

GE 2211 Environmental Science and Engineering

Unit – III

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Air Pollution

M. Subramanian

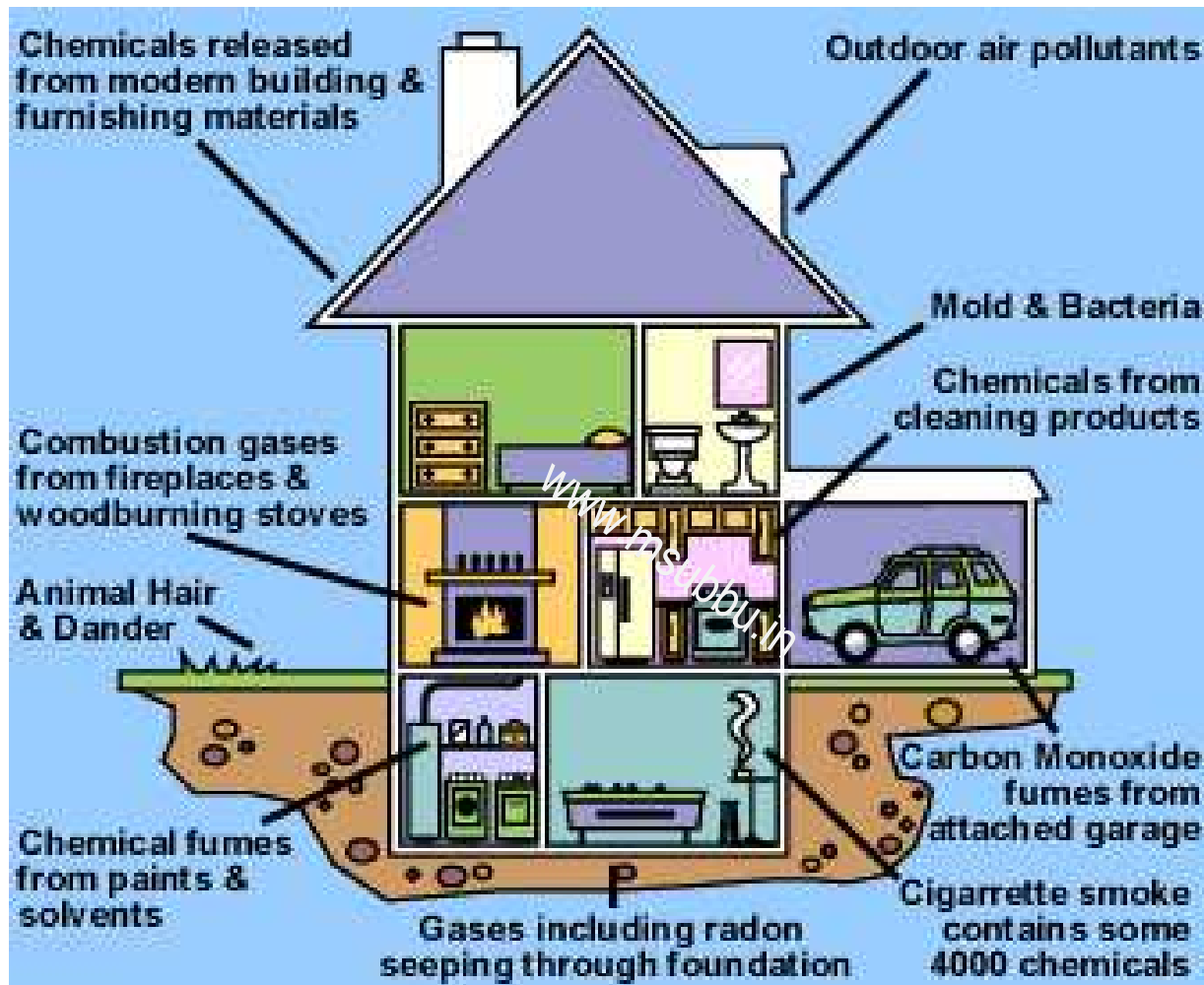
Assistant Professor
Department of Chemical Engineering
Sri Sivasubramaniya Nadar College of Engineering
Kalavakkam – 603 110, Kanchipuram (Dist)
Tamil Nadu, India
[msubbu.in\[AT\]gmail.com](mailto:msubbu.in[AT]gmail.com)

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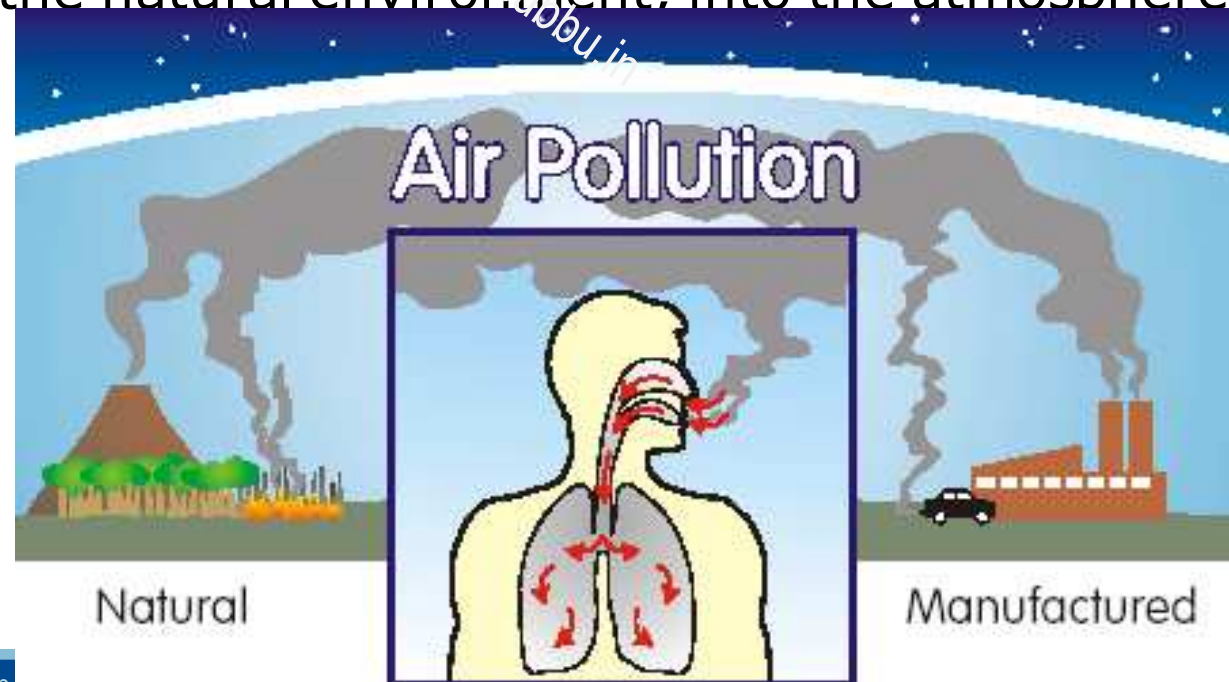




Indoor air pollution

Definition

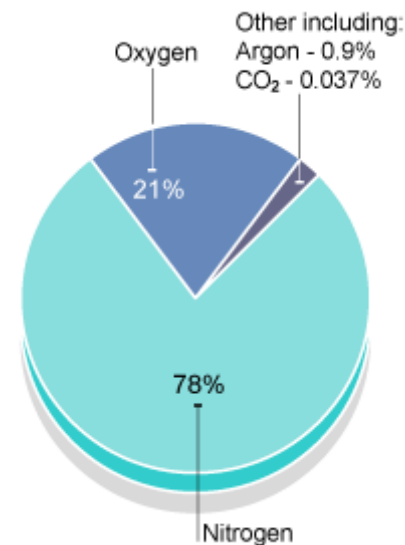
- Air pollution is a phenomenon by which particles (solid or liquid) and gases contaminate the environment.
- **Air pollution** is the introduction of chemicals, particulate matter, or biological materials that cause harm or discomfort to humans or other living organisms, or damages the natural environment, into the atmosphere.



Effects of Air Pollution

- **Health effects** on the population, which might be either chronic (arising from long-term exposure), or acute (due to accidents).
- **Damage to materials** (e.g., the marble statues getting corroded as a result of air pollution)
- **Agricultural damage** - such as reduced crop yields and tree growth
- **Impairment of visibility** - tiny particles scatter light very efficiently
- **Climate change** - certain gases absorb energy emitted by the earth, leading to global warming

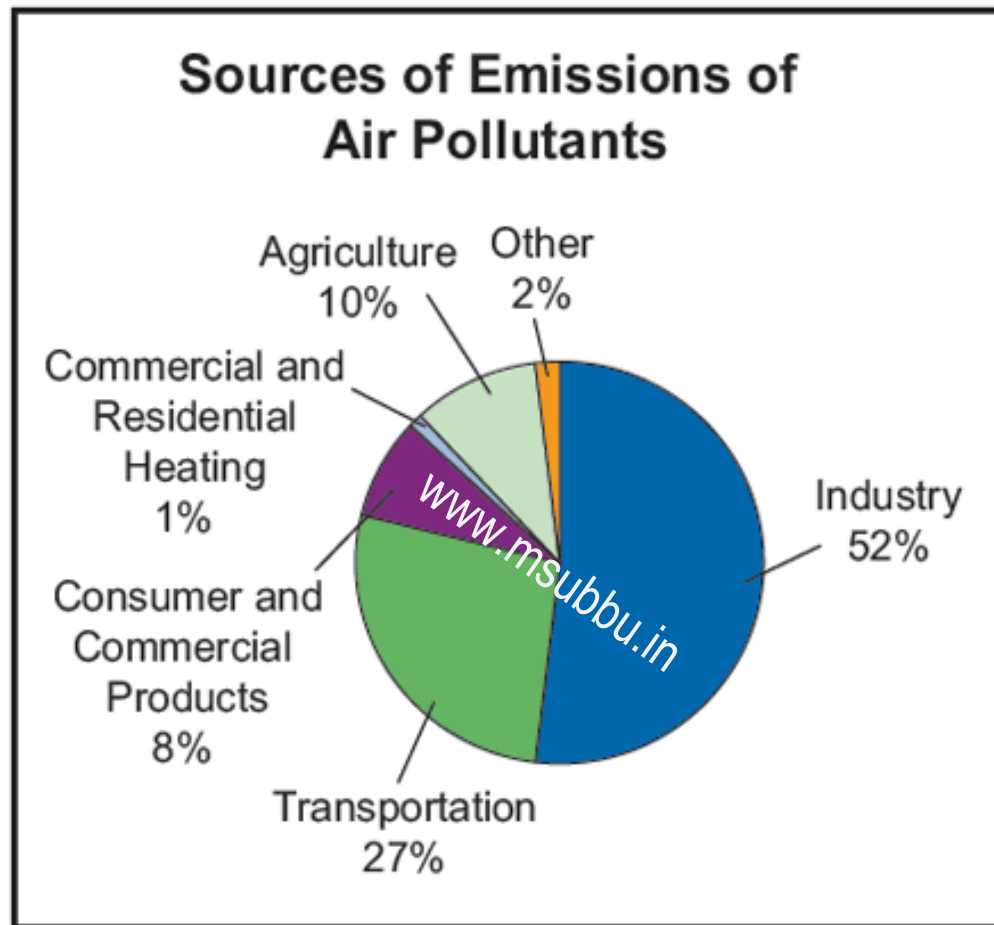
Chemical Composition of Air		
Name	Symbol	% by volume
Nitrogen	N ₂	78.084 %
Oxygen	O ₂	20.9476 %
Argon	Ar	0.934 %
Carbon Dioxide	CO ₂	0.0314 %
Neon	Ne	0.001818 %
Methane	CH ₄	0.0002 %
Helium	He	0.000524 %
Krypton	Kr	0.000114 %
Hydrogen	H ₂	0.00005 %
Xenon	Xe	0.0000087 %



Common Air Pollutants

- carbon monoxide (CO)
- ozone (O₃),
- lead (Pb)
- nitrogen dioxide (NO₂)
- particulate matter (PM)
- sulfur dioxide (SO₂)

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Percent of total Canadian emissions of air pollutants (2002)

Classification of air pollutants

- Natural and anthropogenic pollutants
 - Natural – due to volcanic activity
 - Anthropogenic – produced by humans or controlled processes
- Primary and secondary pollutants
 - Primary pollutants are those that are emitted directly into the atmosphere from an identifiable source (e.g. CO, SO₂)
 - Secondary pollutants are those that are produced in the atmosphere by chemical and physical processes from primary pollutants and natural constituents (e.g. Ozone)

Air Pollutants

- Primary pollutants – enter the atmosphere directly from various sources
 - SO_x , NO_x , CO, VOC, particulate matters, toxic metals
- Secondary pollutants – formed from primary pollutants
 - smog (smoke and fog), ozone, polyacetyl nitrate (PAN)

National Ambient Air Quality Standard (India – by CPCB)

SINo	Pollutant	Annual average in Residential areas
1	SO ₂	60 µg/m ³
2	Oxides of nitrogen as NO ₂	60 µg/m ³
3	CO	2 mg/m ³ (8 hour average)
4	Suspended particulate matter (SPM)	140 µg/m ³
5	Respirable Particulate Matter (RPM) (size less than 10 microns)	60 µg/m ³

Separate standards for: Industrial areas / Residential areas / Sensitive areas

Particulate Matters

- Particulate matter (PM) is the term used to describe solid or liquid particles that are airborne and dispersed (i.e., scattered, separated).
- PM originates from a variety of anthropogenic sources, including diesel trucks, power plants, wood stoves, and industrial processes.
- Fine particles are the major cause of reduced visibility
- Fine particles are detrimental to human health because they can penetrate deep into the lungs
- PM causes soiling and erosion damage to materials, including culturally important objects such as carved monuments and statues

Carbon Monoxide

- Carbon Monoxide (CO) is an odorless, colorless gas that is a by-product of the incomplete burning of fuels
- The major source of CO is motor vehicle exhaust. In cities, as much as 95 percent of all CO emissions result from vehicular (automobile) emissions.
- Other sources of CO emissions include industrial processes, nontransportation-related fuel combustion, and natural sources such as wildfires.

Effects of CO

- It adversely affects human health at only a few parts per million and causes death at 250 parts per million (250 ppm)
- The Centers for Disease Control estimates that each year, 1,500 Americans die from carbon monoxide (CO) poisoning. About 900 of these deaths occur in homes and are preventable
- Carbon Monoxide is inhaled and enters the blood stream where it binds chemically to hemoglobin. Hemoglobin carries oxygen to the cells, but when CO binds to it, hemoglobin is unable to bind with oxygen, thereby reducing the amount of oxygen delivered to all tissues of the body.

SO₂

- Sulfur dioxide (SO₂) is colorless, nonflammable, nonexplosive gas. Almost 90 percent of anthropogenic SO₂ emissions are the result of fossil fuel combustion (mostly coal) in power plants and other stationary sources. A natural source of sulfur oxides is volcanic activities.
- Health effects - High concentrations of sulfur dioxide (SO₂) can result in breathing problems with asthmatic children and adults who are active outdoors. Short-term exposure has been linked to wheezing, chest tightness and shortness of breath.
- **Environmental Effects:** Sulfur dioxide and nitrogen oxides are the major precursors of acid rain, which has acidified soils, lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility.
- Prolonged exposure to SO₂ and sulfate PM causes serious damage to materials such as marble, limestone, and mortar. The carbonates (e.g., limestone, CaCO₃) in these materials are replaced by sulfates (e.g., gypsum, CaSO₄) that are water-soluble and may be washed away easily by

NO_x

- Nitrogen dioxide (NO₂) is a reddish-brown gas. It is a lung irritant and is present in the highest concentrations among other oxides of nitrogen in ambient air
- **Sources:**
 - Anthropogenic emissions of NO_x come from high-temperature combustion processes, such as those occurring in automobiles and power plants.
 - Natural sources of NO₂ are lightning and various biological processes in soil.
- **Effects:**
 - Like carbon monoxide, nitric oxide (NO) reduces the blood's oxygen carrying capacity
 - NO₂ reduces visibility, when combined with water forms nitric acid, a highly corrosive substance

Hydrocarbons

- Hydrocarbons include many of the compounds of carbon and hydrogen
- They are introduced in the atmosphere primarily as the result of incomplete combustion of gasoline
- In low concentrations hydrocarbons do not present important environmental problems, but in high concentrations or in combination with other pollutants, they can have serious effects. Some are believed to be carcinogenic (cancer-inducing)

Lead

- Sources:
 - In the past, motor vehicles were the major contributor of lead emissions to the air.
 - Today industrial processes, primarily metals processing, are the major source of lead emissions to the air.
 - The highest air concentrations of lead are usually found near lead smelters.
 - Other stationary sources are waste incinerators, utilities, and lead-acid battery manufacturers.
 - Lead based paints

Dangers of lead and arsenic poisoning

Arsenic poisoning

Nerve damage

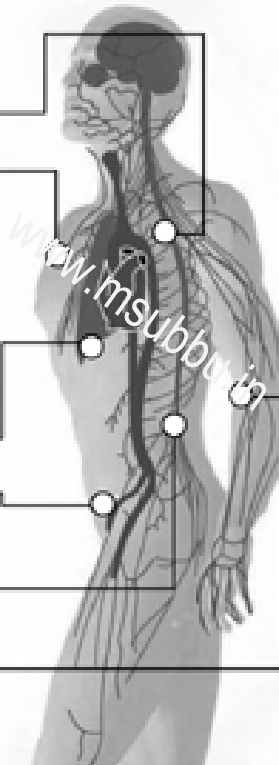
Skin damage:

- Hyperkeratosis (scaling skin)
- Pigment changes

Increased cancer risk:

- Lung
- Bladder
- Kidney and liver cancers

Circulatory problems in skin



Lead poisoning

High levels of lead

- Mental retardation, coma, convulsions and death

Low levels of lead

- Reduced IQ and attention span, impaired growth, reading and learning disabilities, hearing loss and a range of other health and behavioral effects.

Sources: Alliance to End Childhood Lead Poisoning and news wires

The Denver Post

Ozone

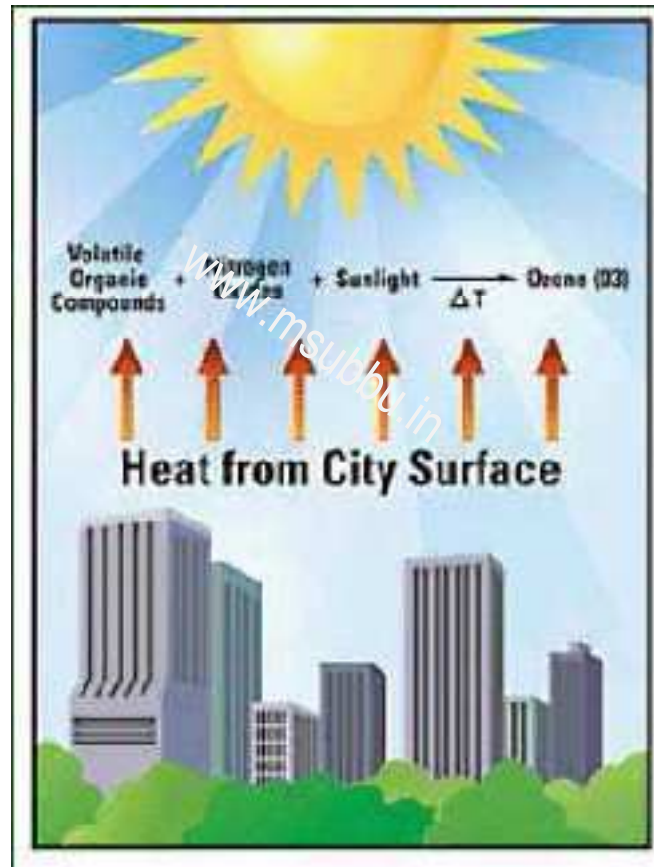
- Ozone (O_3) is a secondary pollutant and is formed in the atmosphere by the reaction of molecular oxygen, O_2 , and atomic oxygen, O , which comes from the photochemical decomposition of NO_2 . Volatile organic compounds or VOCs (e.g., what one smells when re-fuelling the car) must also be present if O_3 is to accumulate in the atmosphere.

- $NO_x + VOC + UV \text{ light} \longrightarrow$ ozone at ground level
(automobiles) (sun)

- Effects:

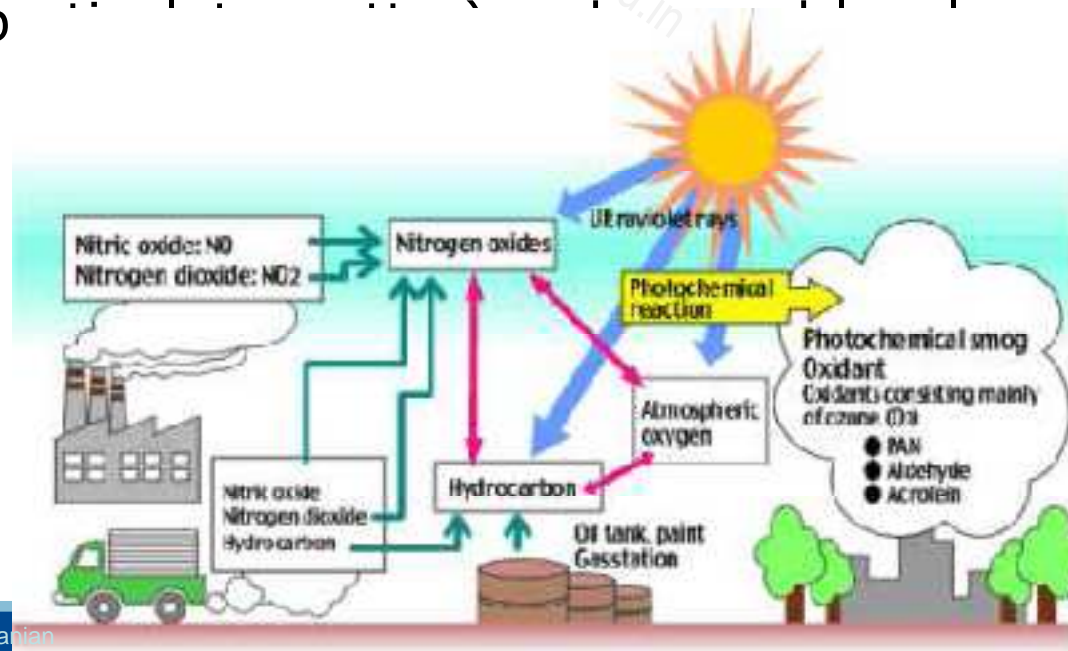
- O_3 occurs naturally in the stratosphere and provides a protective layer from the sun's ultraviolet rays high above the earth.
- However, at ground level, O_3 is a lung and eye irritant and can cause asthma attacks, especially in young children or other susceptible individuals.

Ozone formation at ground level

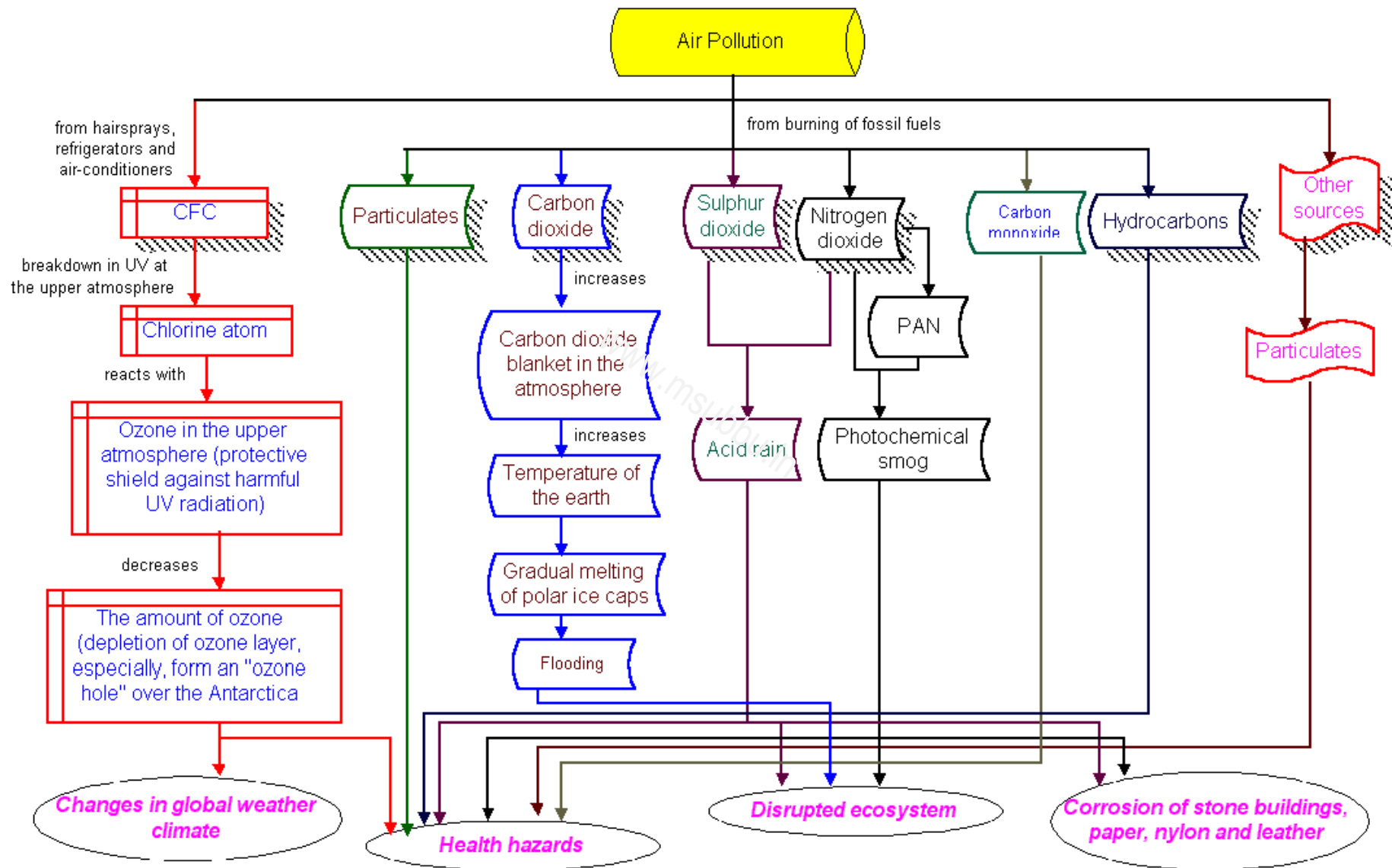


Photochemical Smog

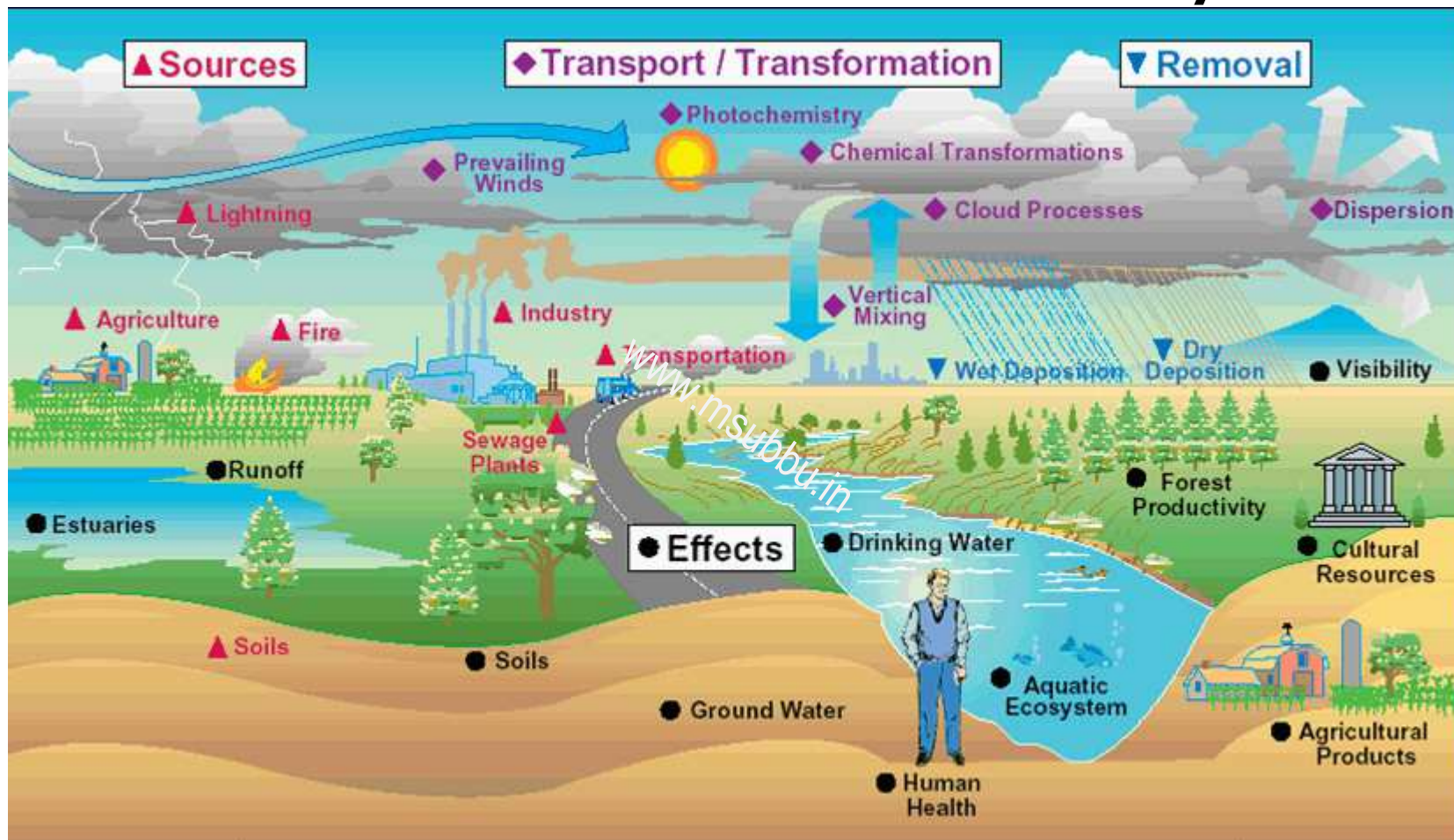
- This forms when sunlight hits various pollutants in the air and forms a mix of detrimental chemicals that can be very dangerous.
- A photochemical smog is the chemical reaction of sunlight, nitrogen oxides (NO_x) and volatile organic compounds (VOCs) in the atmosphere, which leaves airborne particles (called particulates) in the air.



Concept Map on the Effect of Major Air Pollutants on Environment



Air Pollution Pathway



http://www.epa.gov/oar/airtrends/2007/graphics/Air_pollution_pathways_textbox.gif

Control of Primary Air Pollutants

- In general, control of pollutants that are primary in nature, such as SO_2 , NO_2 , CO , and Pb , is easier than control of pollutants that are either entirely secondary (O_3) or have a significant secondary component ($\text{PM}_{2.5}$).
- For example, SO_2 is controlled by the use of scrubbers, which are industrial devices that remove SO_2 from the exhaust gases from power plants. SO_2 emissions are also reduced by the use of low-sulfur coal or other fuels, such as natural gas, that contain lower amounts of sulfur.
- NO_2 from industrial sources also may be minimized by scrubbing. NO_2 from cars, as well as CO , are controlled by the use of catalytic converters, engine design modifications, and the use of cleaner burning grades of gasoline.
- Lead emissions have been reduced significantly since the introduction of lead-free gasoline.

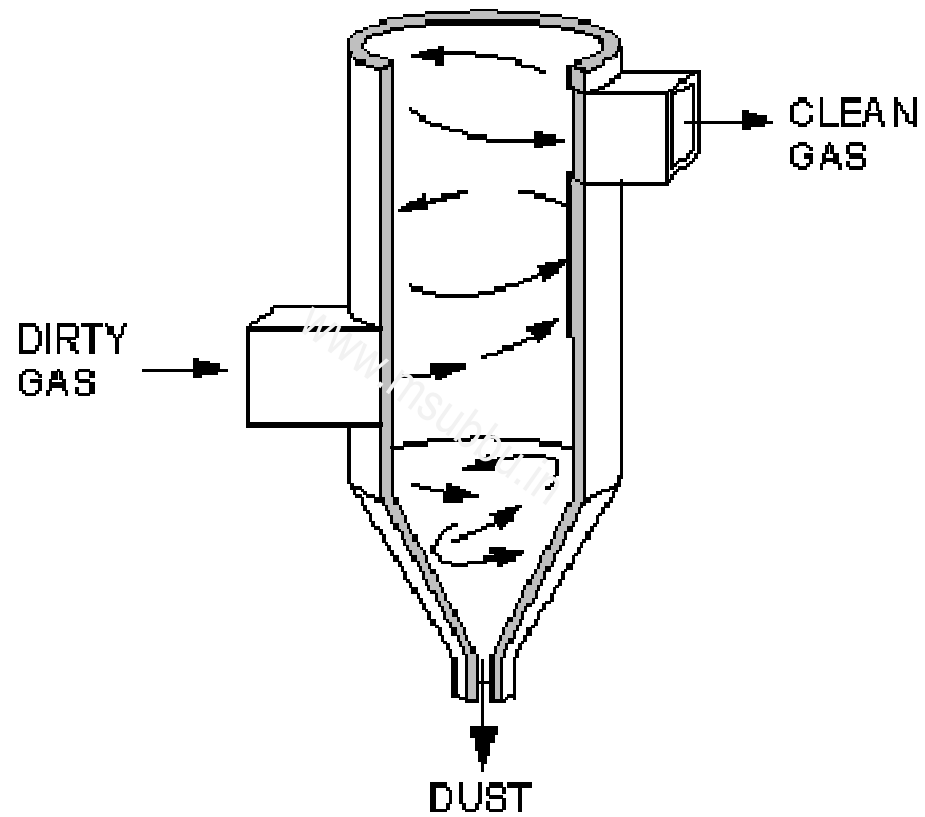
Control of Secondary Pollutants

- Ozone and particulate matter are two of the most difficult pollutants to control.
- Reduction of oxides of nitrogen emissions, together with a reduction of VOC emissions is the primary control strategy for minimizing ozone concentrations.
- Because a large portion of PM_{2.5} is secondary in nature, its control is achieved by control of SO₂, NO₂, and VOC (which are the precursors of sulfates, nitrates, and carbon-containing particulates).

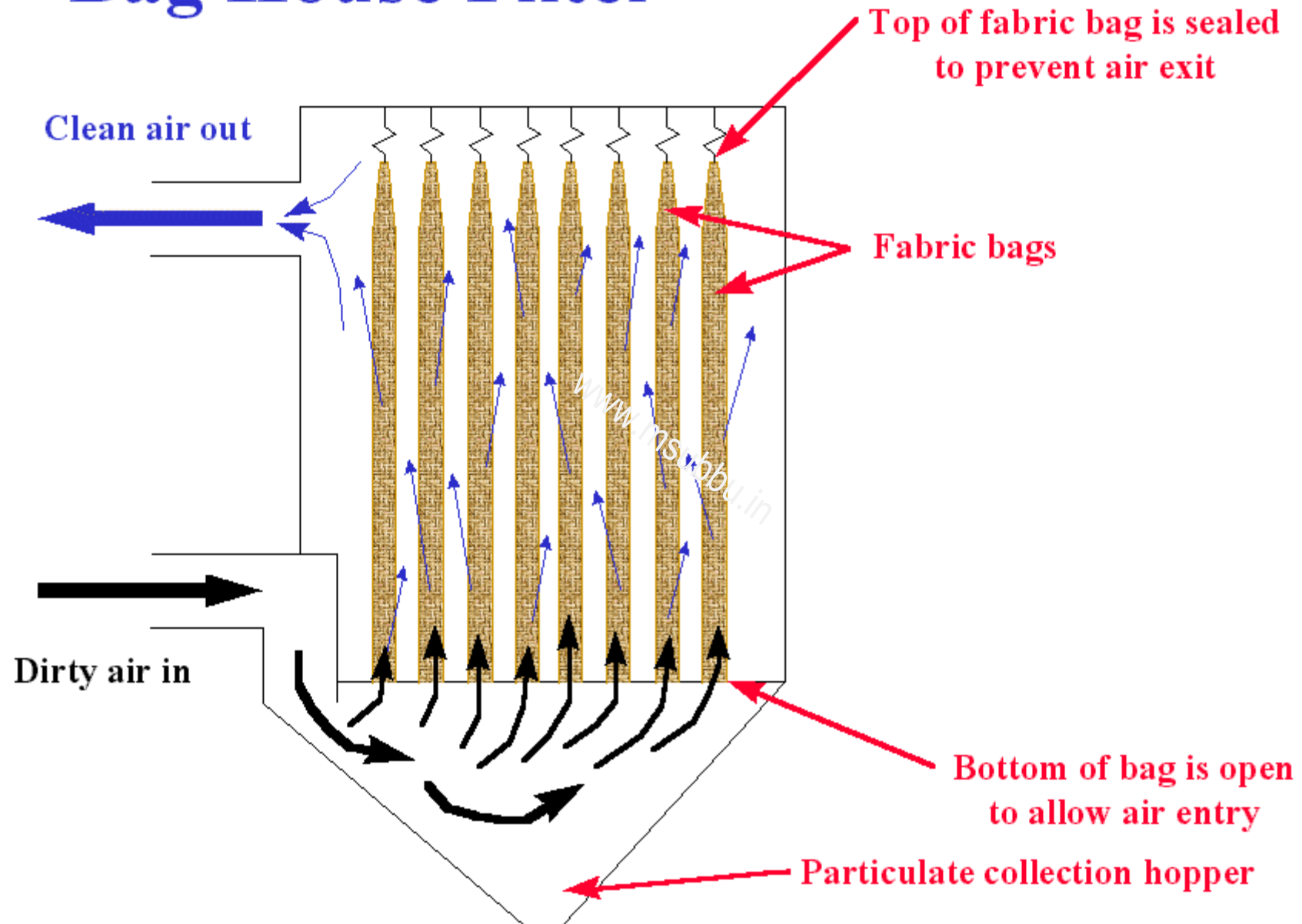
Control Devices

- Particulate pollutants - mechanical collectors, electrostatic precipitators, bag-houses
- Gaseous pollutants – scrubbers, incinerators, adsorbents

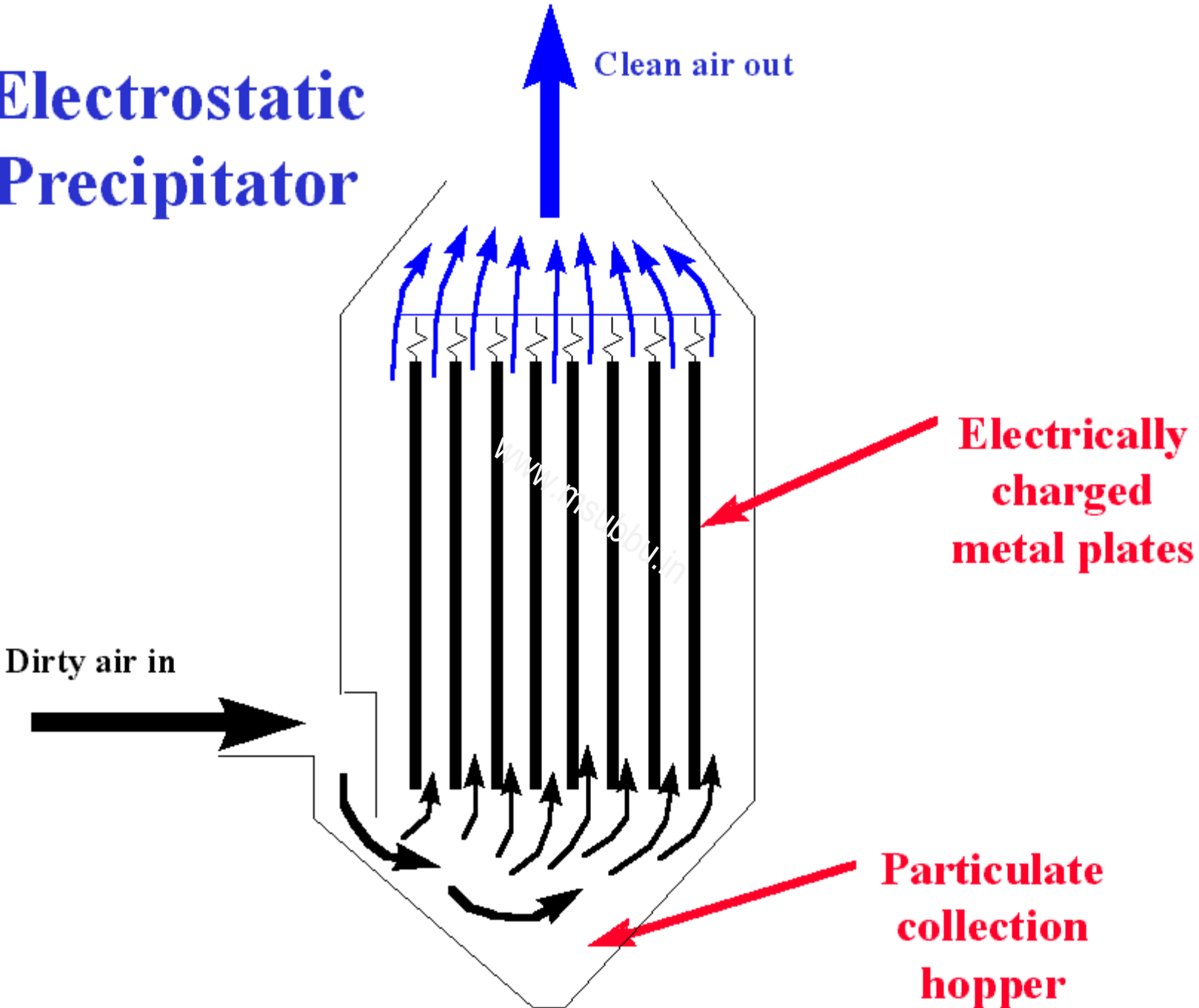
Cyclone



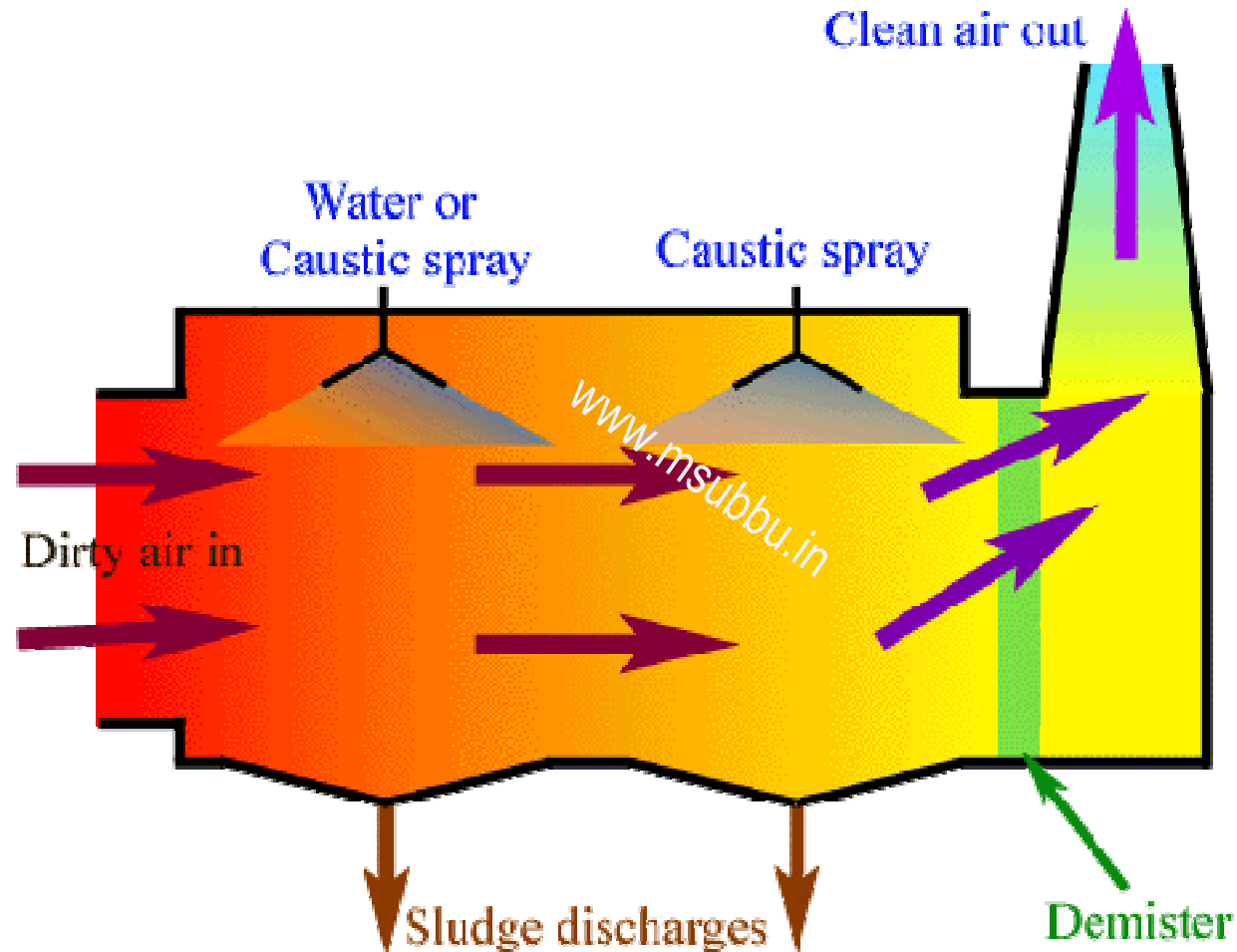
Bag House Filter

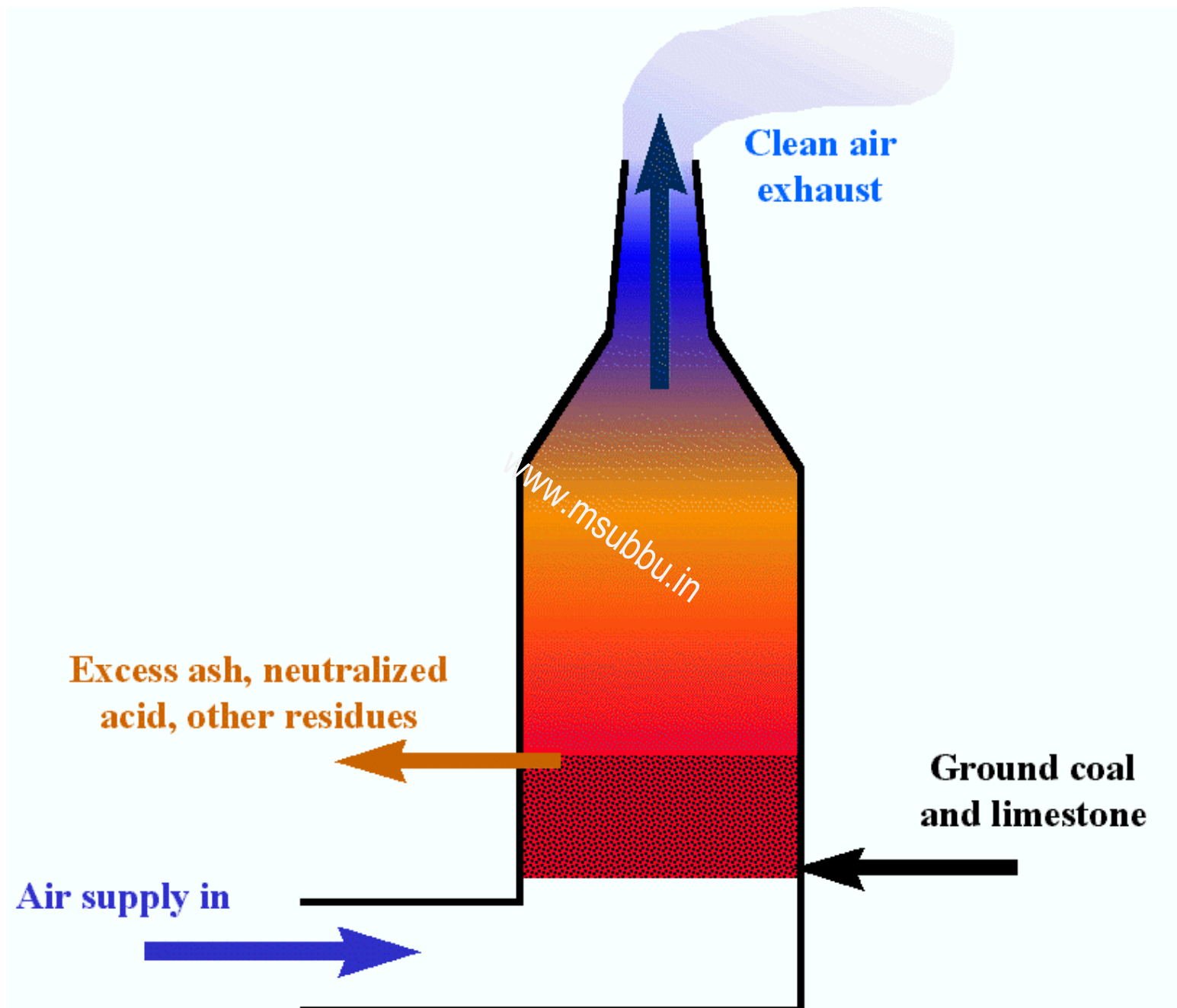


Electrostatic Precipitator



Wet Scrubber





Fluidized bed combustion - to reduce SO₂ pollution