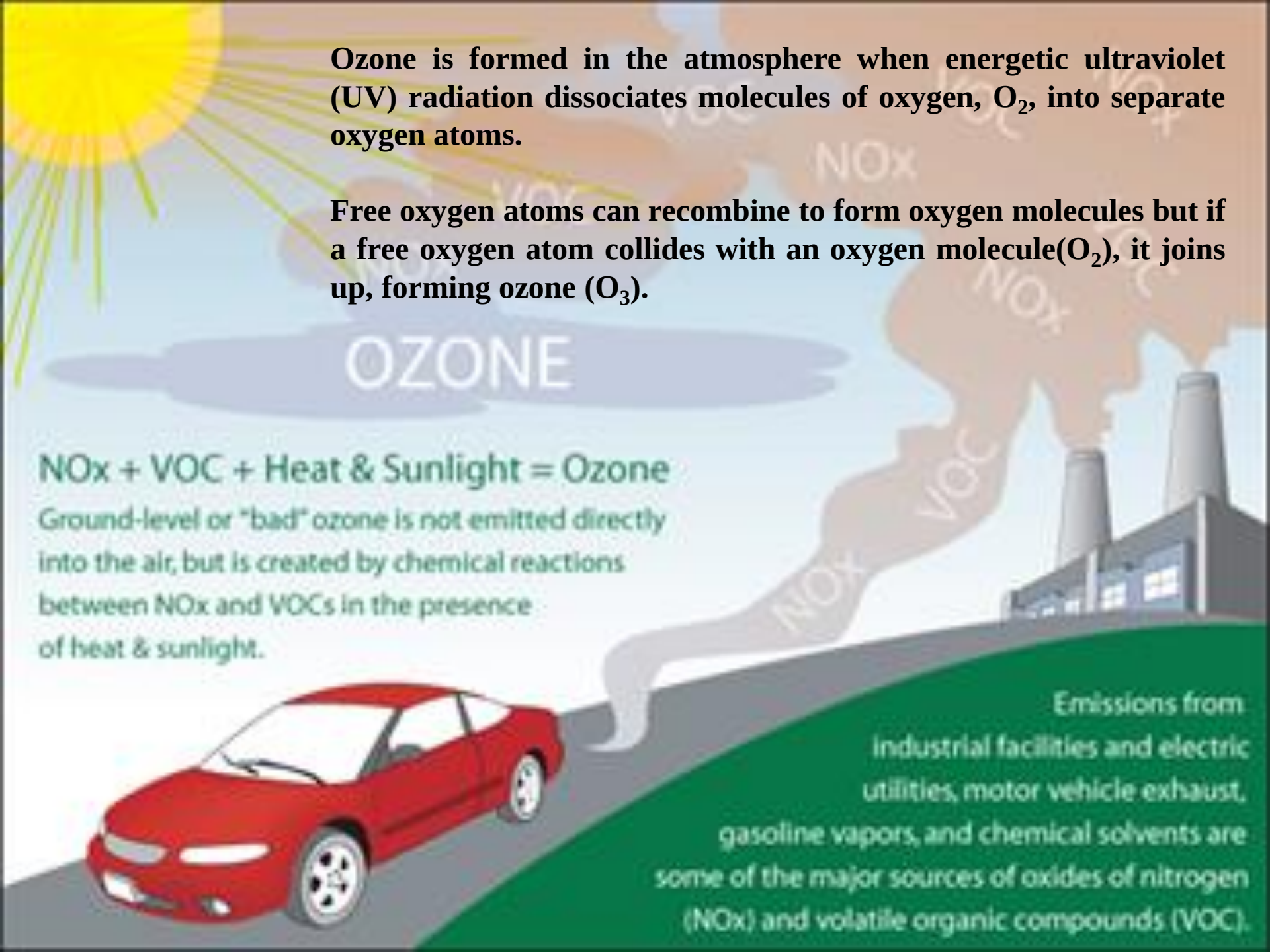
Lead

- Once taken into the body, lead distributes throughout the body in the blood and is accumulated in the bones.
- Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system.
- Lead exposure also affects the oxygen carrying capacity of the blood.

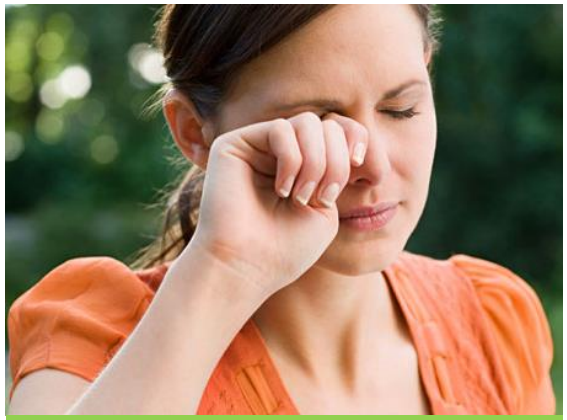


Ozone is formed in the atmosphere when energetic ultraviolet (UV) radiation dissociates molecules of oxygen, O_2, into separate oxygen atoms.

Free oxygen atoms can recombine to form oxygen molecules but if a free oxygen atom collides with an oxygen molecule(O_2), it joins up, forming ozone (O_3).



Ozone and particle pollution



Can cause eye, nose & throat

Can cause coughing & difficulty breathing

Can trigger asthma attacks

Can affect the development of children's lungs

Can cause heart disease, abnormal heart rhythms, congestive heart failure, stroke, & premature death

Sulfur dioxide

- At high concentrations, gaseous SO_2 can harm trees and plants by damaging foliage and decreasing growth and can contribute to acid rain which can harm sensitive ecosystems.
- Short-term exposures to SO_2 can harm the human respiratory system and make breathing difficult. Children, the elderly, and those who suffer from asthma are particularly sensitive to effects of SO_2.

SO_2

Air quality standards

Ambient Standards

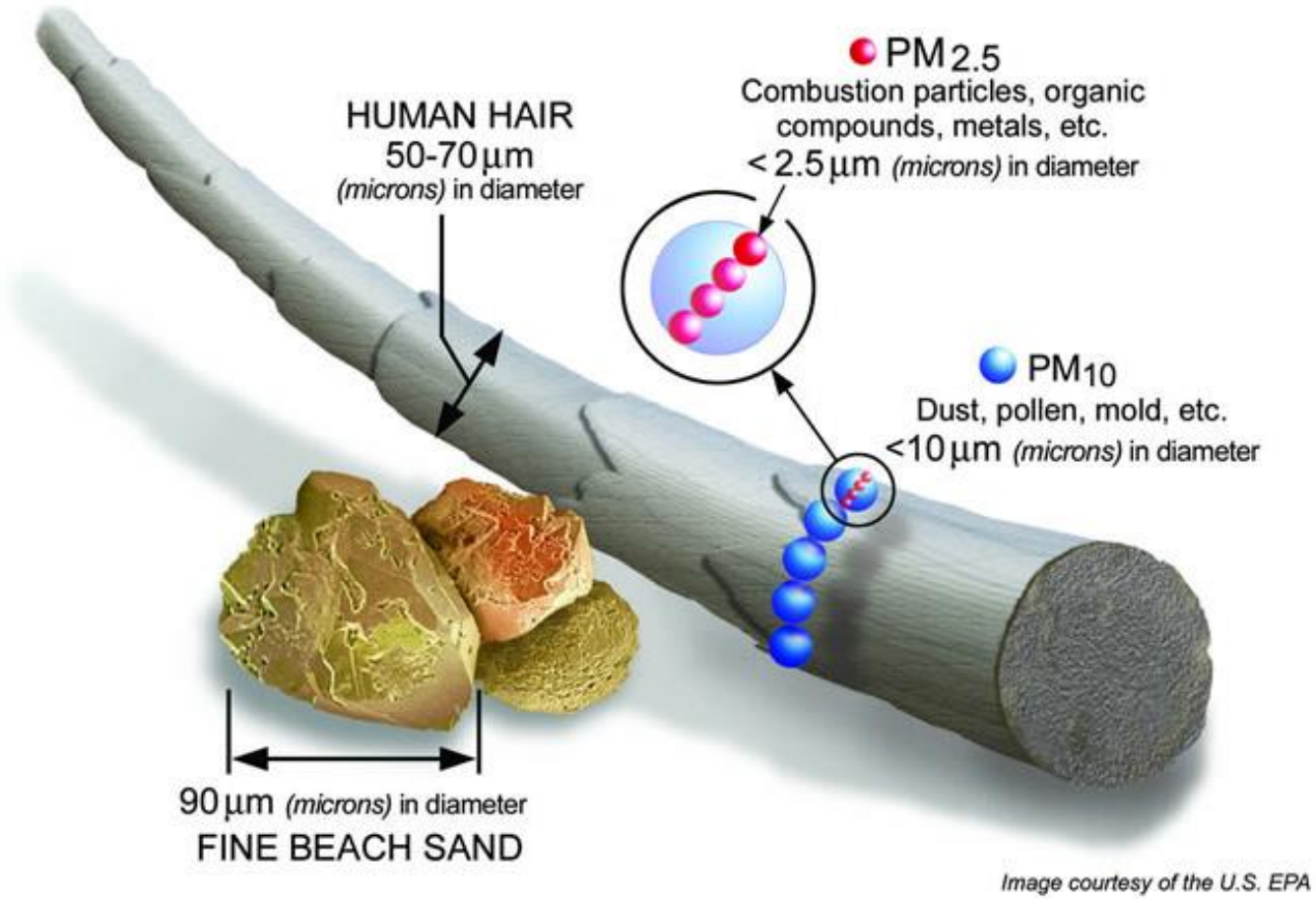
- ***Primary standards*** provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly (EPA)
- ***Secondary standards*** provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings (EPA)

Particulate Matter

- Sea salt, soil dust, volcanic particles, smoke from forest fires account for particulate emissions each year.
- Small particles are removed from the atmosphere by accretion to water droplets, which grow in size until they are large enough to precipitate.
- Larger particles are removed by direct washout by falling raindrops.

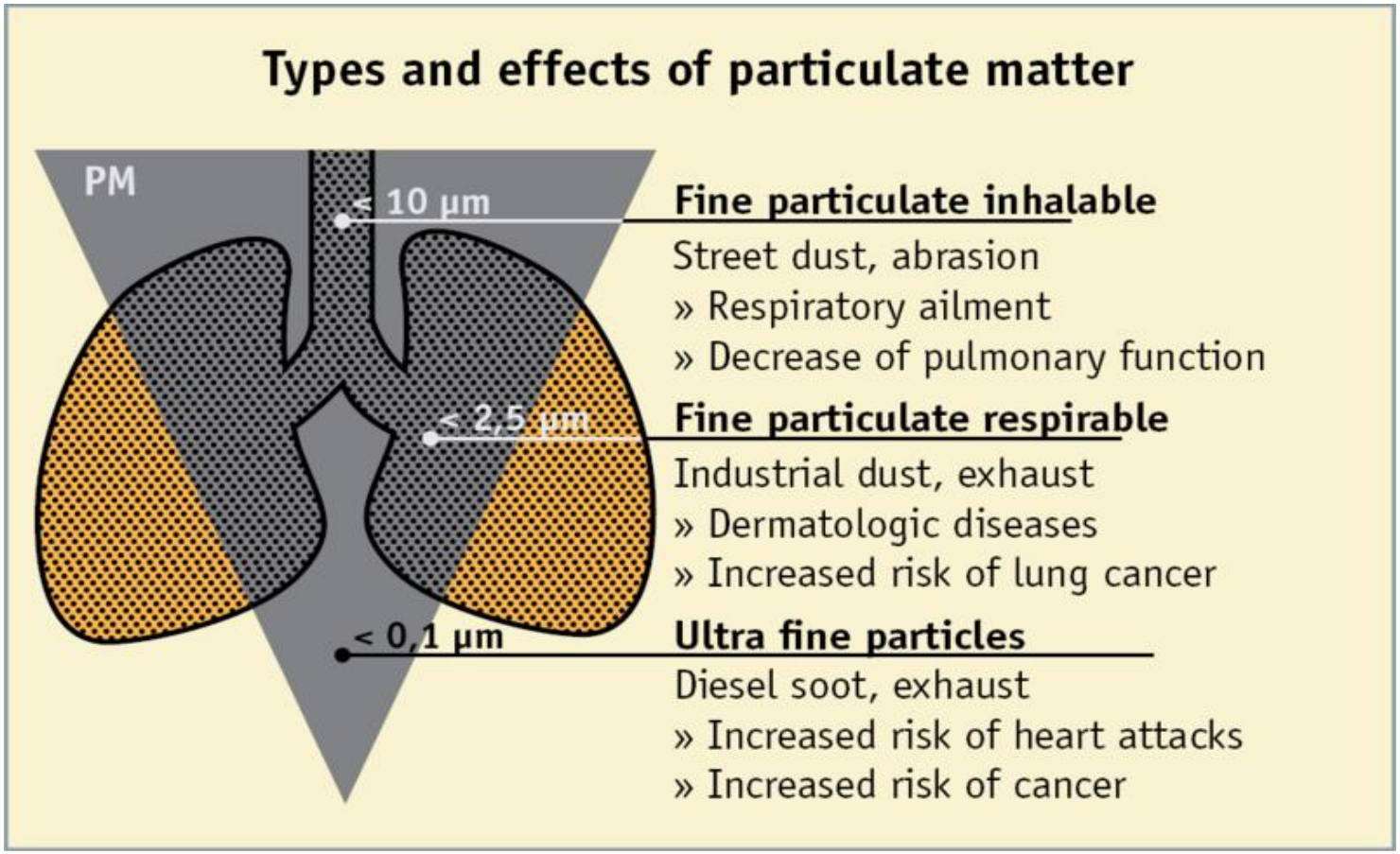
PARTICULATE MATTER: WHAT IS IT?

A complex mixture of extremely small particles and liquid droplets.

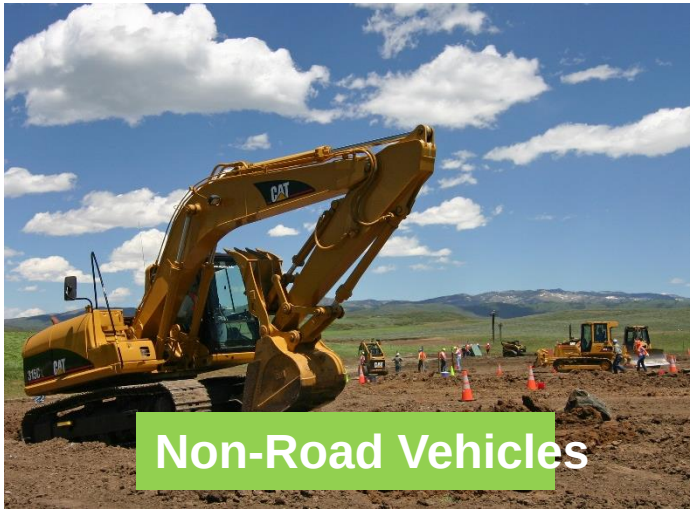


Particulate Matter

Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems.



Fine and Coarse Particles Can Be Emitted Directly or Formed in the Air from Gases



NATIONAL AMBIENT AIR QUALITY STANDARDS

S. No.	Pollutant	Time Weighted Average	Concentration in Ambient Air		
			Industrial, Residential, Rural and Other Area	Ecologically Sensitive Area (notified by Central Government)	Methods of Measurement
(1)	(2)	(3)	(4)	(5)	(6)
1	Sulphur Dioxide (SO_2), $\mu g/m^3$	Annual*	50	20	- Improved West and Gaeke
		24 hours**	80	80	-Ultraviolet fluorescence
2	Nitrogen Dioxide (NO_2), $\mu g/m^3$	Annual*	40	30	- Modified Jacob & Hochheiser (Na-Arsenite)
		24 hours**	80	80	- Chemiluminescence
3	Particulate Matter (size less than 10µm) or PM_{10} $\mu g/m^3$	Annual*	60	60	- Gravimetric - TOEM
		24 hours**	100	100	- Beta attenuation
4	Particulate Matter (size less than 2.5µm) or $PM_{2.5}$ $\mu g/m^3$	Annual*	40	40	- Gravimetric - TOEM
		24 hours**	60	60	- Beta attenuation
5	Ozone (O_3) $\mu g/m^3$	8 hours**	100	100	- UV photometric - Chemileninescence
		1 hour**	180	180	- Chemical Method
6	Lead (Pb) $\mu g/m^3$	Annual*	0.50	0.50	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper
		24 hours**	1.0	1.0	- ED-XRF using Teflon filter
7	Carbon Monoxide (CO) mg/m^3	8 hours**	02	02	- Non Dispersive Infra Red (NDIR) spectroscopy
		1 hour**	04	04	
8	Ammonia (NH_3) $\mu g/m^3$	Annual*	100	100	-Chemiluminescence
		24 hours**	400	400	-Indophenol blue method

(1)	(2)	(3)	(4)	(5)	(6)
9	Benzene (C_6H_6) $\mu g/m^3$	Annual*	05	05	- Gas chromatography based continuous analyzer - Adsorption and Desorption followed by GC analysis
10	Benzo(a)Pyrene (BaP) - particulate phase only, ng/m^3	Annual*	01	01	- Solvent extraction followed by HPLC/GC analysis
11	Arsenic (As), ng/m^3	Annual*	06	06	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper
12	Nickel (Ni), ng/m^3	Annual*	20	20	- AAS /ICP method after sampling on EPM 2000 or equivalent filter paper

* Annual arithmetic mean of minimum 104 measurements in a year at a particular site taken twice a week 24 hourly at uniform intervals.

** 24 hourly or 08 hourly or 01 hourly monitored values, as applicable, shall be complied with 98% of the time in a year. 2% of the time, they may exceed the limits but not on two consecutive days of monitoring.

Note. — Whenever and wherever monitoring results on two consecutive days of monitoring exceed the limits specified above for the respective category, it shall be considered adequate reason to institute regular or continuous monitoring and further investigation.

Clean Air Planning in India

A timeline of clean air planning in India.

Year	Action
1974	Central Pollution Control Board (CPCB) established under the water (prevention and control act)
1981	CPCB entrusted with the powers and functions under the Air (Prevention and Control of Pollution)
1986	CPCB adds provisions for environment (protection) act
April 1994	National ambient air quality standards were introduced
1997	MoEFCC prepared an action plan for controlling pollution in Delhi
January 1998	Environment Pollution (Prevention & Control) Authority (EPCA) established to address air pollution in the national capital region of Delhi
October 1998	National ambient air quality standards were revised
2003	Supreme court issued directives to prepare clean air plans for cities - Ahmedabad, Kanpur, Sholapur, Lucknow, Bangalore, Chennai, and Hyderabad to reduce RSPM levels.
2009	CPCB introduced the Comprehensive Environmental Pollution Index as a tool for environmental assessment on industrial clusters
November 2009	National ambient air quality standards were revised and $PM_{2.5}$ added to the list
January 2014	National air quality index (AQI) methodology was established
2015	CPCB issued directives under Air Act, 1981, for the implementation of 42 action points that includes control and mitigation measures in the major cities including Delhi and the National Capital Region (NCR)
April 2016	$PM_{2.5}$ is included for all manual stations under the national ambient monitoring programme (NAMP)
December 2016	Graded Response Action Plan (GRAP) established to address air pollution emergencies in NCR Delhi
April 2018	MoEFCC circulated a draft concept note of National Clean Air Programme (NCAP) with multiple time bound strategies to reduce air pollution
July 2018	102 non-attainment cities were announced under NCAP
October 2018	National Green Tribunal (NGT) directed the states and union territories with non-attainment cities under NCAP to prepare action plan
	EPCA reconstituted with new members from the government, academia, and civil society
January 2019	NCAP - a time-bound national level strategy to tackle increasing air pollution, was launched by MoEFCC
	Examination and approval of clean air plans by 3-member central committee was constituted
August 2019	Addition of 20 new non-attainment cities after NGT's intervention
2024	NCAP target to reduce $PM_{2.5}$ pollution in 122 non-attainment cities by 20–30%, compared to 2017 levels

Air Quality Monitoring

- At source- Source Monitoring
- Ambient Air quality Monitoring
- Indoor air quality monitoring
- Personal exposure monitoring

BENEFITS OF AIR QUALITY MONITORING

- Facilitate the background concentration(s) measurements,
- Monitor current levels as a baseline for assessment,
- Check the air quality relative to standards or limit values,
- Detect the importance of individual sources,
- Enable comparison of the air quality data from different areas and countries,
- Collect data for the air quality management,
- Traffic and land-use planning purposes,
- Observe trends (related to emissions),
- Develop abatement strategies,
- Determine the exposure and assess the effects of air pollution on health, vegetation or building materials,
- Inform the public about the air quality and raise the awareness,
- Develop warning systems for the prevention of undesired air pollution episodes,
- Facilitate the source apportionment and identification,
- Supply data for research investigations,
- Develop/validate management tools (such as models),
- Develop and test analytical instruments and to support legislation in relation to the air quality limit values and guidelines.

Air Pollution Monitoring

- At source- Source Monitoring
- Ambient Air quality Monitoring
- Indoor air quality monitoring
- Personal exposure monitoring

Air Pollution Control

- Atmospheric Cleaning Processes

1. Gravitational Settling
2. Absorption
3. Washout/Scavenging
4. Gases dissolve in water
5. Adsorption

Two broad approaches of cleaning

1. Dilution
2. Control at source- Process change, product change

Removal of particulate matter

Air pollution is minimized by

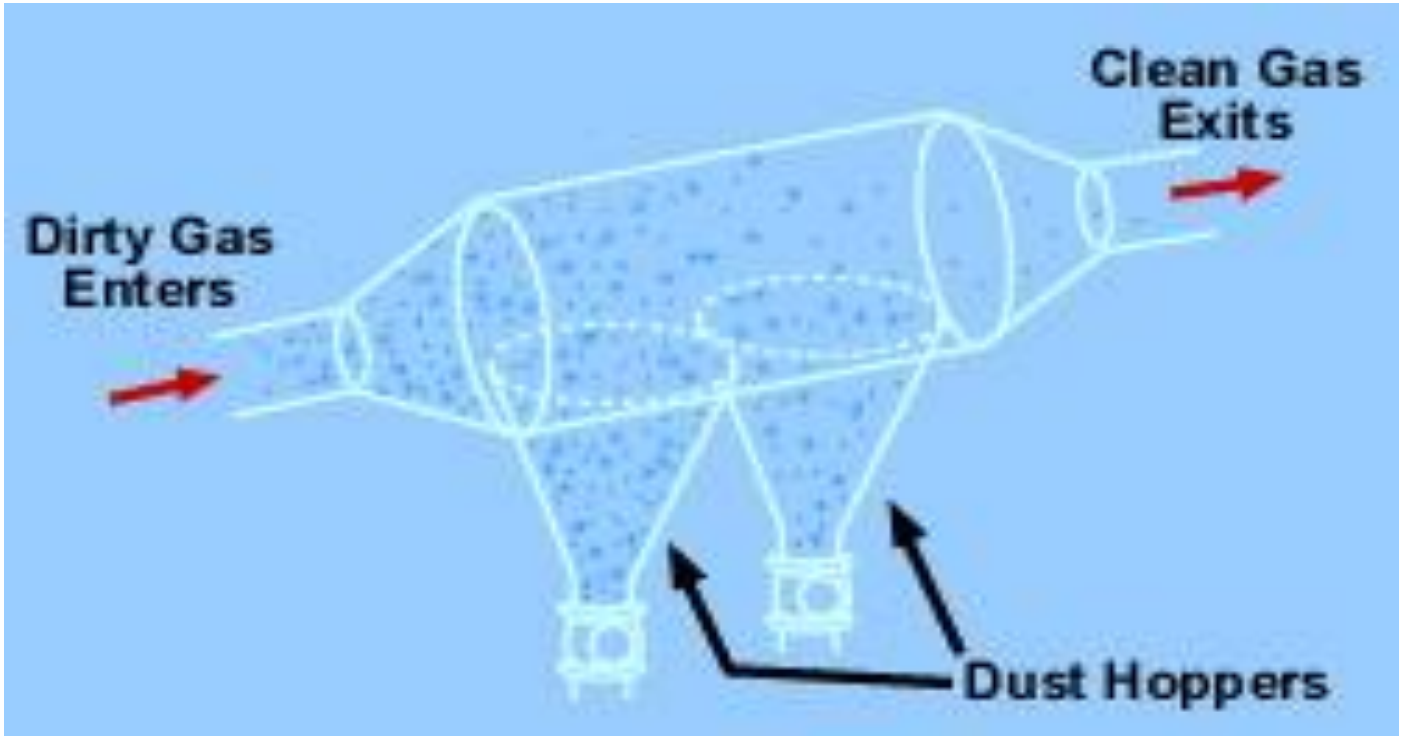
1. Selecting proper raw material.
2. Modifying the equipment.
3. Changing the process reaction.
4. Regulating or recovering the waste.
5. Changing the operational schedule.
6. Using proper control device

Choice of control equipment

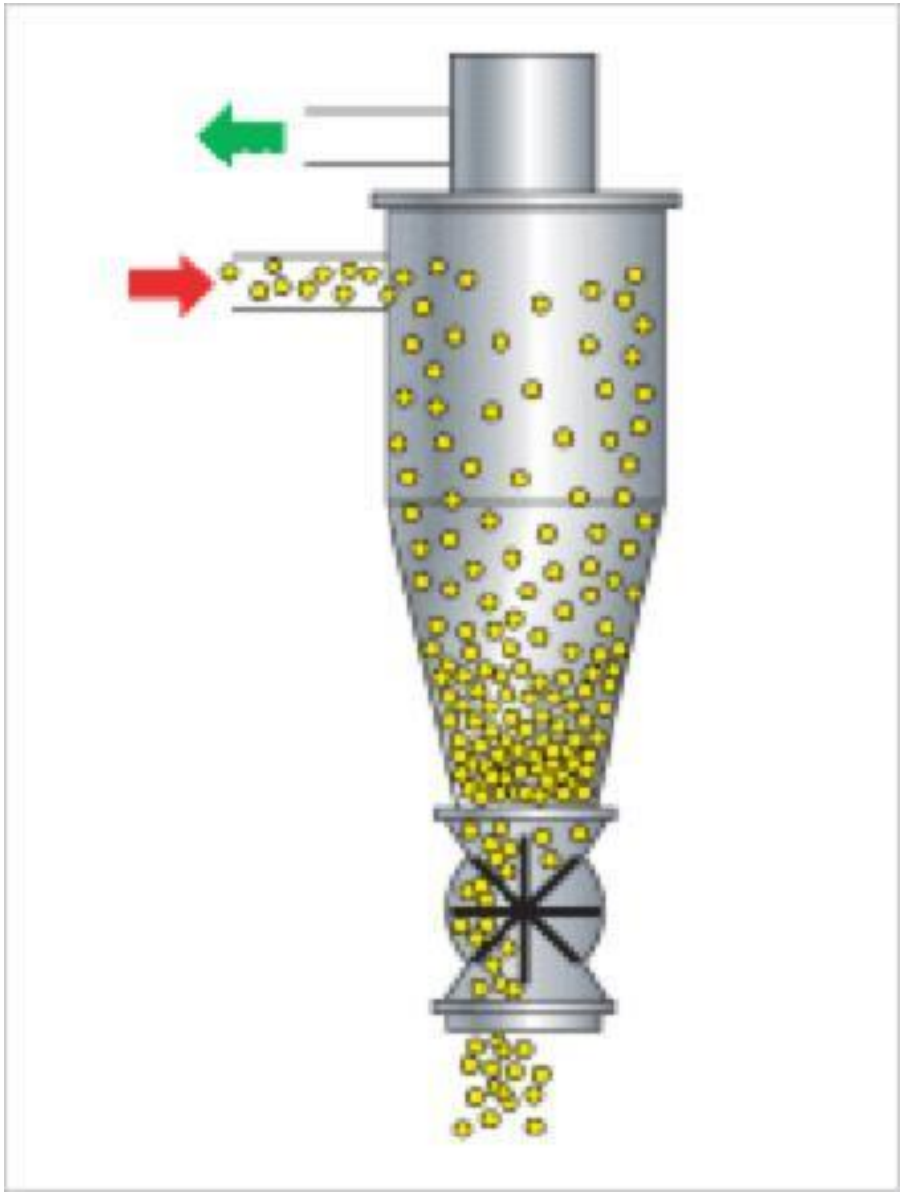
- Physical and chemical properties of the particles.
- Particulate size,co ncentration and volume of impurities.
- Temperature and humidity of the medium.
- Carrier gas volume and rate of removal.
- Efficiency required.
- Economic consideration.

Air pollution control

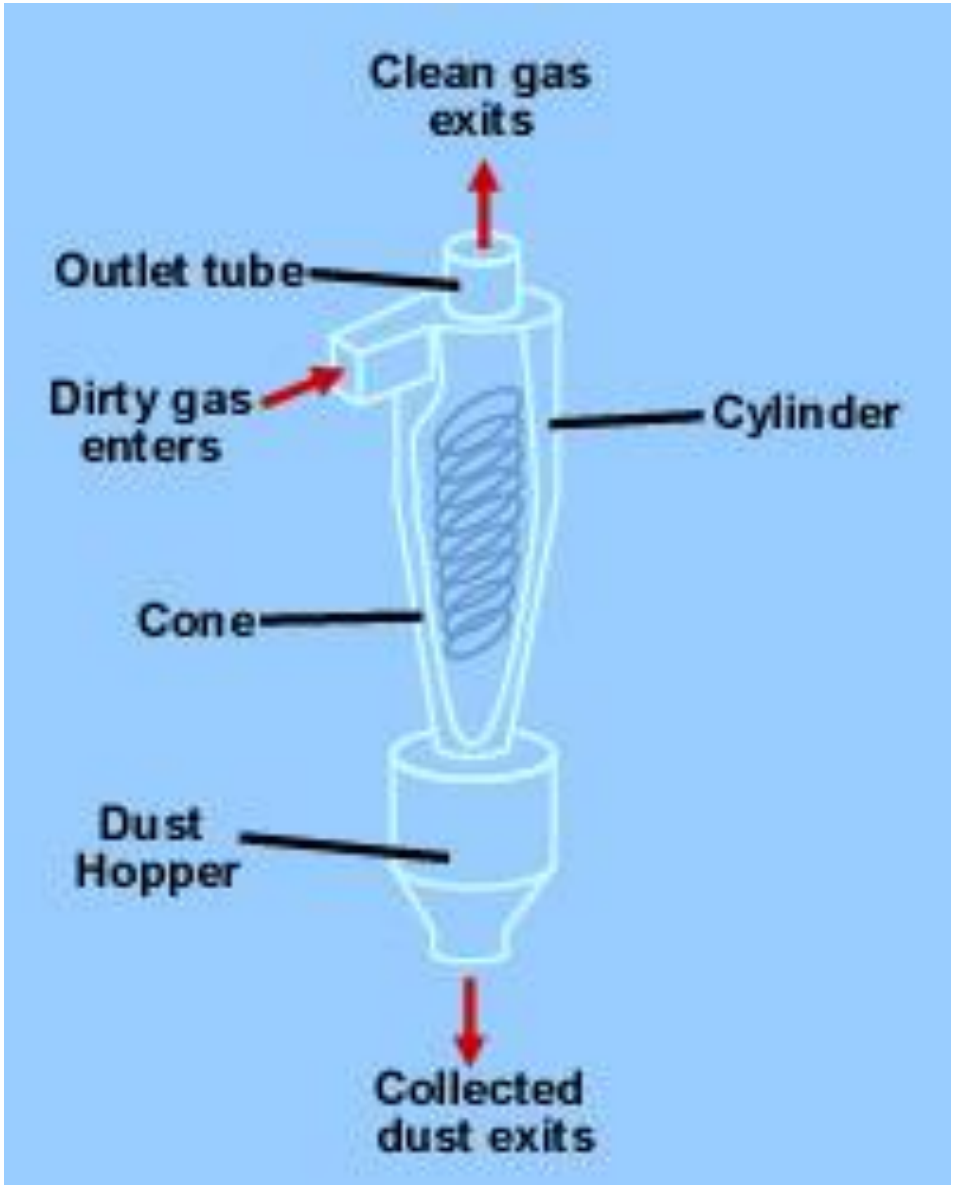
1. Settling chambers Settling chambers use the force of gravity to remove solid particles. The gas stream enters a chamber where the velocity of the gas is reduced. Large particles drop out of the gas and are recollected in hoppers.



Cyclones



Cyclones


Clean gas exits
Outlet tube
Dirty gas enters
Cylinder
Cone
Dust Hopper
Collected dust exits

Scrubbers

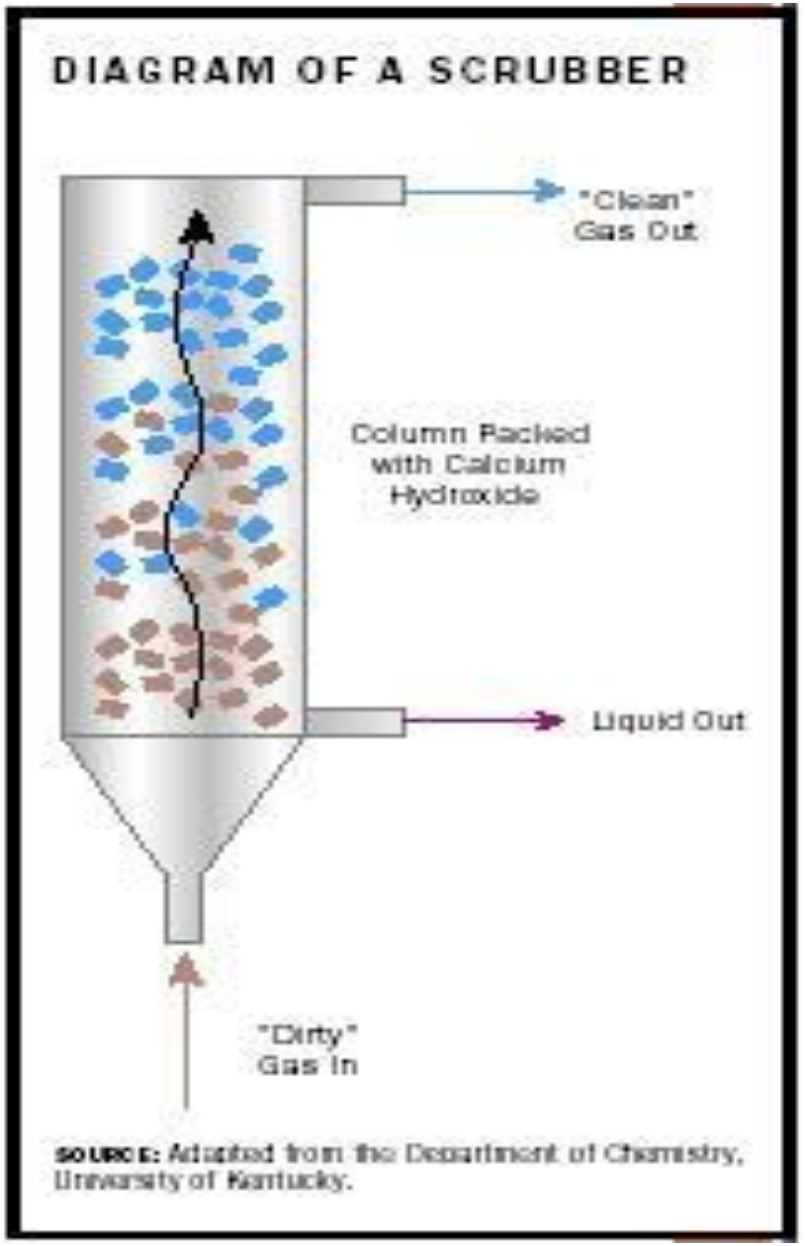
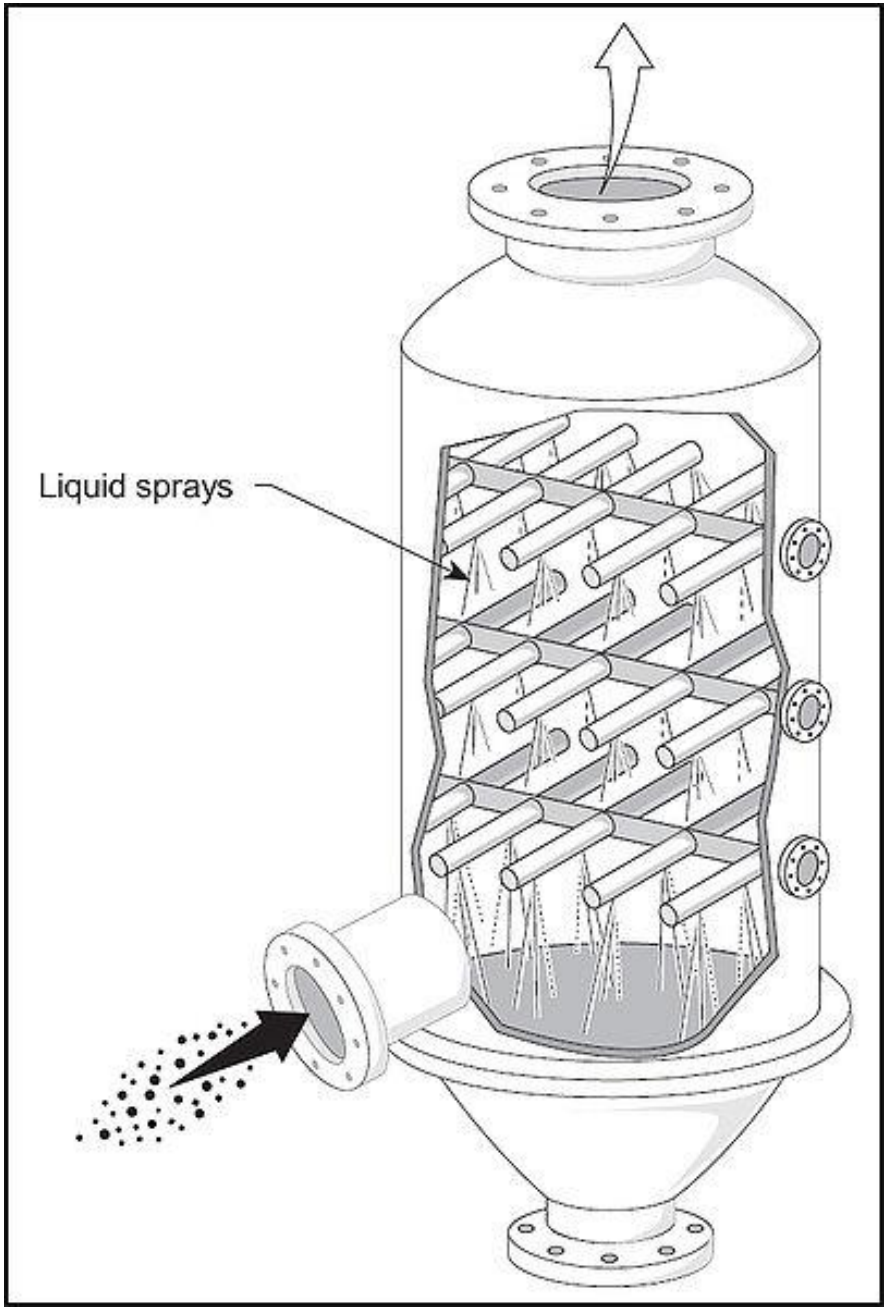
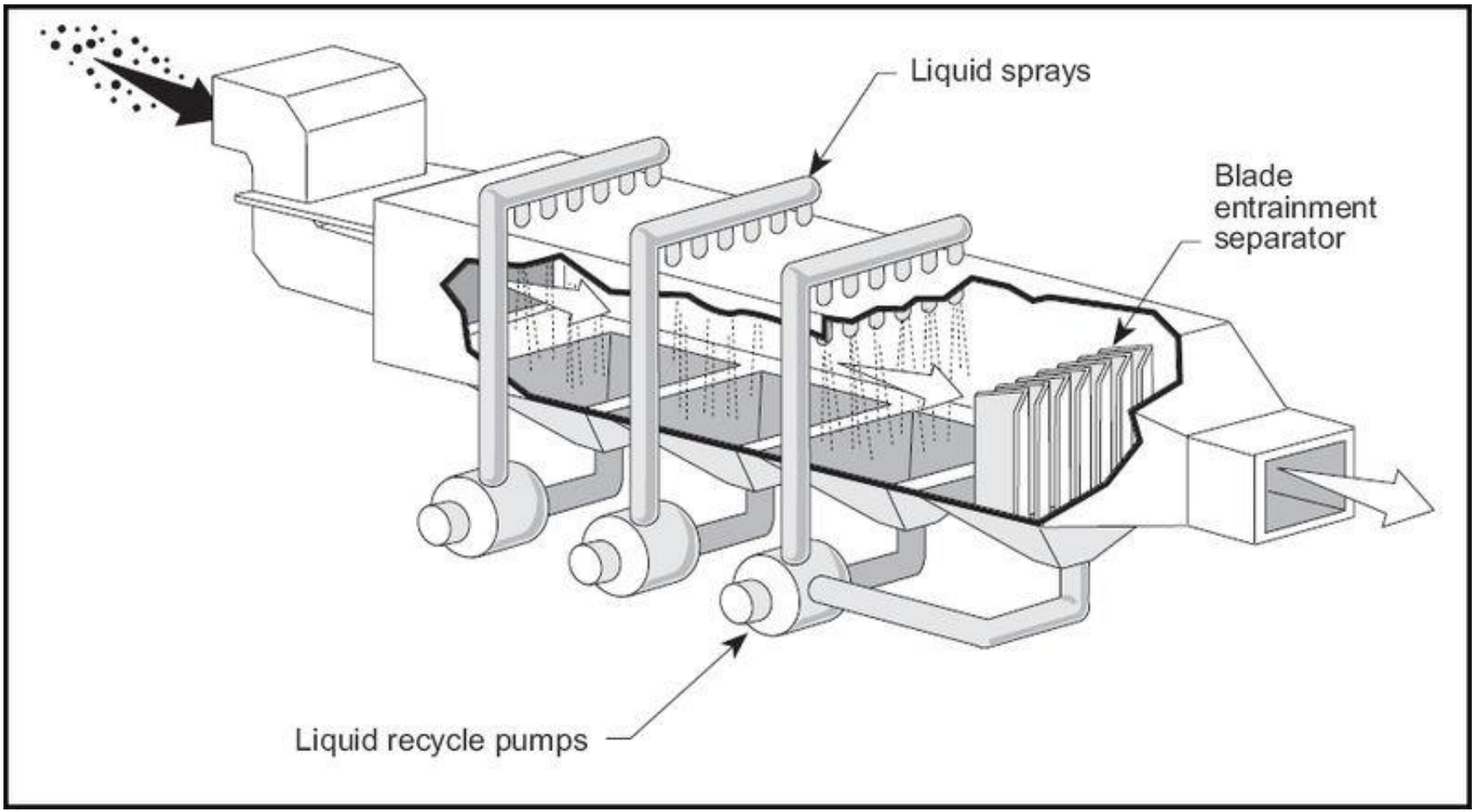


DIAGRAM OF A SCRUBBER
"Clean" Gas Out
Column Packed with Calcium Hydroxide
Liquid Out
"Dirty" Gas In
SOURCE: Adapted from the Department of Chemistry, University of Kentucky.

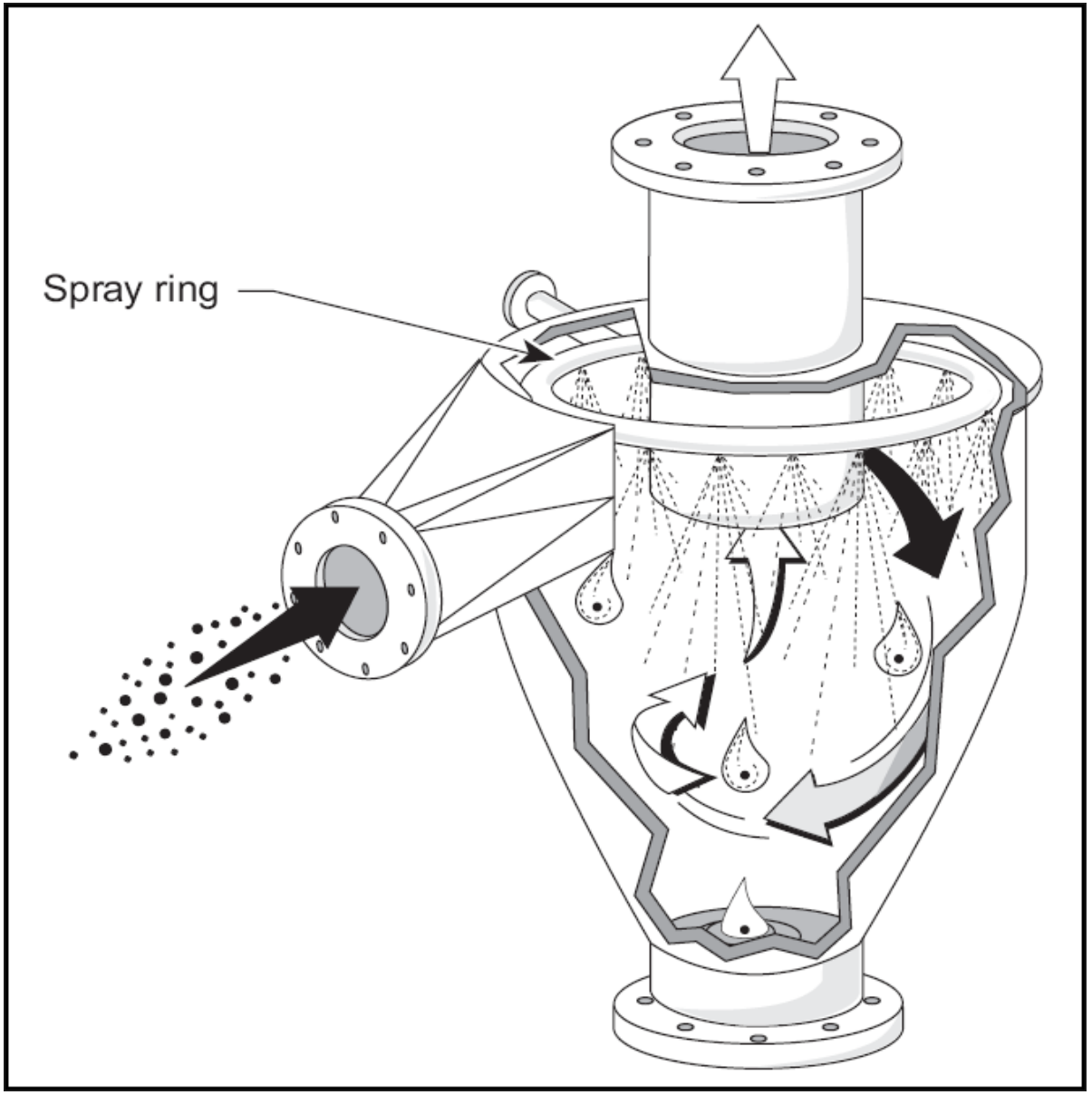
Spray chamber



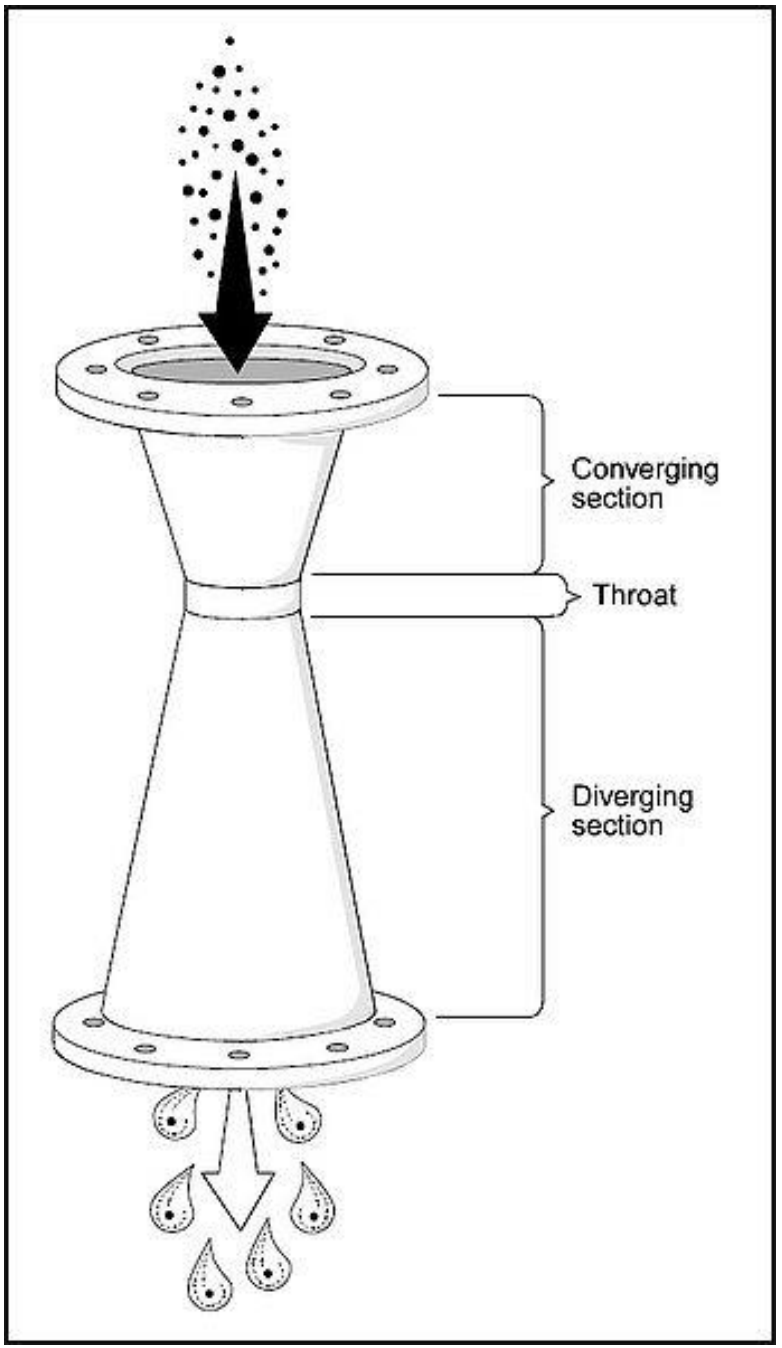
Baffle scrubber



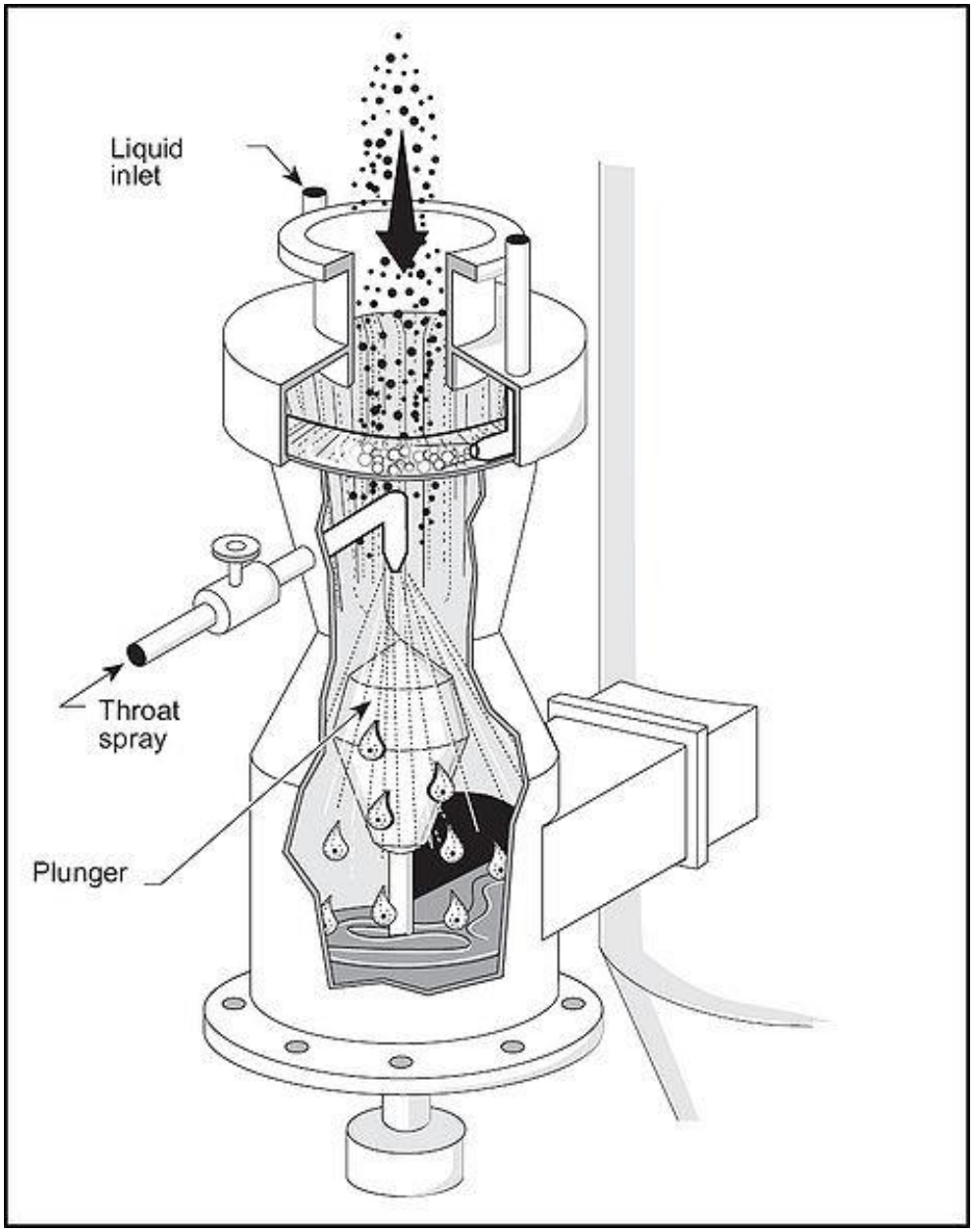
Cyclone scrubber



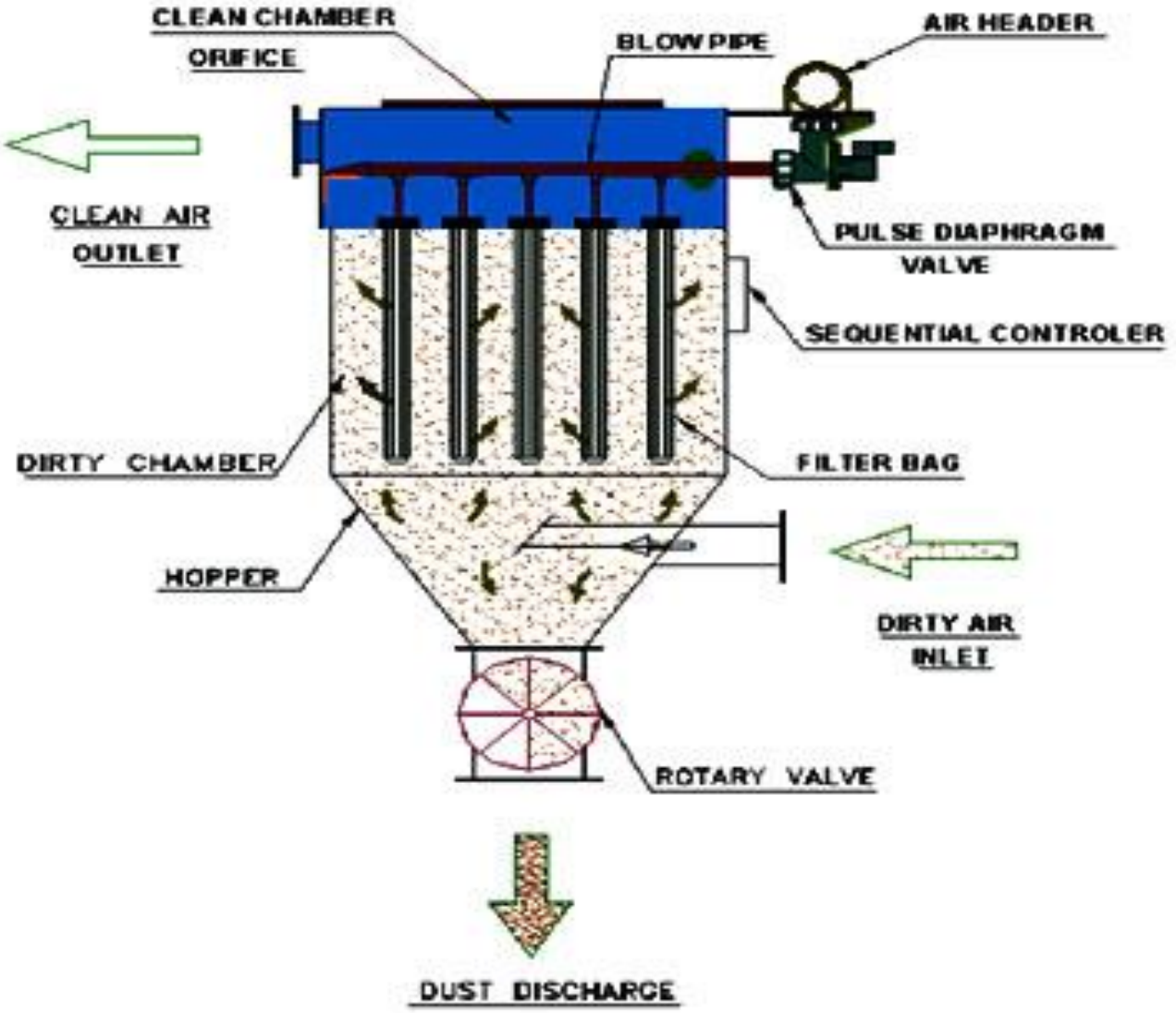
Venturi scrubber



Venturi scrubber



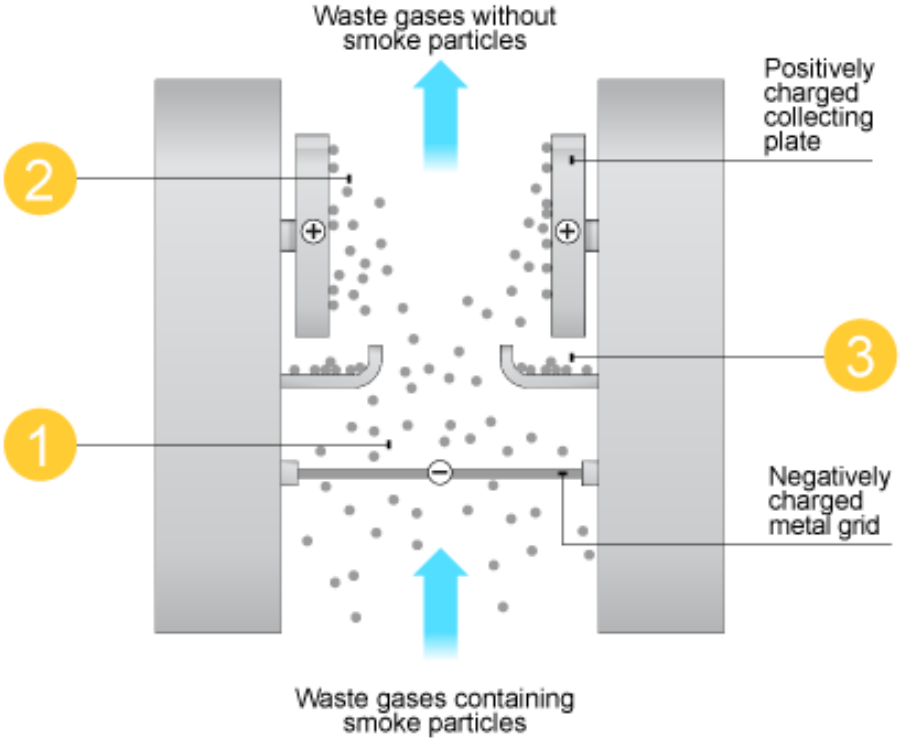
Bag filter


CLEAN CHAMBER
ORIFICE
BLOW PIPE
AIR HEADER
CLEAN AIR
OUTLET
PULSE DIAPHRAGM
VALVE
SEQUENTIAL CONTROLER
DIRTY CHAMBER
FILTER BAG
HOPPER
DIRTY AIR
INLET
ROTARY VALVE
DUST DISCHARGE

Bag filter

- Semipermeable wooven material is used.
- common material used are cotton, wool, nylon orlon, teflon, fibre glass and stainless steel.
- Remove fine particle of 1 micron size with 95% efficiency.

Electrostatic precipitator

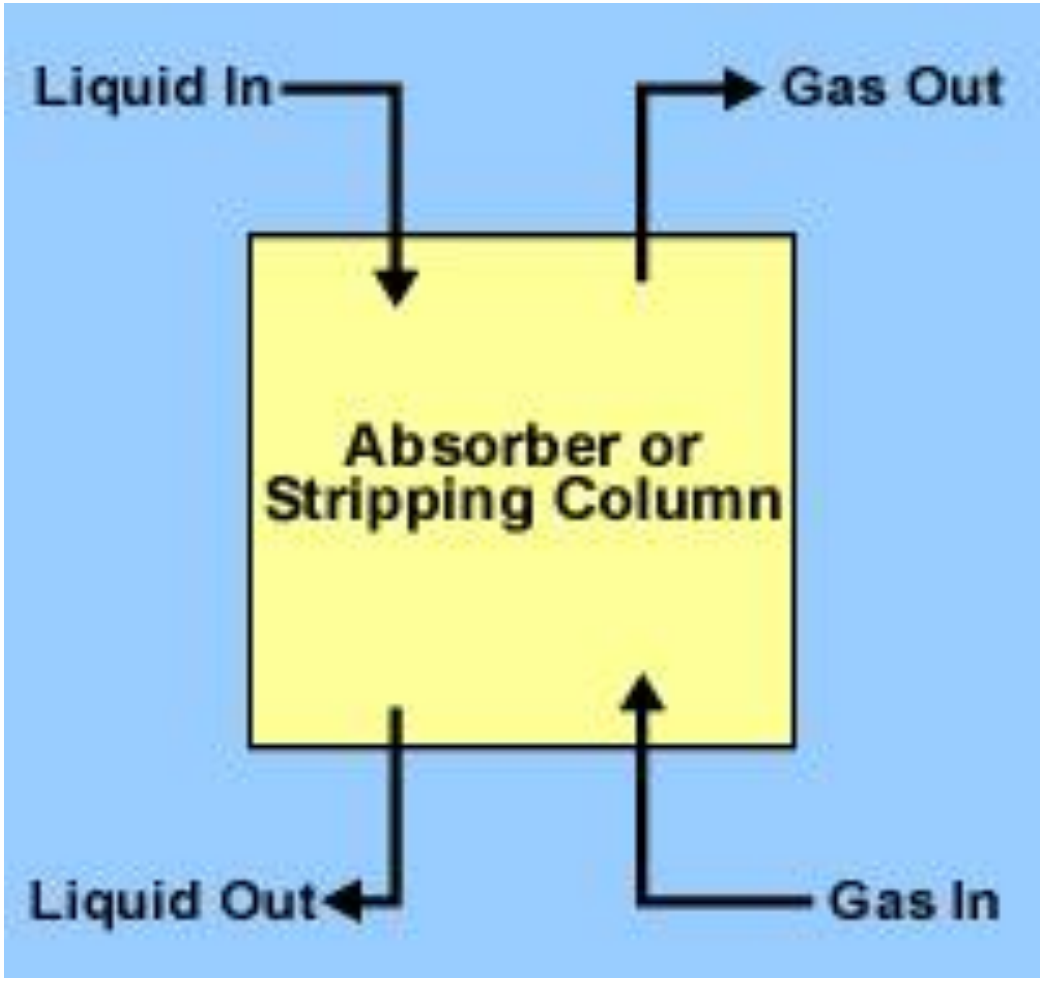


1. **Smoke particles pick up a negative charge.**
2. **Smoke particles are attracted to the collecting plates.**
3. **Collecting plates are knocked to remove the smoke particles.**

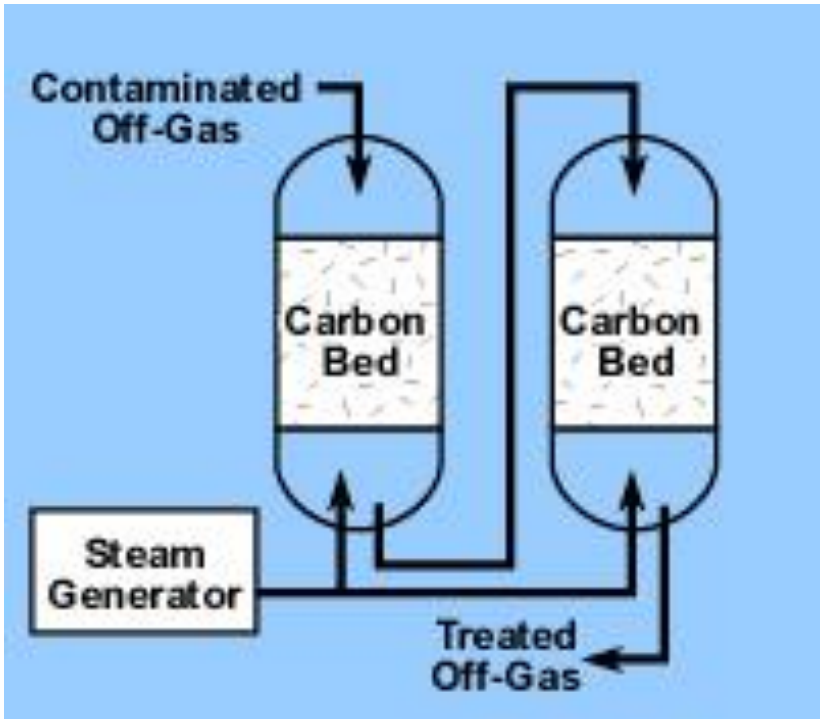
steps

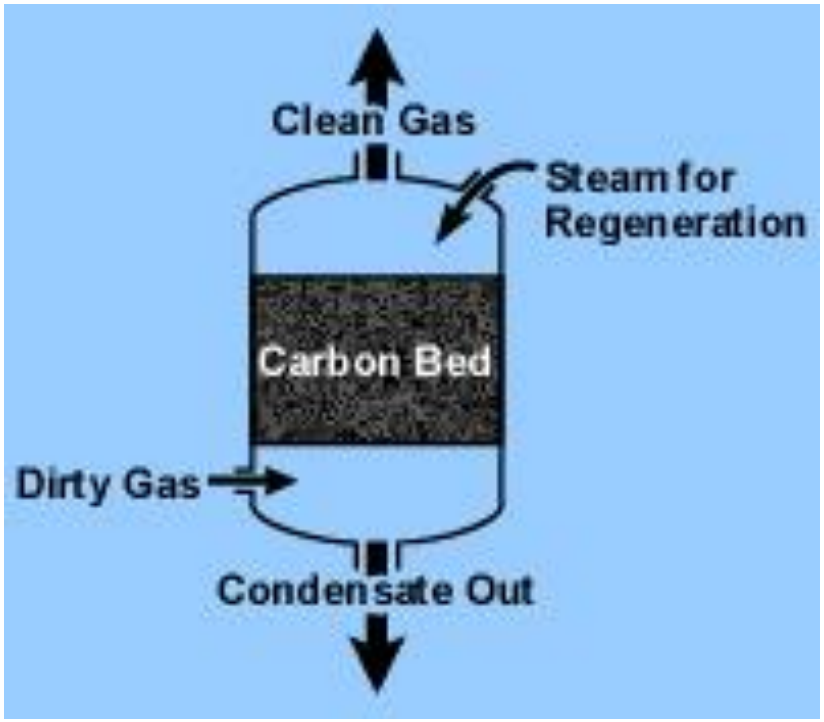
- Impart electrostatic charge to the particle.
- Create electric field in the flow region.
- Particle develop force of attraction.
- Particle migrate towards opposite charged particle.
- Electrode collects the impurities.
- Particle dust is removed by shaking or rapping electrode.
- Hopper below collects the dry particulate matter.

Pollution control by absorption



Pollution control by adsorption





Summarizing control methods

- Dilution- Chimney height
- Zoning- Green belt
- Source Modification
- Control Equipments

Impact of Meteorology on Air Pollution

- Lapse rate: The rate of change of temperature with altitude. It decreases with height. That's known as environmental Lapse rate (ELR)
- Adiabatic lapse rate(ALR): Decrease of temperature of a rising air parcel is known as adiabatic lapse rate
- ALR can be dry adiabatic (9.8^0 C/Km) or wet adiabatic (6^0 C/Km)
- ALR and ELR determines **atmospheric stability**

ELR> ALR –

Super adiabatic condition

Atmospheric condition unstable

Less pollution

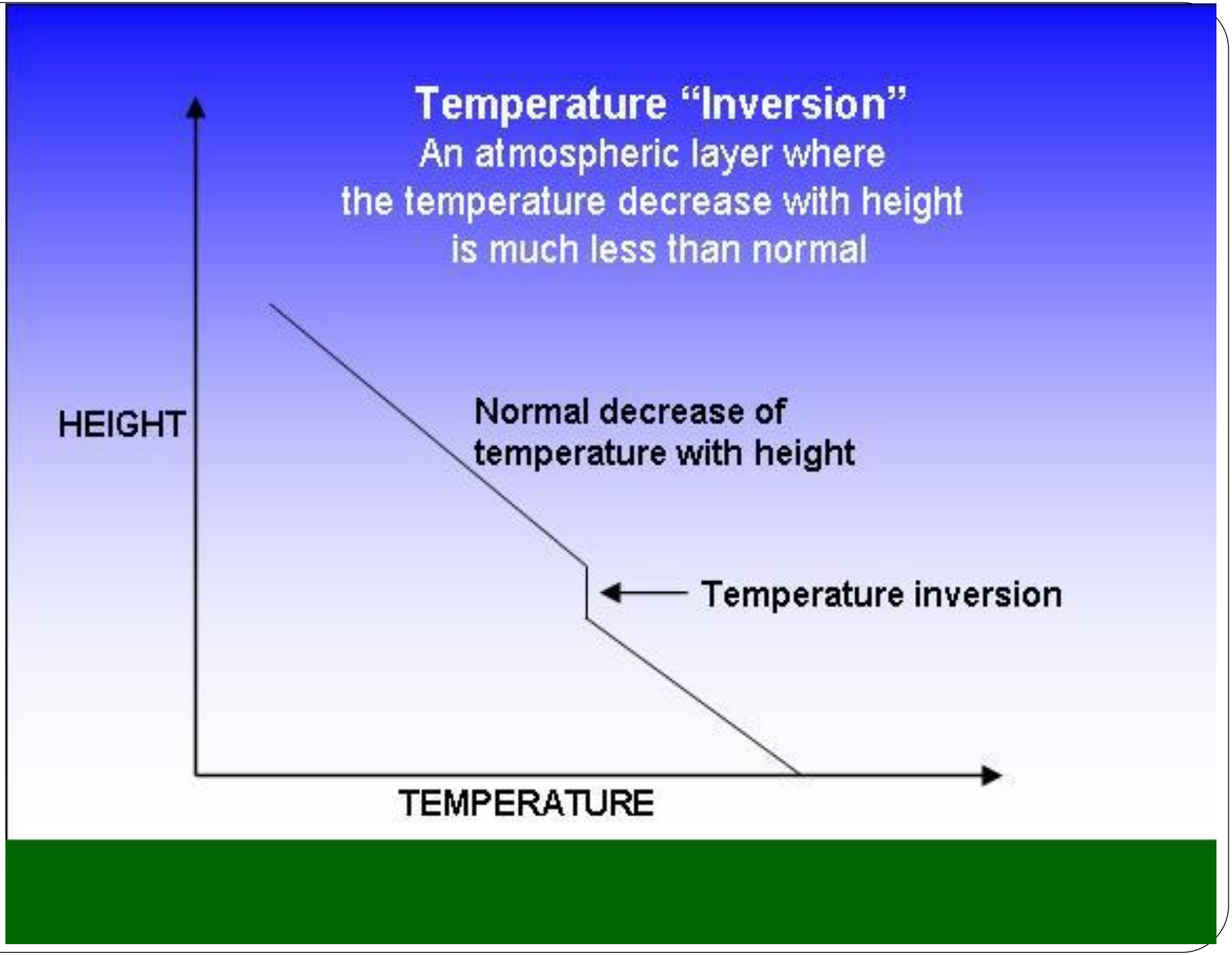
ELR<ALR- Sub adiabatic condition

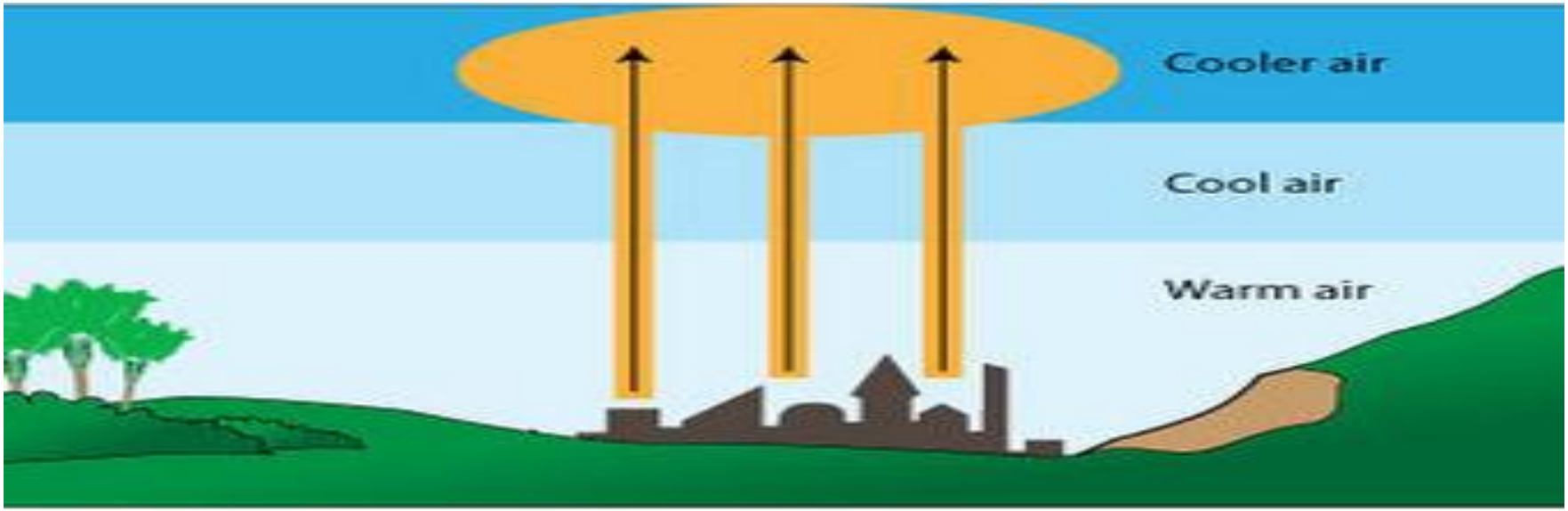
Stable condition

More pollution

Temperature inversion

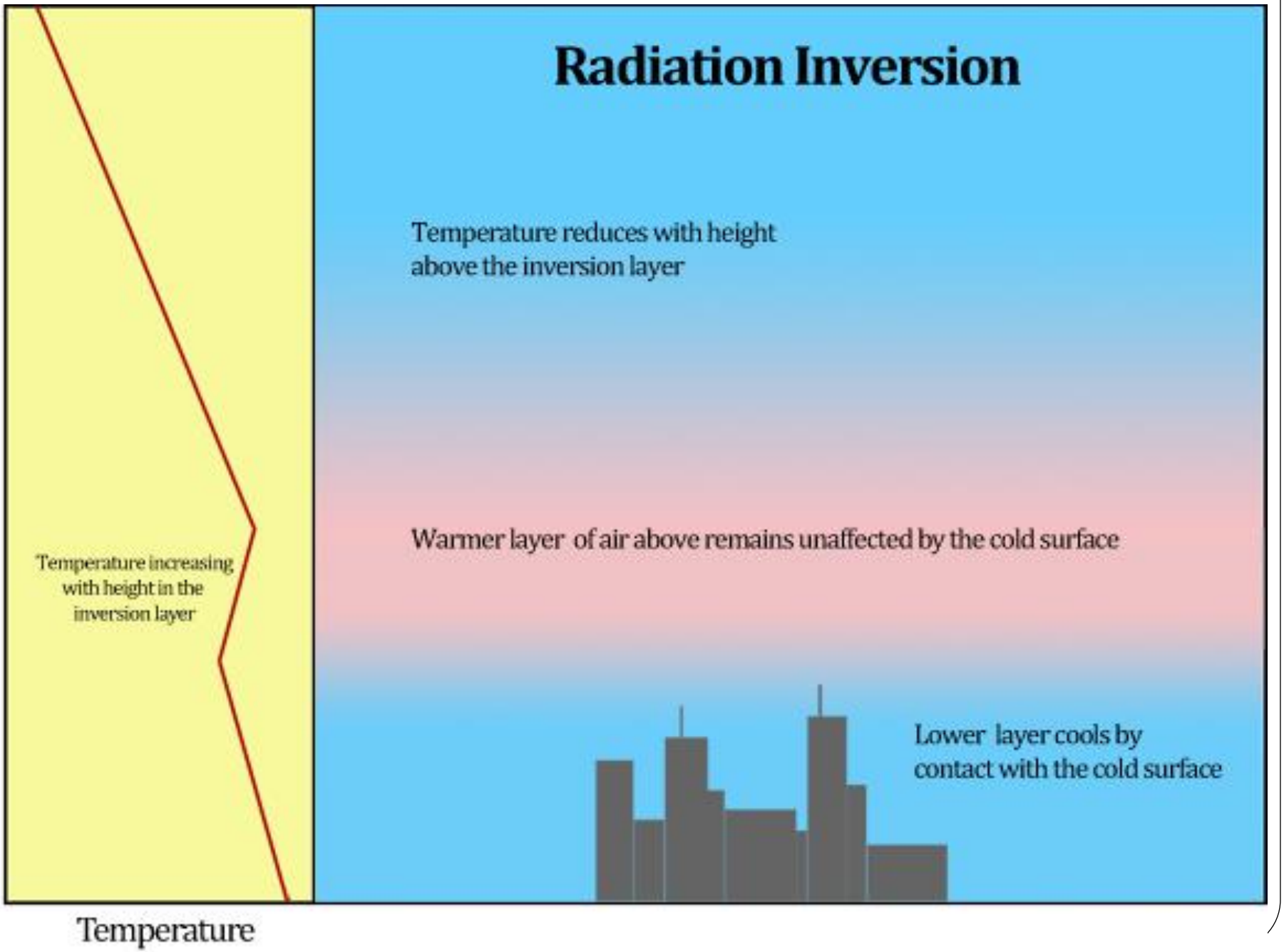
- Increase in temperature with altitude.
- Unfavorable for dispersion of pollutants.
- Dense and cooler air stays below the warm air.
- Fog traps gaseous and PM.
- Effects are reduced if gaseous pollutants are minimized at source; stack height increased; location of industries.

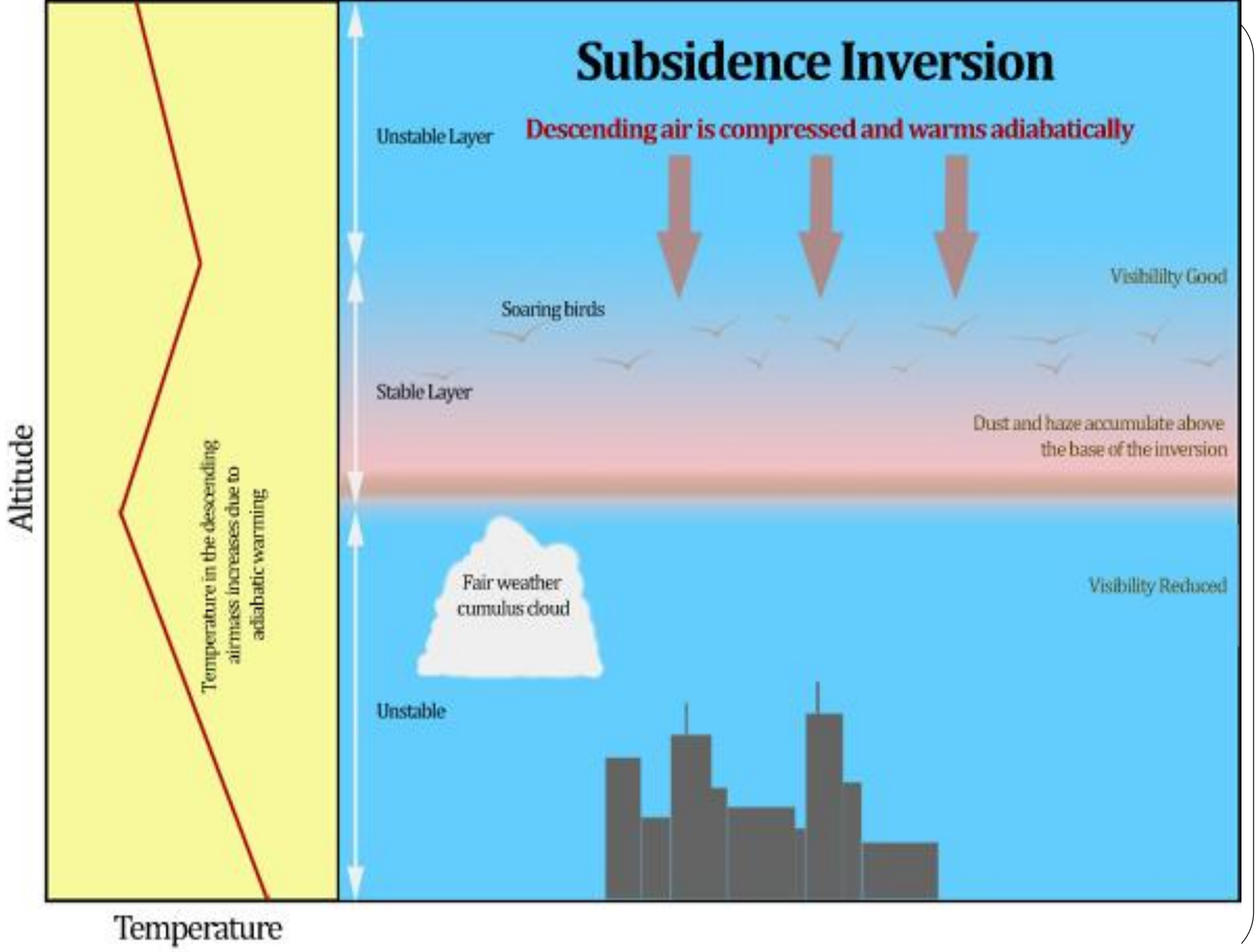

Temperature "Inversion"
An atmospheric layer where
the temperature decrease with height
is much less than normal
HEIGHT
Normal decrease of
temperature with height
Temperature inversion
TEMPERATURE



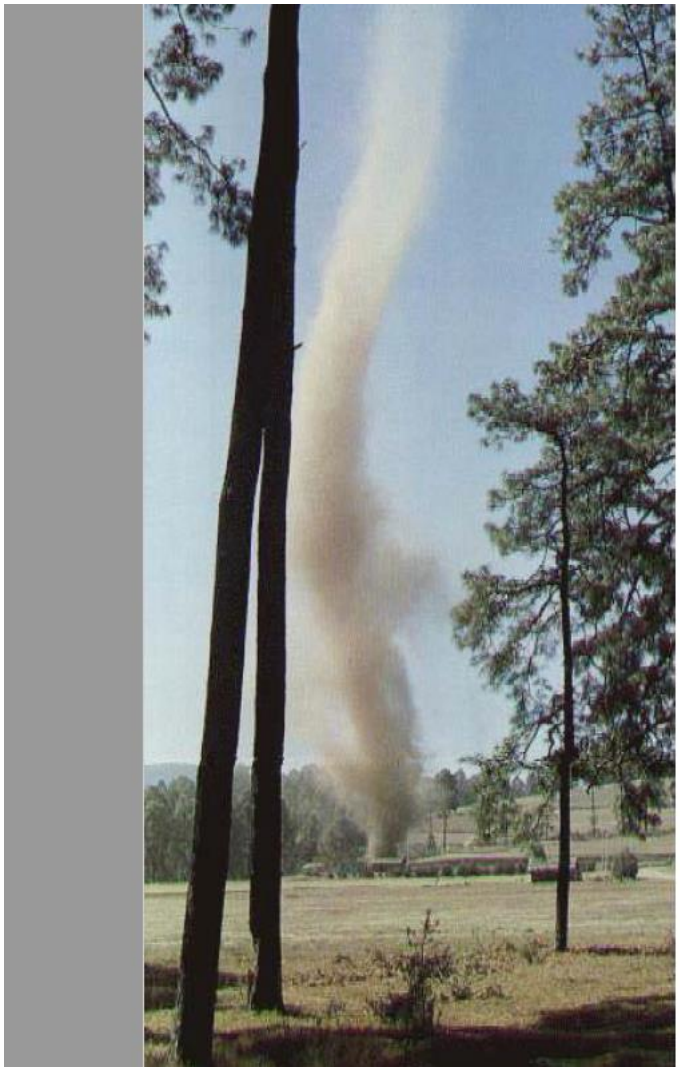
Normal pattern

Thermal inversion


Radiation Inversion
Temperature reduces with height above the inversion layer
Warmer layer of air above remains unaffected by the cold surface
Lower layer cools by contact with the cold surface
Temperature increasing with height in the inversion layer
Altitude
Temperature


Subsidence Inversion
Unstable Layer
Descending air is compressed and warms adiabatically
Visibility Good
Soaring birds
Stable Layer
Dust and haze accumulate above the base of the inversion
Fair weather cumulus cloud
Visibility Reduced
Unstable
Temperature in the descending airmass increases due to adiabatic warming
Altitude
Temperature

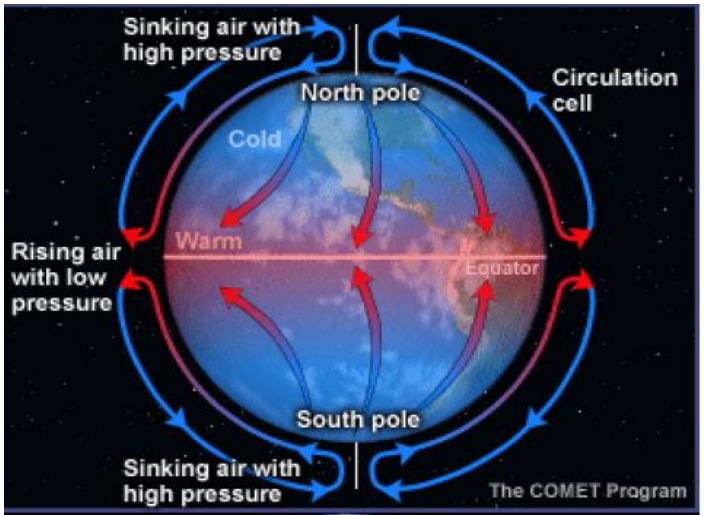
Wind

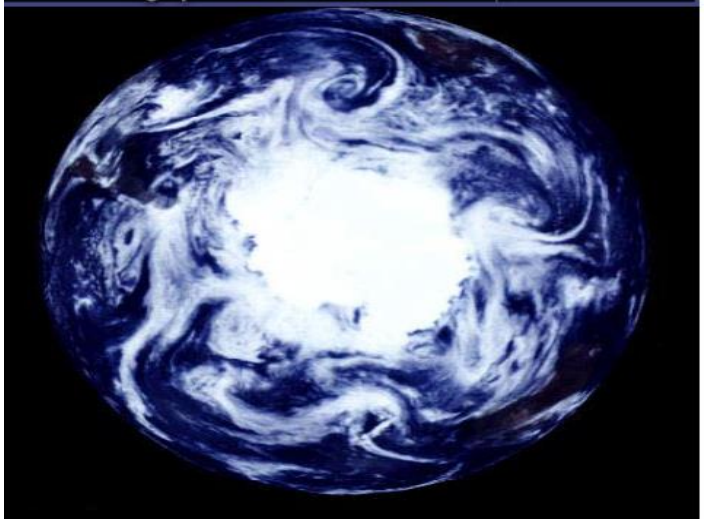


WIND

- **Wind** can be defined simply as air in motion
- Speed of wind varies from absolute calm to speeds as high as 380 kilometers per hour
- **Coriolis Force** *Pressure, Gradient Force* and *Friction* are the three forces that determine wind direction and speed

Wind

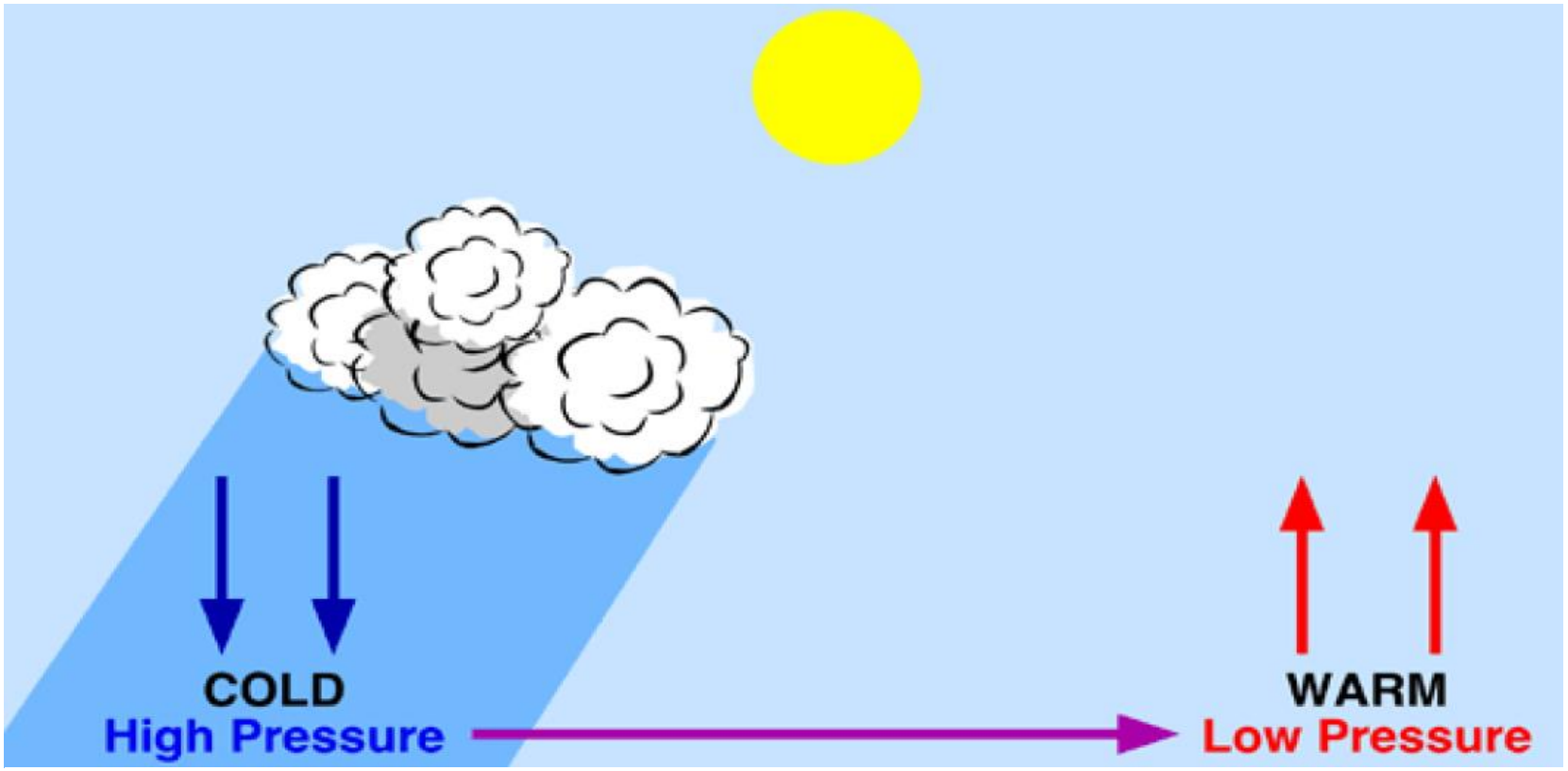




CORIOLIS FORCE

- The Coriolis force is caused by the Earth's rotation around its axis. It is a strange force, but plays a very important role in air flow.

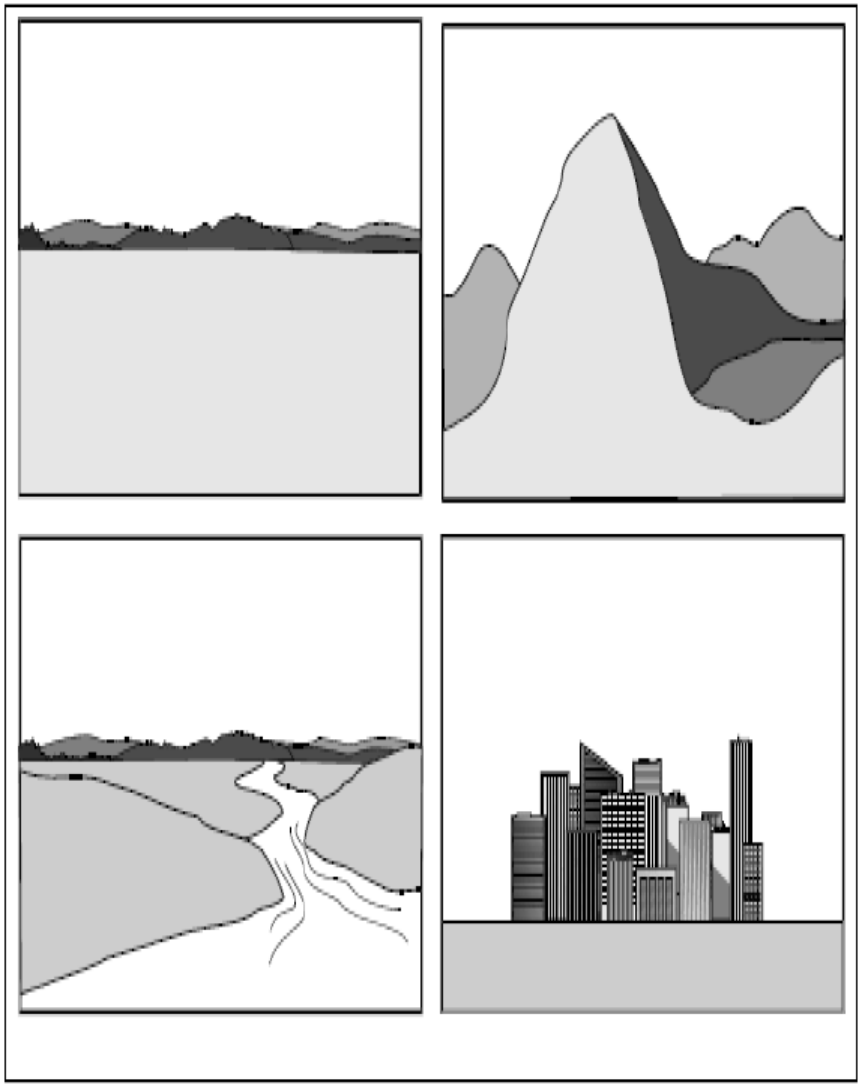
Wind



PRESSURE GRADIENT FORCE

- Pressure change over a unit distance is called **pressure gradient force**, and the greater this force the faster the winds will blow
- Is the primary force influencing the formation of wind from local to global scales

Wind



TOPOGRAPHICAL INFLUENCES

- The physical characteristics of the earth's surface are referred to as **terrain features or topography**
- grouped into four categories: flat, mountain/valley, land/water, and urban

Factors influencing dispersion

1. **Temperature**

Generally the smoke has a higher temperature at the output of the chimney.
The plume will ascend through the combined effect of the initial speed and buoyancy.

2. **Humidity**

Water- vapour amount in the ambient air. Warmer air can hold more water vapour at equilibrium than colder air. If air is cooled below the saturation temperature, some of the water vapour condenses into liquid, which releases latent heat and warms the air.

3. **Pressure**

Air normally would tend to flow directly from high pressure regions towards regions of low pressure, which in the horizontal usually means from a cold area toward a warm area.

4. **Wind speed**

The process of transport is driven by the vectorial field of the wind. A smoke which is released by a chimney will be transported along a stream line of the vector field.

Factors influencing dispersion

5. **Wind direction**

Wind is circular, in air pollution meteorology wind is represented in 16 direction N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, NNW. The wind direction provides the downwind movement of pollutant concentration from the stack.

6. **Mixing height / layer**

The vertical extent to which air pollutants mixing takes place from the ground surface. The dispersion of pollutants in the lower atmosphere is greatly aided by mixing height. It varies diurnally from season to season and it also affected by topographical features.

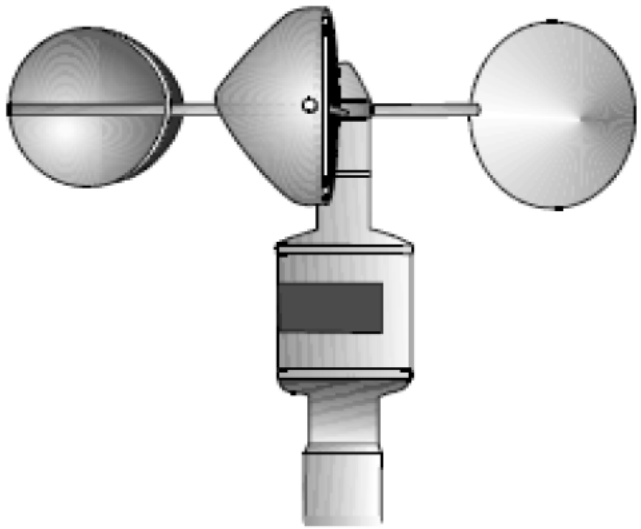
6. **Stability**

The amount of turbulence in the ambient air has major effect upon the rise of stack gas plumes and upon the subsequent dispersion of pollutants. The amount turbulence can be categorized into different stability classes.

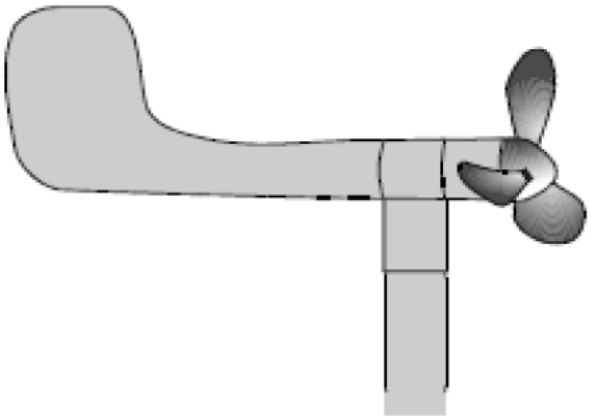
The most widely used turbulence categories are Pasquill stability classes A to F, consists of stable, neutral and unstable categories.

Meteorological Instruments

Wind Speed



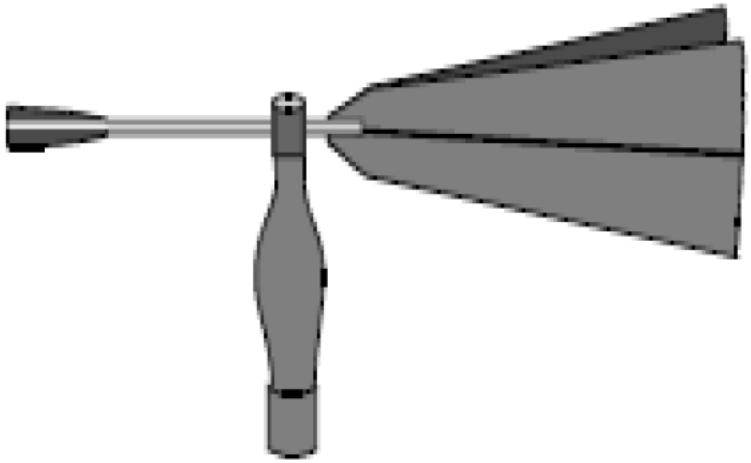
(a) Rotating cup anemometer



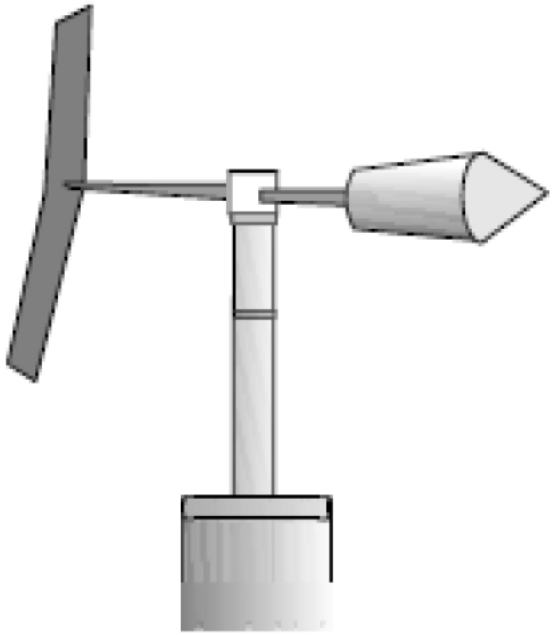
(b) Propeller anemometer

Meteorological Instruments

Wind Direction



Splayed vane



Typical wind vane

Meteorological Instruments

Pyranometere for Solar radiation

Meteorological Instruments

ALL in One