MODULE 03

ENVIRONMENTAL POLLUTION

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- **Pollution** is the introduction of contaminants into the natural environment that cause adverse change.

- Pollution can take the form of chemical substances or energy, such as noise, heat or light.

- Pollutants, the components of pollution, can be either foreign substances/energies or naturally occurring contaminants.

- The major **types of pollution** are listed below:

1) **Air pollution**
2) **Water pollution**
3) **Land pollution**
4) **Noise pollution**
5) **E-pollution**
6) Light pollution
7) Radioactive pollution
8) Thermal pollution
9) Plastic pollution
10) Littering

AIR POLLUTION

• **Air pollution** is the introduction of chemicals, particulates or biological molecules into Earth's atmosphere thereby causing diseases, death to humans, damage to other living organisms such as food crops, or the natural or built environment.

AIR POLLUTANT

- An **air pollutant** is a substance in the air that can have adverse effects on humans and the ecosystem.
- The substance can be solid particles, liquid droplets, or gases.
- A pollutant can be of natural origin or man-made.
- Pollutants are classified as primary and secondary.
- Primary pollutants are usually produced from a process, such as ash from a volcanic eruption or carbon monoxide gas from motor vehicle exhaust.
- Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground level ozone is a prominent example of a secondary pollutant.
- Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

PRIMARY AIR POLLUTANTS

Sulphur oxides (SO_x) - particularly sulphur dioxide, a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Coal and petroleum often contain sulphur compounds, and their combustion generates sulphur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain.[This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.

Primary Air Pollutants

Nitrogen oxides (NO_x) - Nitrogen oxides, particularly nitrogen dioxide, are expelled from high temperature combustion, and are also produced during thunderstorms by electric discharge. They can be seen as a brown haze dome above or a plume downwind of cities. Nitrogen dioxide is a chemical compound with the formula NO_2. It is one of several nitrogen oxides. One of the most prominent air pollutants, this reddish-brown toxic gas has a characteristic sharp, biting odour.

PRIMARY AIR POLLUTANTS

Carbon monoxide (CO) - CO is a colourless, odourless, toxic yet non-irritating gas. It is a product by incomplete combustion of fuel such as natural gas, coal or wood. Vehicular exhaust is a major source of carbon monoxide.

Primary Air Pollutants

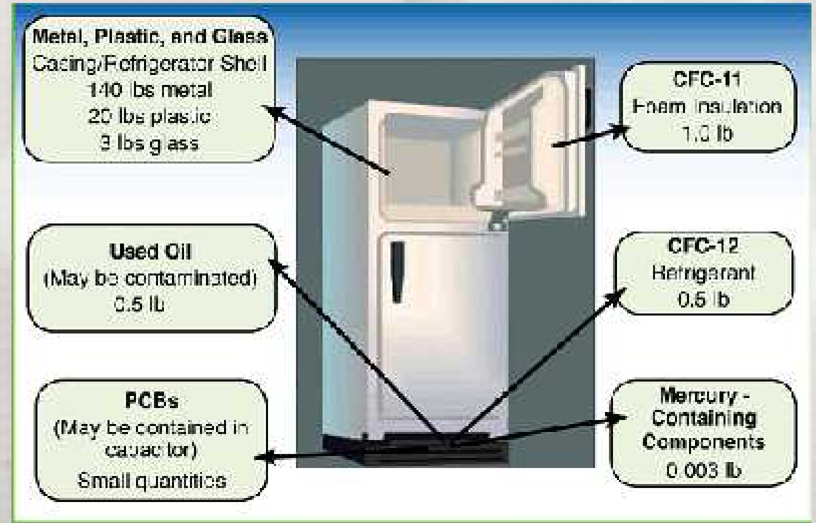
Volatile organic compounds - VOCs are a well-known outdoor air pollutant. They are categorized as either methane (CH_4) or non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming. Other hydrocarbon VOCs are also significant greenhouse gases because of their role in creating ozone and prolonging the life of methane in the atmosphere. This effect varies depending on local air quality. The aromatic NMVOCs benzene, toluene and xylene are suspected carcinogens and may lead to leukemia with prolonged exposure. 1,3-butadiene is another dangerous compound often associated with industrial use.

PRIMARY AIR POLLUTANTS

Particulates, alternatively referred to as particulate matter (PM), atmospheric particulate matter, or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to combined particles and gas. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols. Averaged worldwide, anthropogenic aerosols—those made by human activities—currently account for approximately 10 percent of our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer.

PRIMARY AIR POLLUTANTS

Chlorofluorocarbons (CFCs) - harmful to the ozone layer; emitted from products are currently banned from use. These are gases which are released from air conditioners, refrigerators, aerosol sprays, etc. CFC's on being released into the air rises to stratosphere. Here they come in contact with other gases and damage the ozone layer. This allows harmful ultraviolet rays to reach the earth's surface. This can lead to skin cancer, disease to eye and can even cause damage to plants.



Primary Air Pollutants

Ammonia (NH_3) - emitted from agricultural processes. Ammonia is a compound with the formula NH_3. It is normally encountered as a gas with a characteristic pungent odour. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous. In the atmosphere, ammonia reacts with oxides of nitrogen and sulphur to form secondary particles

Primary Air Pollutants

Persistent free radicals connected to airborne fine particles are linked to cardiopulmonary disease.

Toxic metals, such as lead and mercury, especially their compounds.

Odours, such as from garbage, sewage, and industrial processes.

Radioactive pollutants - produced by nuclear explosions, nuclear events, war explosives, and natural processes such as the radioactive decay of radon.

Secondary Air Pollutants

Particulates created from gaseous primary pollutants and compounds in **photochemical smog**. Smog is a kind of air pollution. Classic smog results from large amounts of coal burning in an area caused by a mixture of smoke and sulphur dioxide. Modern smog does not usually come from coal but from vehicular and industrial emissions that are acted on in the atmosphere by ultraviolet light from the sun to form secondary pollutants that also combine with the primary emissions to form photochemical smog.

SECONDARY AIR POLLUTANTS

Ground level ozone (O_3) formed from NO_x and VOCs. Ozone (O_3) is a key constituent of the troposphere. It is also an important constituent of certain regions of the stratosphere commonly known as the Ozone layer. Photochemical and chemical reactions involving it drive many of the chemical processes that occur in the atmosphere by day and by night. At abnormally high concentrations brought about by human activities (largely the combustion of fossil fuel), it is a pollutant, and a constituent of smog.

Minor Air Pollutants

Persistent organic pollutants (POPs) are organic compounds that are resistant to environmental degradation through chemical, biological, and photolytic processes. Because of this, they have been observed to persist in the environment, to be capable of long-range transport, bioaccumulate in human and animal tissue, biomagnify in food chains, and to have potentially significant impacts on human health and the environment.

Sources of Air Pollutants

There are various locations, activities or factors which are responsible for releasing pollutants into the atmosphere. These sources can be classified into two major categories:

1) Anthropogenic or Man Made Sources

2) Natural Sources

Anthropogenic or Man-made Sources of Air Pollutants

Stationary sources include smoke stacks of power plants, manufacturing facilities (factories) and waste incinerators, as well as furnaces and other types of fuel-burning heating devices. In developing and poor countries, traditional biomass burning is the major source of air pollutants; traditional biomass includes wood, crop waste and dung.

Mobile sources include motor vehicles, marine vessels, and aircraft.

Anthropogenic or Man-made Sources of Air Pollutants

Controlled burn practices in agriculture and forest management. Controlled or prescribed burning is a technique sometimes used in forest management, farming, prairie restoration or greenhouse gas abatement. Fire is a natural part of both forest and grassland ecology and controlled fire can be a tool for foresters. Controlled burning stimulates the germination of some desirable forest trees, thus renewing the forest.

Fumes from paint, hair spray, varnish, aerosol sprays and other solvents.

ANTHROPOGENIC OR MAN-MADE SOURCES OF AIR POLLUTANTS

Waste deposition in landfills, which generate methane. Methane is highly flammable and may form explosive mixtures with air. Methane is also an asphyxiant and may displace oxygen in an enclosed space. Asphyxia or suffocation may result if the oxygen concentration is reduced to below 19.5% by displacement.

Military resources, such as nuclear weapons, toxic gases, germ warfare and rocketry.

Natural Sources of Air Pollutants

• Dust from natural sources, usually **large areas of land with little or no vegetation**

• Methane, emitted by the **digestion of food by animals**

• Smoke and carbon monoxide from **wildfires**

• **Volcanic activity**, which produces sulphur, chlorine and ash particulates

Natural Sources of Air Pollutants

Radon gas from **radioactive decay within the Earth's crust**. Radon is a colourless, odourless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.

Vegetation, in some regions, emits environmentally significant amounts of VOCs on warmer days. These VOCs react with primary anthropogenic pollutants—specifically, NO_x, SO_2, and anthropogenic organic carbon compounds — to produce a seasonal haze of secondary pollutants. Black gum, poplar, oak and willow are some examples of vegetation that can produce abundant VOCs.

Effects of Air Pollution

- Health Effects
- Agricultural Effects
- **Global Warming**
- **Acid Rain**
- **Ozone Layer Depletion**
- **Photochemical Smog**

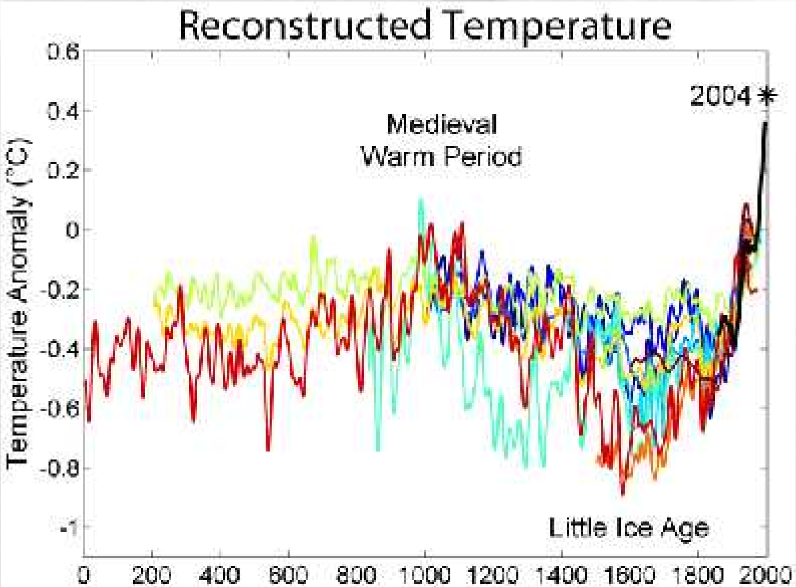
Health & Agricultural Effects of Air Pollution in India

- India has the highest death rate due to air pollution in the world.
- India also has more deaths from asthma than any other nation according to the World Health Organisation.
- Causes of deaths include strokes, heart disease, COPD, lung cancer, and lung infections.
- The capital city of India, Delhi has been facing major smog related problems in the recent year especially during the winters.
- In India in 2014, it was reported that air pollution had cut crop yields in the most affected areas by almost half in 2010 when compared to 1980 levels

EFFECTS OF AIR POLLUTION : **GLOBAL WARMING**

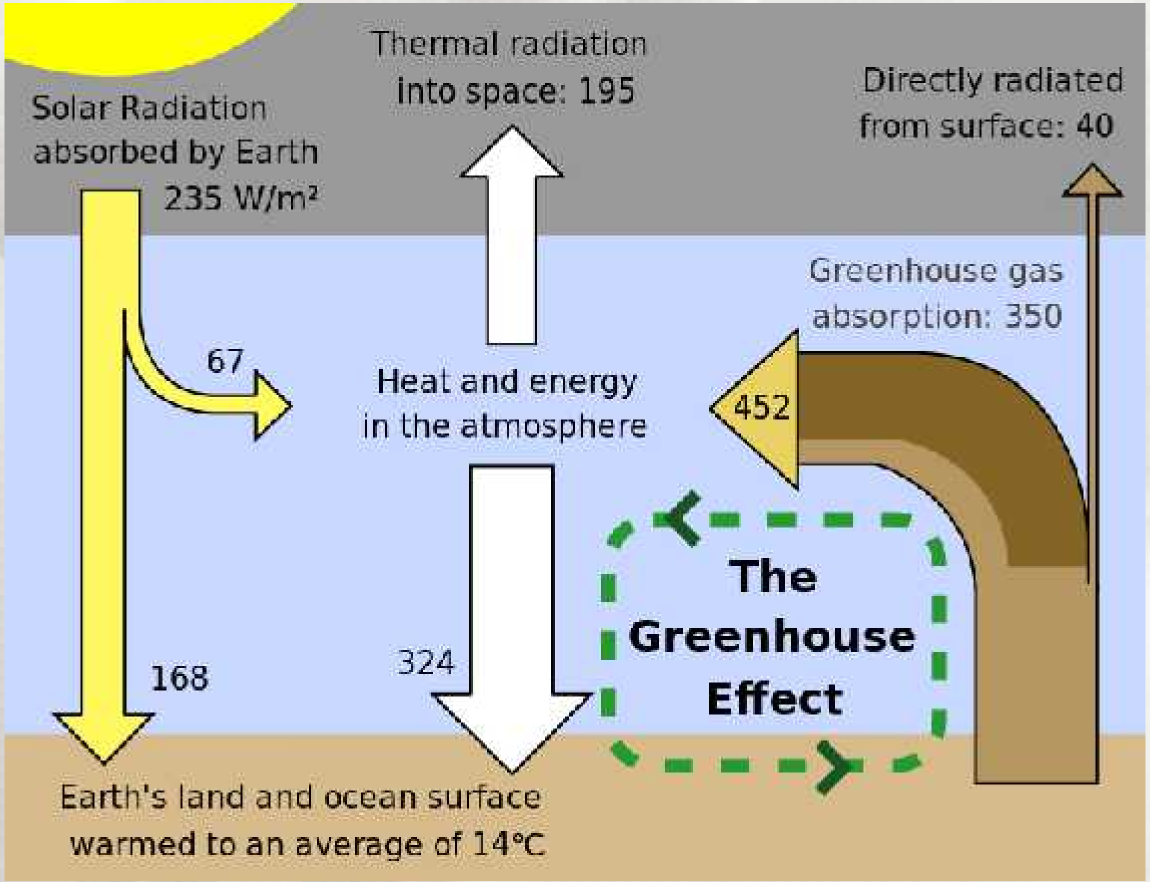
- **Global warming** and climate change are terms for the observed century-scale rise in the average temperature of the Earth's climate system and its related effects.

- 14 of the 15 hottest years have been in the 21st century.
- **2014 was the warmest year on record since 1880 and also the 38th consecutive year with above-average temperatures**.



Effects of Air Pollution : Global Warming

- **Causes of Global Warming: Greenhouse Effect**



Greenhouse Gases: Carbon dioxide, methane, ozone, water vapour.

Effects of Air Pollution : Global Warming

Effects of Global Warming

- Melting of Ice Sheet
- Sea Level Rise
- Extreme Weather
- Changes in Ecological Systems
- Habitat Inundation
- Destabilization of Average Global Temperature
- Ocean Acidification

Effects of Air Pollution : Global Warming

Remedies for Global Warming

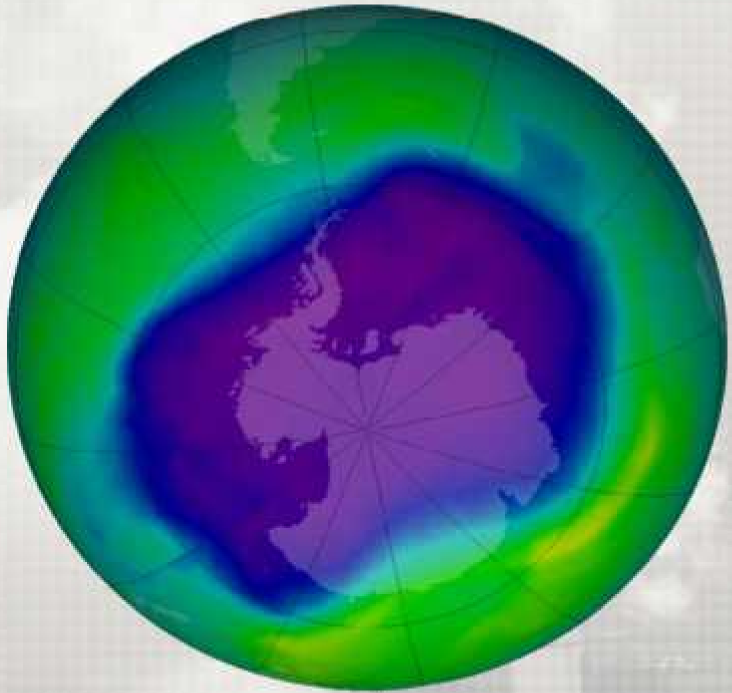
- Reduce greenhouse gas emissions
- Enhance the capacity of carbon sinks to absorb GHGs
- Energy conservation and energy efficiency
- Use of low-carbon technology
- Preventing deforestation, encouraging reforestation
- Adaptation to climate change
- Climate engineering

OZONE LAYER DEPLETION

- **Ozone Layer Depletion** is the steady decline of about 4% in the total volume of ozone in the earth's stratosphere (the ozone layer)

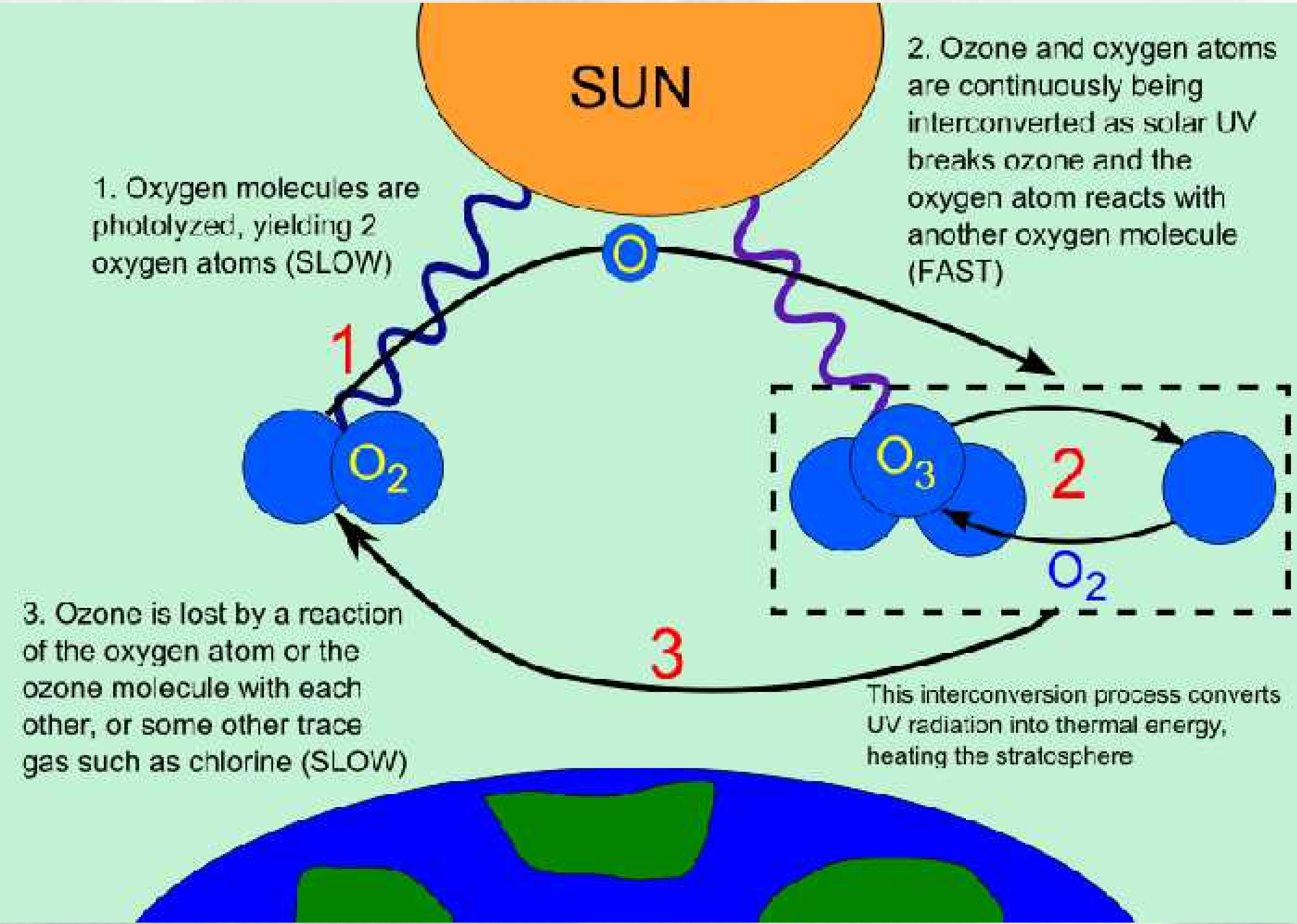
- This phenomenon has been observed since the late 1970s.

- This phenomenon is the most rampant at the polar regions where due to the springtime decrease in stratospheric ozone, **ozone holes** are formed *as shown in this figure*.



OZONE LAYER DEPLETION

- **Ozone Cycle**



Ozone Layer Depletion

- **Causes**

- Chlorofluorocarbons (**CFCs**) and other halogenated ozone depleting substances (**ODS**) are mainly responsible for man-made chemical ozone depletion.

$$CFCl_3 + \text{electromagnetic radiation} \rightarrow Cl + \cdot CFCl_2$$

$$Cl + O_3 = ClO + O_2$$

$$ClO + O_3 = Cl + 2O_2$$

Ozone Layer Depletion

- **Causes**

- A single chlorine atom would keep on destroying ozone (thus a catalyst) for up to two years.
- On average, a single chlorine atom is able to react with 100,000 ozone molecules before it is removed from the catalytic cycle. This fact plus the amount of chlorine released into the atmosphere yearly by chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) demonstrates how dangerous CFCs and HCFCs are to the environment.
- On a per atom basis, bromine is even more efficient than chlorine at destroying ozone, but there is much less bromine in the atmosphere at present.

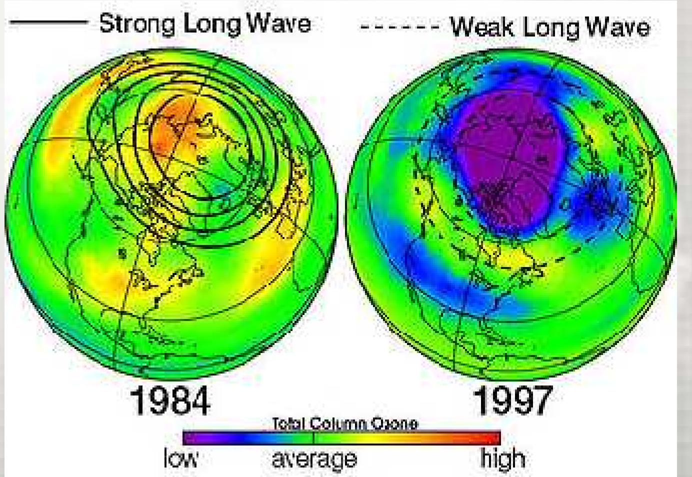
Ozone Layer Depletion

- **Effects**

✓ Increased UV radiation
✓ Biological effects
✓ Basal and squamous cell carcinomas
✓ Malignant melanoma
✓ Cortical cataracts
✓ Increased tropospheric ozone
✓ Increased production of vitamin D
✓ Effects on non-human animals
✓ Effects on crops

- **Remedies**

✓ Decrease CFC release
✓ Find alternative to CFC as a cooling agent
✓ International policy



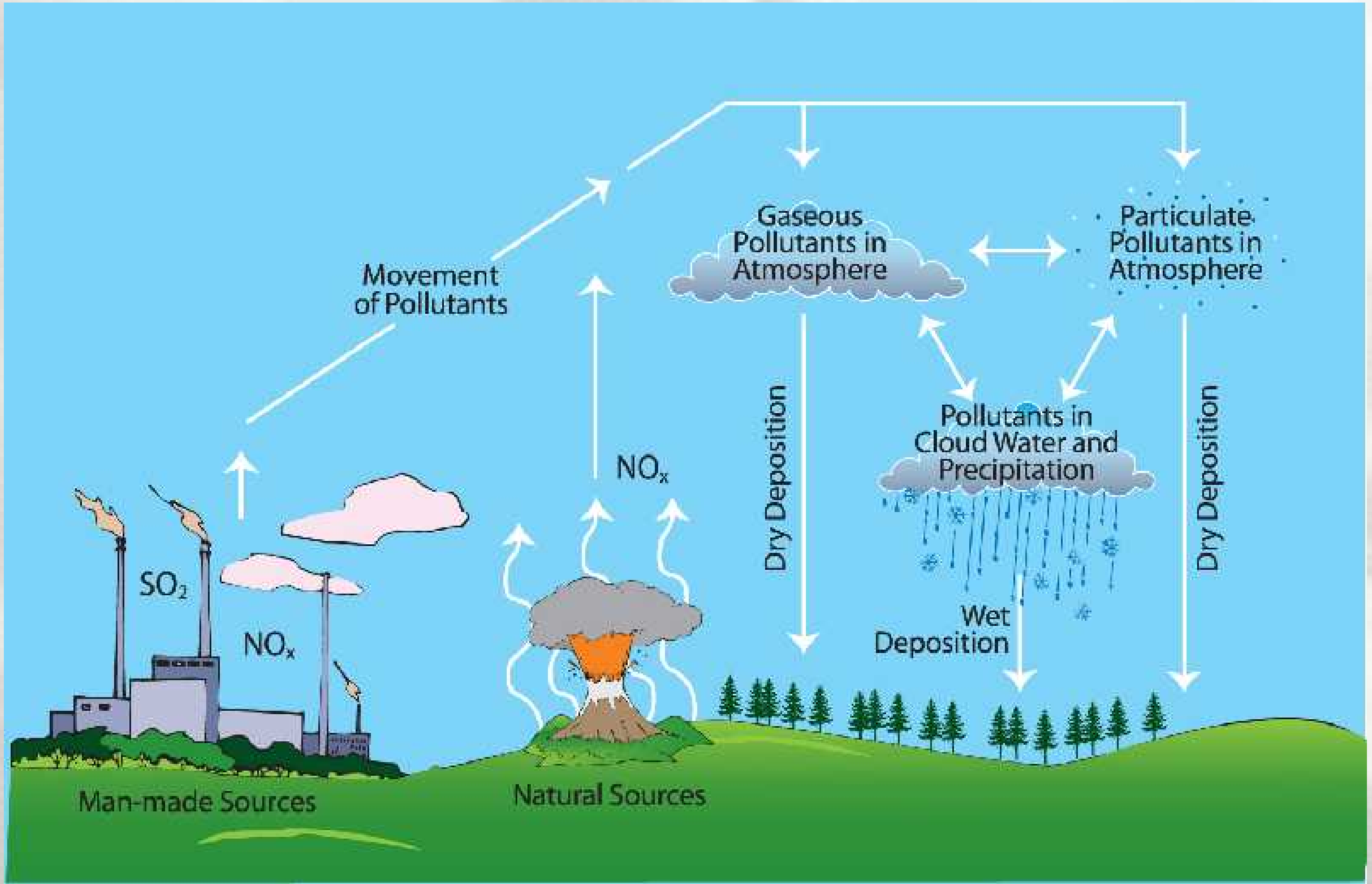
EFFECTS OF AIR POLLUTION : ACID RAIN

- **Acid rain** is a rain or any other form of precipitation that is unusually acidic, meaning that it possesses elevated levels of hydrogen ions (low pH). It can have harmful effects on plants, aquatic animals and infrastructure. Acid rain is caused by emissions of sulphur dioxide and nitrogen oxide, which react with the water molecules in the atmosphere to produce acids.

Effect of Acid Rain on Stone

Effects of Air Pollution : Acid Rain

Causes of Acid Rain



Effects of Air Pollution : Acid Rain

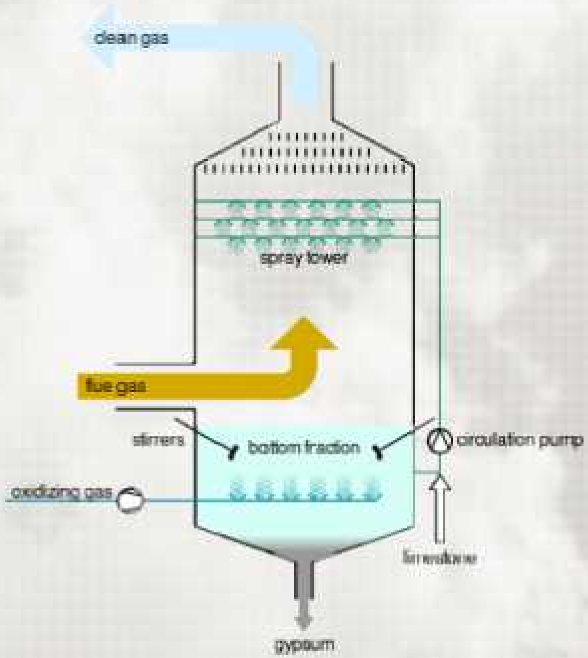
Effects of Acid Rain

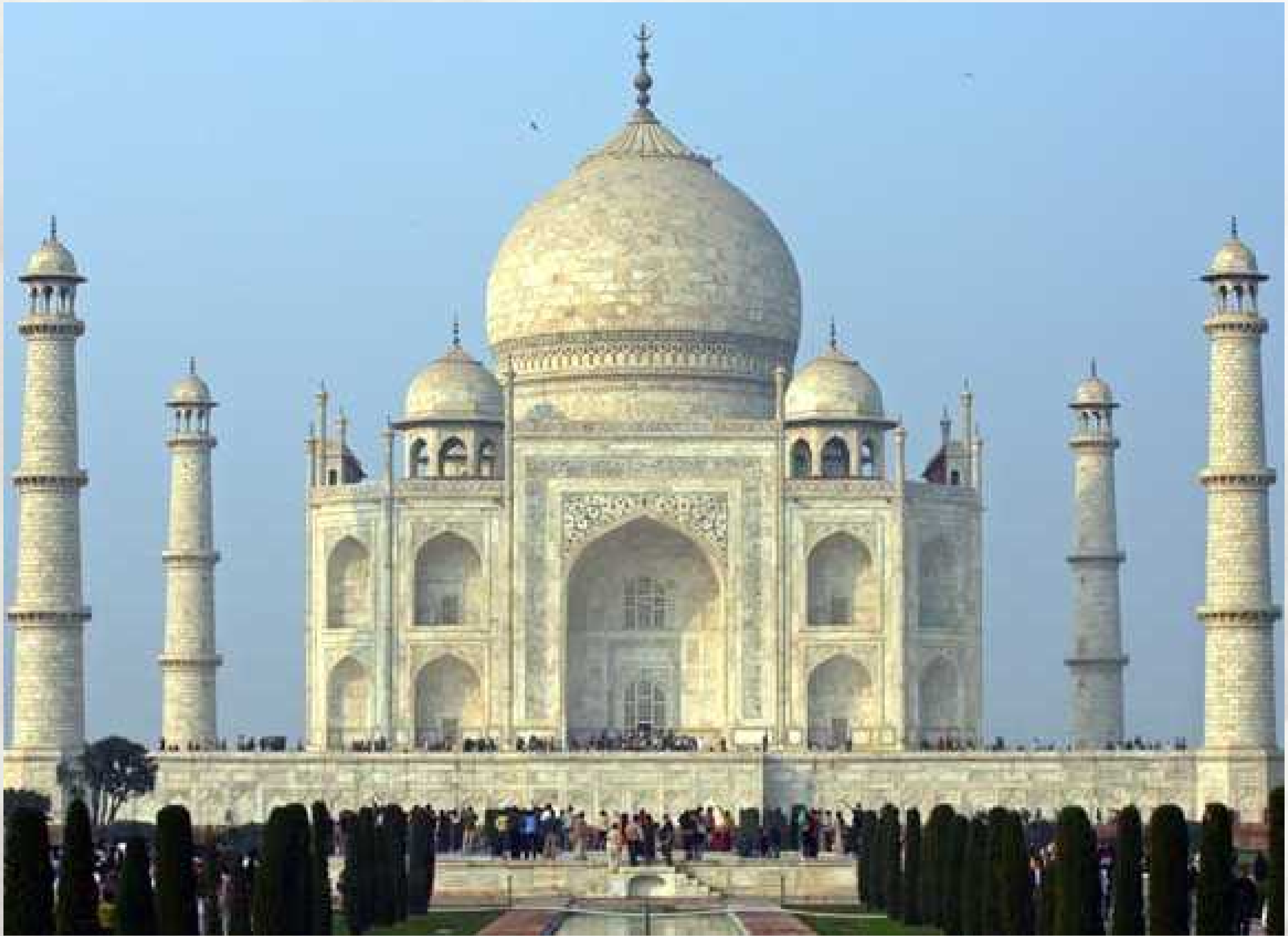
- Surface water and aquatic animals
- Soils
- Forest and vegetation
- Corrosion of steel
- Adverse effects on stones
- Human health effects

Effects of Air Pollution : Acid Rain

Remedies for Acid Rain

- Use of flue-gas desulpherization (FGD)
- Use of wet scrubber in power plants
- Use of fluidized bed combustion
- Vehicle emission control
- International treaties
- Emissions trading





Decolouration of the Taj Mahal due to Acid Rain

Solution applied:

EFFECTS OF AIR POLLUTION : PHOTOCHEMICAL SMOG

- **Photochemical Smog** is the haze in the atmosphere accompanied by high levels of ozone and nitrogen oxides, caused by the action of sunlight and pollutants.

- Smog = smoke + fog

- Cities like Los Angeles, New York, Sydney and Vancouver frequently suffer episodes of photochemical smog.

Effects of Air Pollution : Photochemical Smog

• **Causes/Pollutants Involved** :

✓ Nitrogen Oxides
✓ Volatile Organic Compounds
✓ Ozone
✓ Peroxyacetyl Nitrates (PAN)

• **Conditions for Photochemical Smog** :

✓ Source of Nitrogen oxides and VOCs
✓ Time of the day
✓ Meteorological factors (precipitation, wind, temperature)
✓ Topography

Effects of Air Pollution : Photochemical Smog

- **Chemistry of Photochemical Smog** :

$$O_3 + NO » NO_2 + O_2$$

$$NO + RO_2 » NO_2 + \text{other products}$$

$$NO_2 + \text{sunlight} » NO + O$$

$$O + O_2 » O_3$$

$$NO_2 + R » \text{products such as PAN}$$

Effects of Air Pollution : Photochemical Smog

- **Effects of Photochemical Smog** :

✓ Decreased visibility
✓ Heart and lung problems
✓ Suppression of plant growth
✓ Decreased immunity
✓ Spread of cancer
✓ Eye irritation
✓ Respiratory problems
✓ Bronchial congestion
✓ Harsh odour

- **Remedies** :

✓ Decrease of nitrogen oxide and VOC emissions


AP

Baghouse Filter

Baghouse Filter - Introduction

- A **baghouse** (BH, B/H), bag filter (BF) or fabric filter (FF) is an air pollution control device that removes particulates out of air or gas released from commercial processes or combustion for electricity generation.

- Power plants, steel mills, pharmaceutical producers, food manufacturers, chemical producers and other industrial companies often use baghouses to control emission of air pollutants.

- Baghouses came into widespread use in the late 1970s after the invention of high-temperature fabrics (for use in the filter media) capable of withstanding temperatures over 350 °F.

- Unlike electrostatic precipitators, where performance may vary significantly depending on process and electrical conditions, functioning baghouses typically have a particulate collection efficiency of 99% or better, even when particle size is very small.

Baghouse Filter – Operation

• Most baghouses use long, cylindrical bags (or tubes) made of woven or felted fabric as a filter medium.

• For applications where there is relatively low dust loading and gas temperatures are 250 °F or less, pleated, nonwoven cartridges are sometimes used as filtering media instead of bags.

• Dust-laden gas or air enters the baghouse through hoppers (large funnel-shaped containers used for storing and dispensing particulate) and is directed into the baghouse compartment.

•The gas is drawn through the bags, either on the inside or the outside depending on cleaning method, and a layer of dust accumulates on the filter media surface until air can no longer move through it.

• When sufficient pressure drop (delta P) occurs, the cleaning process begins.

• Cleaning can take place while the baghouse is online (filtering) or is offline (in isolation).

• When the compartment is clean, normal filtering resumes again.

BAGHOUSE FILTER – OPERATION

Baghouse Filter – Operation

• Baghouses are very efficient particulate collectors because of the dust cake formed on the surface of the bags.

• The fabric provides a surface on which dust collects through the following four mechanisms:

- **Inertial collection:** Dust particles strike the fibers placed perpendicular to the gas-flow direction instead of changing direction with the gas stream.
- **Interception:** Particles that do not cross the fluid streamlines come in contact with fibers because of the fiber size.
- **Brownian movement:** Submicrometre particles are diffused, increasing the probability of contact between the particles and collecting surfaces.
- **Electrostatic forces:** The presence of an electrostatic charge on the particles and the filter can increase dust capture.

• A combination of these mechanisms results in formation of the dust cake on the filter, which eventually increases the resistance to gas flow. The filter must be cleaned periodically.

BAGHOUSE FILTER – TYPES

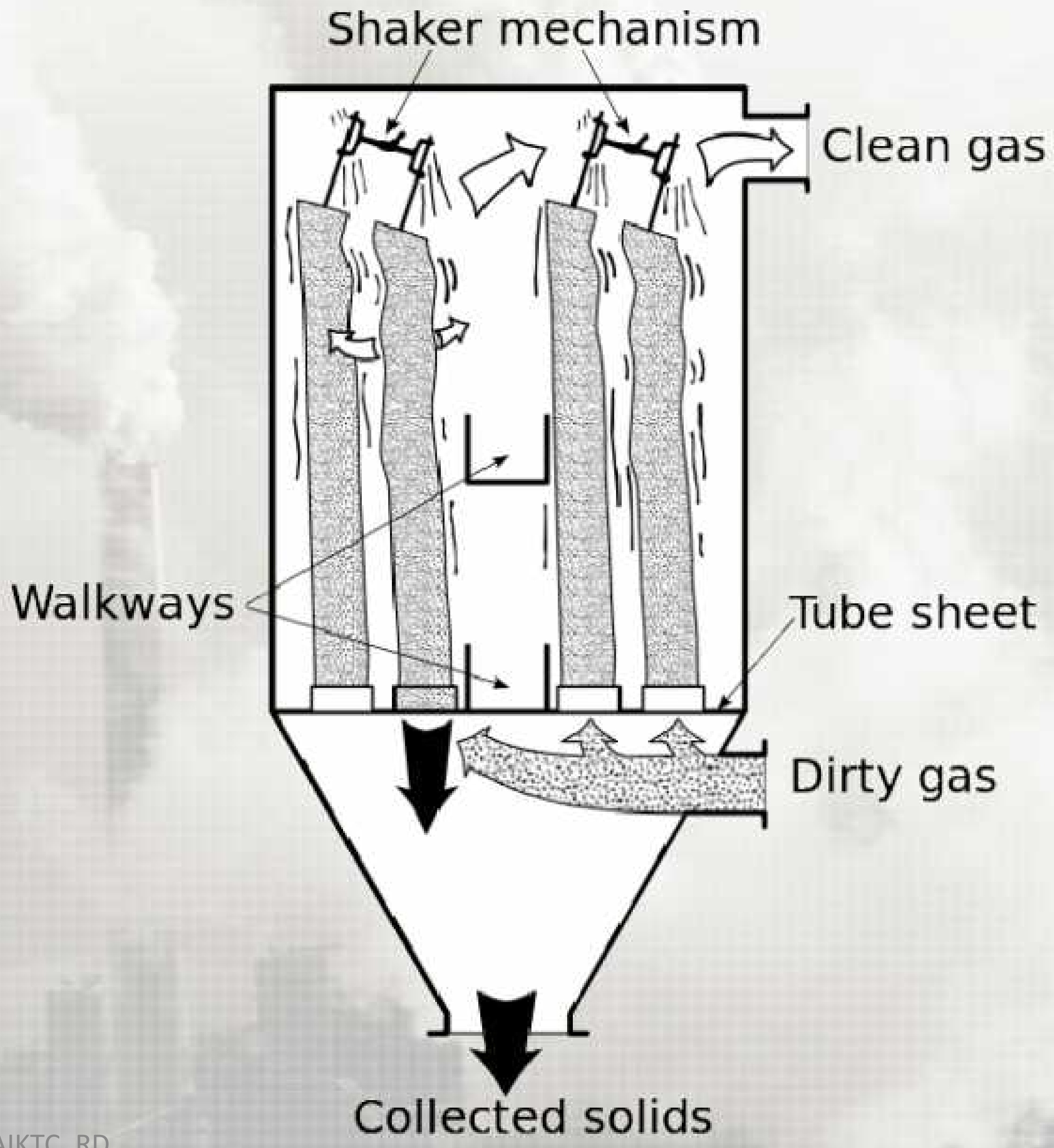
- Baghouses are classified based on the cleaning method used.
- The three most common types of baghouses are:

Mechanical shakers

Reverse gas

Reverse jet

BAGHOUSE FILTER – MECHANICAL SHAKER BAGHOUSE



BAGHOUSE FILTER – MECHANICAL SHAKER BAGHOUSE

In mechanical-shaker baghouses, tubular filter bags are fastened onto a cell plate at the bottom of the baghouse and suspended from horizontal beams at the top. Dirty gas enters the bottom of the baghouse and passes through the filter, and the dust collects on the inside surface of the bags.

Cleaning a mechanical-shaker baghouse is accomplished by shaking the top horizontal bar from which the bags are suspended. Vibration produced by a motor-driven shaft and cam creates waves in the bags to shake off the dust cake.

Shaker baghouses range in size from small, handshaker devices to large, compartmentalized units. They can operate intermittently or continuously. Intermittent units can be used when processes operate on a batch basis-when a batch is completed, the baghouse can be cleaned. Continuous processes use compartmentalized baghouses; when one compartment is being cleaned, the airflow can be diverted to other compartments.

In shaker baghouses, there must be no positive pressure inside the bags during the shake cycle. Pressures as low as 0.02 in. wg can interfere with cleaning.

The air to cloth ratio for shaker baghouses is relatively low, hence the space requirements are quite high. However, because of the simplicity of design, they are popular in the minerals processing industry.

Baghouse Filter – Mechanical Shaker Baghouse

Advantages

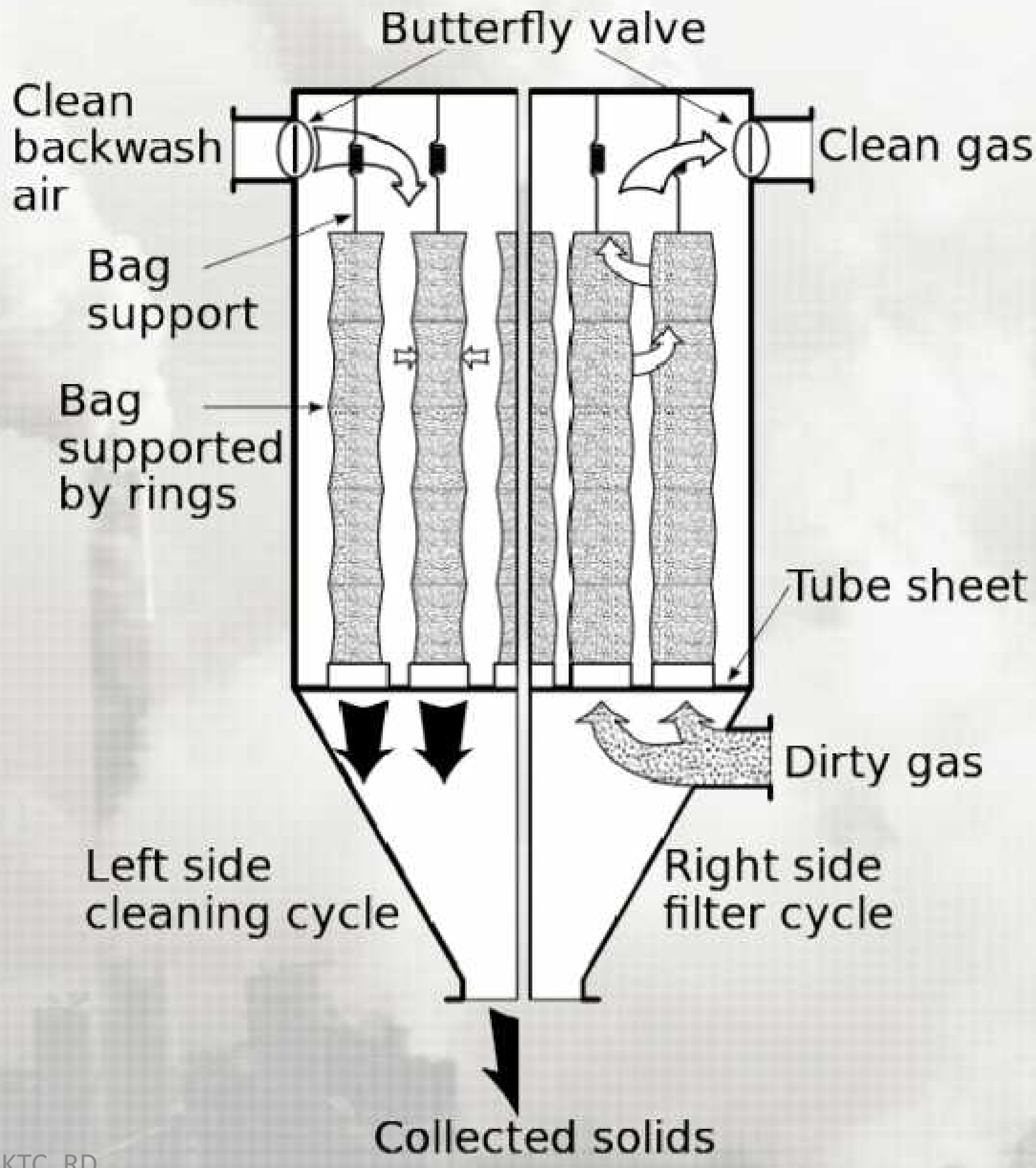
- It has high collection efficiency for respirable dust
- It can use strong woven bags, which can withstand intensified cleaning cycle to reduce residual dust buildup
- It is simple to operate
- It has low pressure drop for equivalent collection efficiencies

Baghouse Filter – Mechanical Shaker Baghouse

Disadvantages

- It has low air-to-cloth ratio (1.5 to 2 ft/min)
- It cannot be used in high temperatures
- It requires large amounts of space
- It needs large numbers of filter bags
- It consists of many moving parts & require frequent maintenance
- Personnel must enter baghouse to replace bags, creating potential for exposure to toxic dust
- Can result in reduced cleaning efficiency if even a slight positive pressure exists inside bags

Baghouse Filter – Reverse Air Baghouse



Baghouse Filter – Reverse Air Baghouse

In reverse-air baghouses, the bags are fastened onto a cell plate at the bottom of the baghouse and suspended from an adjustable hanger frame at the top. Dirty gas flow normally enters the baghouse and passes through the bag from the inside, and the dust collects on the inside of the bags.

Reverse-air baghouses are compartmentalized to allow continuous operation. Before a cleaning cycle begins, filtration is stopped in the compartment to be cleaned. Bags are cleaned by injecting clean air into the dust collector in a reverse direction, which pressurizes the compartment. The pressure makes the bags collapse partially, causing the dust cake to crack and fall into the hopper below. At the end of the cleaning cycle, reverse airflow is discontinued, and the compartment is returned to the main stream.

The flow of the dirty gas helps maintain the shape of the bag. However, to prevent total collapse and fabric chafing during the cleaning cycle, rigid rings are sewn into the bags at intervals.

Space requirements for a reverse-air baghouse are comparable to those of a shaker baghouse; however, maintenance needs are somewhat greater

Baghouse Filter – Reverse Air Baghouse

Advantages

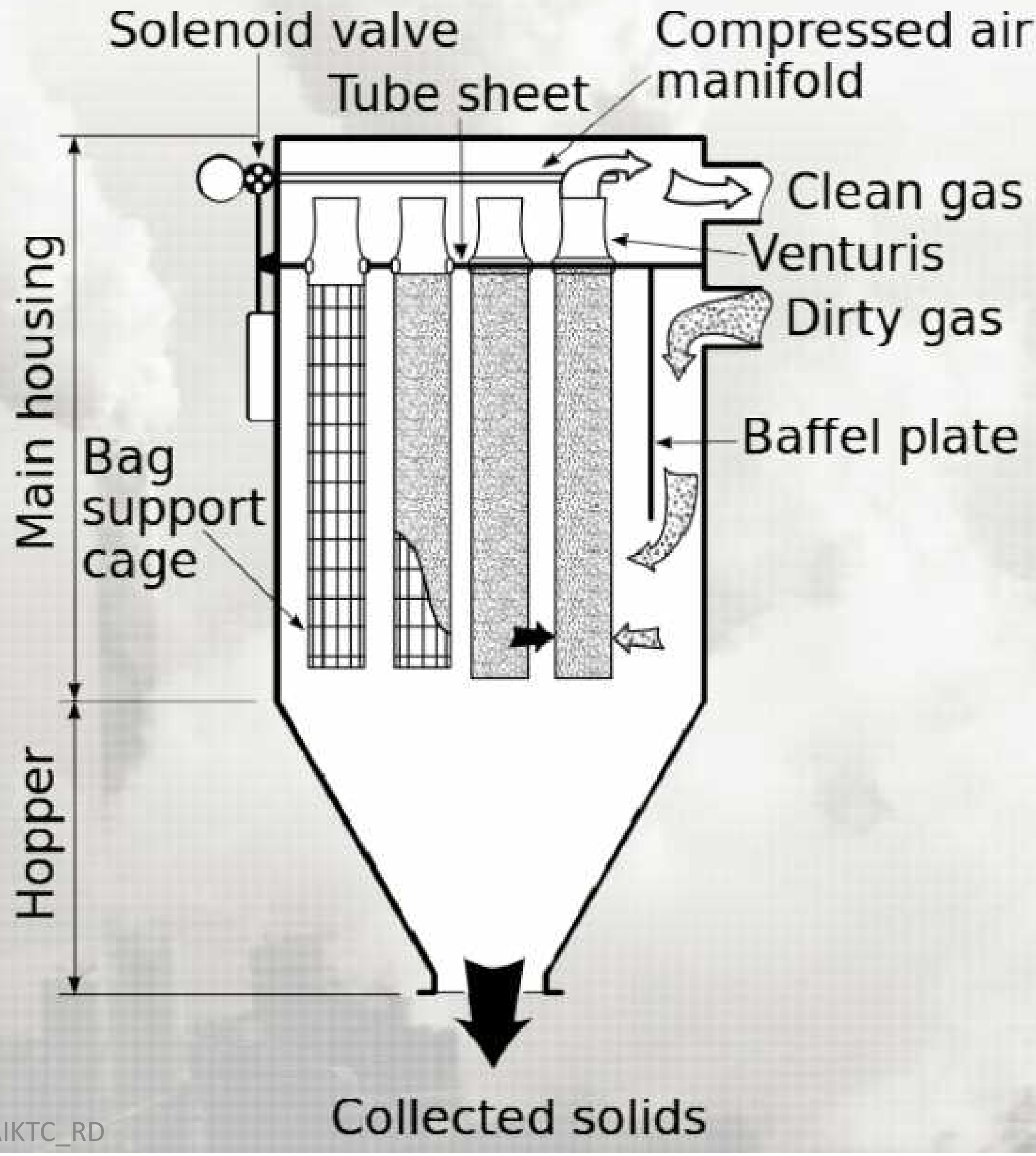
- It has high collection efficiency for respirable dust
- It is preferred for high temperatures due to gentle cleaning action
- It has low pressure drop for equivalent collection efficiencies

Baghouse Filter – Reverse Air Baghouse

Disadvantages

- It has low air-to-cloth ratio (1 to 2 ft/min)
- It requires frequent cleaning due to gentle cleaning action
- It has no effective way to remove residual dust buildup
- Cleaning air must be filtered
- Personnel must enter baghouse to replace bags, creating potential for exposure to toxic dust

BAGHOUSE FILTER – REVERSE JET BAGHOUSE



Baghouse Filter – Reverse Jet Baghouse

In reverse-pulse-jet baghouses, individual bags are supported by a metal cage (filter cage), which is fastened onto a cell plate at the top of the baghouse. Dirty gas enters from the bottom of the baghouse and flows from outside to inside the bags. The metal cage prevents collapse of the bag.

Bags are cleaned by a short burst of compressed air injected through a common manifold over a row of bags. The compressed air is accelerated by a venturi-nozzle mounted at the reverse-jet baghouse top of the bag. Since the duration of the compressed-air burst is short (0.1s), it acts as a rapidly moving air bubble, travelling through the entire length of the bag and causing the bag surfaces to flex. This flexing of the bags breaks the dust cake, and the dislodged dust falls into a storage hopper below.

Reverse-pulse-jet dust collectors can be operated continuously and cleaned without interruption of flow because the burst of compressed air is very small compared with the total volume of dusty air through the collector. Because of this continuous-cleaning feature, reverse-jet dust collectors are usually not compartmentalized.

The short cleaning cycle of reverse-jet collectors reduces recirculation and redeposit of dust. These collectors provide more complete cleaning and reconditioning of bags than shaker or reverse-air cleaning methods. Also, the continuous-cleaning feature allows them to operate at higher air-to-cloth ratios, so the space requirements are lower.

This cleaning system works with the help of digital sequential timer attached to the fabric filter. this timer indicates the solenoid valve to inject the air to the blow pipe.

Baghouse Filter – Reverse Jet Baghouse

Advantages

- It has high collection efficiency for respirable dust
- It has high air-to-cloth ratio (6 to 10 ft/min)
- It has increased efficiency and minimal residual dust buildup due to aggressive cleaning action
- It can clean continuously
- It can use strong woven bags
- It has lower bag wear
- It has a small size and fewer bags due to high air to cloth ratio
- Some designs allow bag changing without entering baghouse
- It has low pressure drop for equivalent collection efficiencies

BAGHOUSE FILTER – REVERSE JET BAGHOUSE

DISADVANTAGES

- It requires use of dry compressed air
- It may not be used readily in high temperatures unless special fabrics are used
- It cannot be used if high moisture content or humidity levels are present in the exhaust gases

Baghouse Cleaning Considerations

Sonic Horns

Some baghouses have sonic horns installed to provide supplementary vibration cleaning energy.

The horns, which generate high intensity, low frequency sounds waves, are turned on just before or at the start of the cleaning cycle to help break the bonds between particles on the filter media surface and aid in dust removal.

BAGHOUSE CLEANING CONSIDERATIONS

CLEANING SEQUENCES

1. INTERMITTENT CLEANING (Periodic Cleaning)

Intermittently cleaned baghouses are composed of many compartments or sections.

One at a time, each compartment is periodically closed off from the incoming dirty gas stream, cleaned, and then brought back online.

While the individual compartment is out of place, the gas stream is diverted from the compartment's area.

This makes shutting down the production process unnecessary during cleaning cycles.

Baghouse Cleaning Considerations

Cleaning Sequences

2. Continuos Cleaning

Continuously cleaned baghouse compartments are always online for automatic filtering.
A blast of compressed air momentarily interrupts the collection process to clean the bag.
This is known as pulse jet cleaning.
Pulse jet cleaning does not require taking compartments offline. Continuously cleaned baghouses are designed to prevent complete shutdown during bag maintenance and failures to the primary system.

Baghouse Performance

Baghouse performance is dependent upon the following factors:

Gas Temperature - Fabrics are designed to operate within a certain range of temperature. Fluctuation outside of these limits even for a small period of time, can weaken, damage, or ruin the bags.

Pressure Drop - Baghouses operate most effectively within a certain pressure drop range. This spectrum is based on a specific gas volumetric flow rate.

Opacity - Opacity measures the quantity of light scattering that occurs as a result of the particles in a gas stream. Opacity is not an exact measurement of the concentration of particles; however, it is a good indicator of the amount of dust leaving the baghouse.

Gas Volumetric Flow Rate - Baghouses are created to accommodate a range of gas flows. An increase in gas flow rates causes an increase in operating pressure drop and air-to-cloth ratio. These increases require the baghouse to work more strenuously, resulting in more frequent cleanings and high particle velocity, two factors that shorten bag life.

The chemical composition, moisture, acid dew point, and particle loading and size distribution of the gas stream are essential factors as well.

VENTURI SCRUBBER

VENTURI SCRUBBER

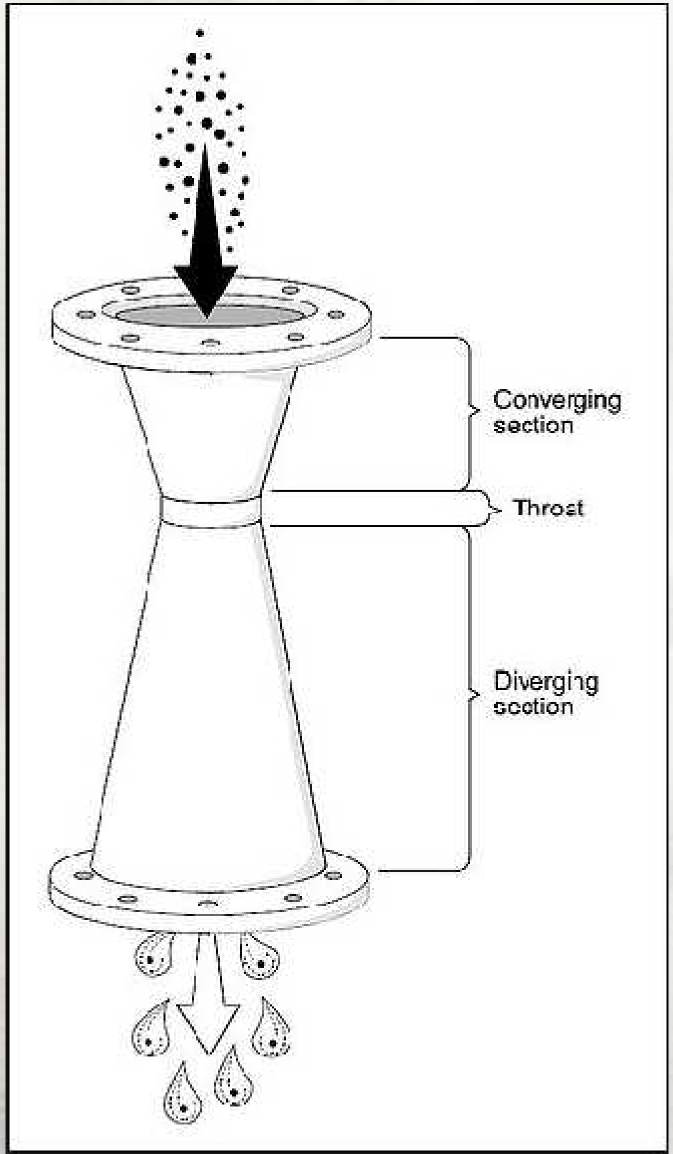
A venturi scrubber is designed to effectively use the energy from the inlet gas stream to atomize the liquid being used to scrub the gas stream.

This type of technology is a part of the group of air pollution controls collectively referred to as wet scrubbers.

Venturi devices have also been used for over 100 years to measure fluid flow (Venturi tubes derived their name from Giovanni Battista Venturi, an Italian physicist).

About 35 years ago, *Johnstone (1949)* and other researchers found that they could effectively use the venturi configuration to remove particles from gas streams.

Venturi Scrubber: Working



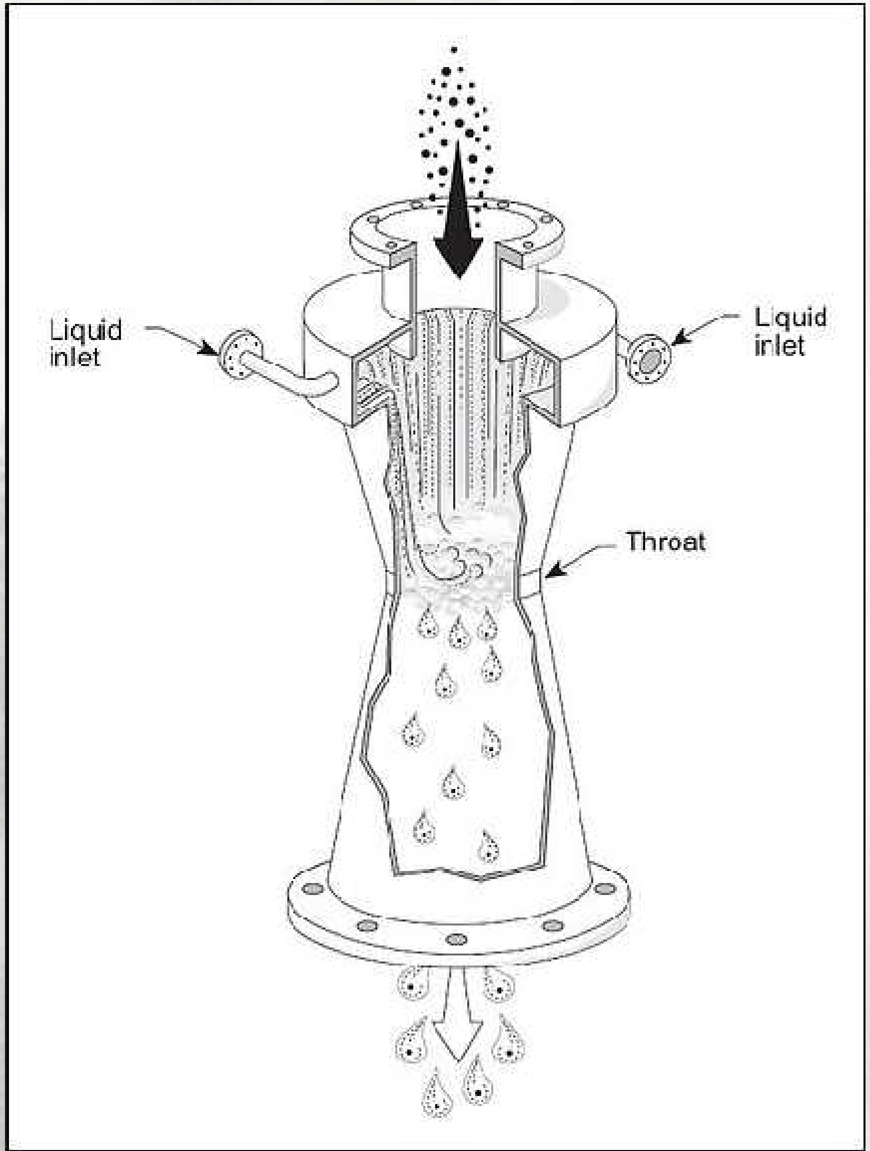
Venturi Scrubber: Working

- A venturi scrubber consists of three sections: a converging section, a throat section, and a diverging section.
- The inlet gas stream enters the converging section and, as the area decreases, gas velocity increases (in accordance with the Bernoulli's equation).
- Liquid is introduced either at the throat or at the entrance to the converging section.
- The inlet gas, forced to move at extremely high velocities in the small throat section, shears the liquid from its walls, producing an enormous number of very tiny droplets.
- Particle and gas removal occur in the throat section as the inlet gas stream mixes with the fog of tiny liquid droplets.
- The inlet stream then exits through the diverging section, where it is forced to slow down.
- Venturis can be used to collect both particulate and gaseous pollutants, but they are more effective in removing particles than gaseous pollutants.

VENTURI SCRUBBER: TYPES

1. Wetted Throat Venturi Scrubber
2. Non-Wetted Throat Venturi Scrubber
3. Rectangular Throat Venturi Scrubber
4. Adjustable Throat Venturi Scrubber with Plunger
5. Adjustable Throat Venturi Scrubber with Movable Plates
6. Venturi Rod Scrubber

VENTURI SCRUBBER: **WETTED THROAT VENTURI SCRUBBER**



Venturi Scrubber: Wetted Throat Venturi Scrubber

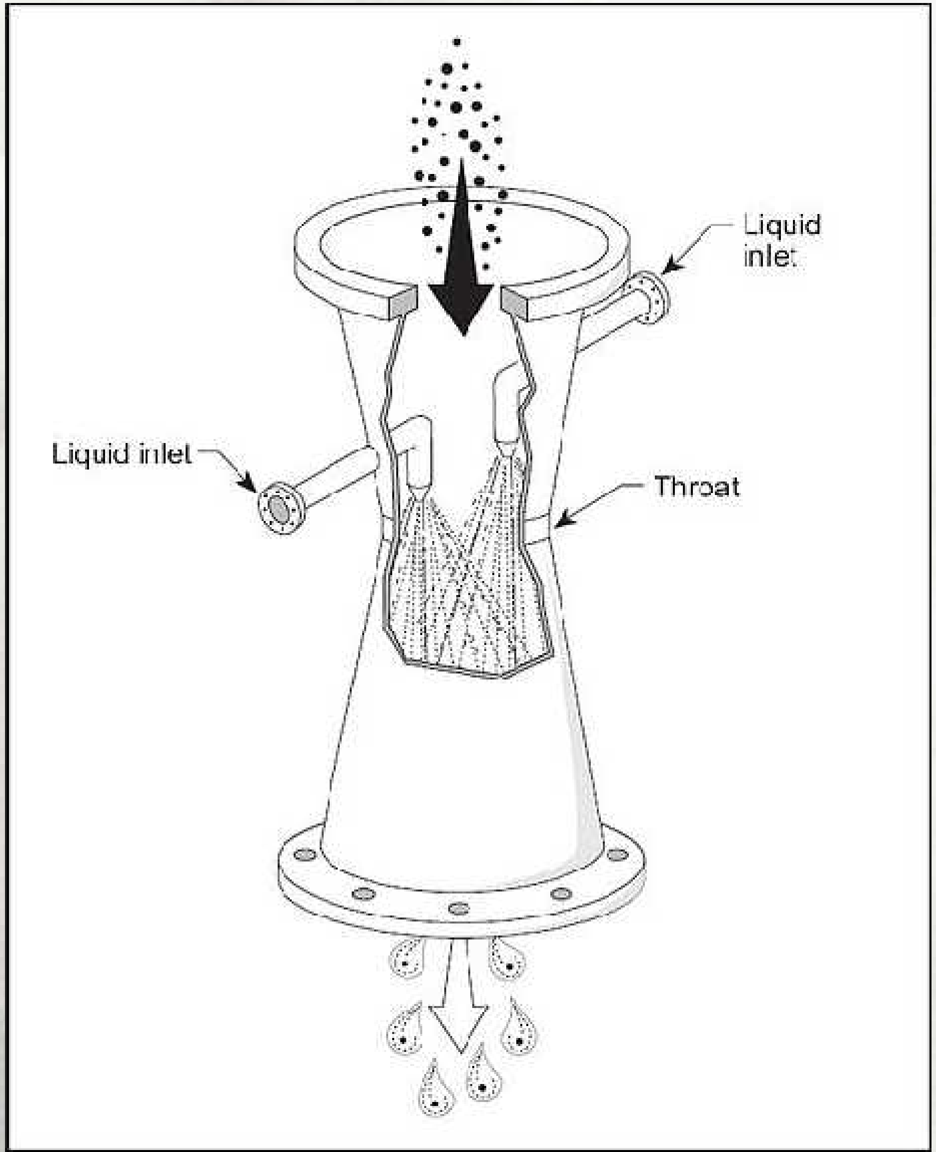
- Liquid is injected at the converging section.

- Thus, the liquid coats the venturi throat making it very effective for handling hot, dry inlet gas that contains dust.

- Otherwise, the dust would have a tendency to cake on or abrade a dry throat.

- These venturis are sometimes referred to as having a wetted approach.

VENTURI SCRUBBER: NON - WETTED THROAT VENTURI SCRUBBER



Venturi Scrubber: Non - Wetted Throat Venturi Scrubber

• Liquid is injected at the venturi throat.

• Since it is sprayed at or just before the throat, it does not actually coat the throat surface.

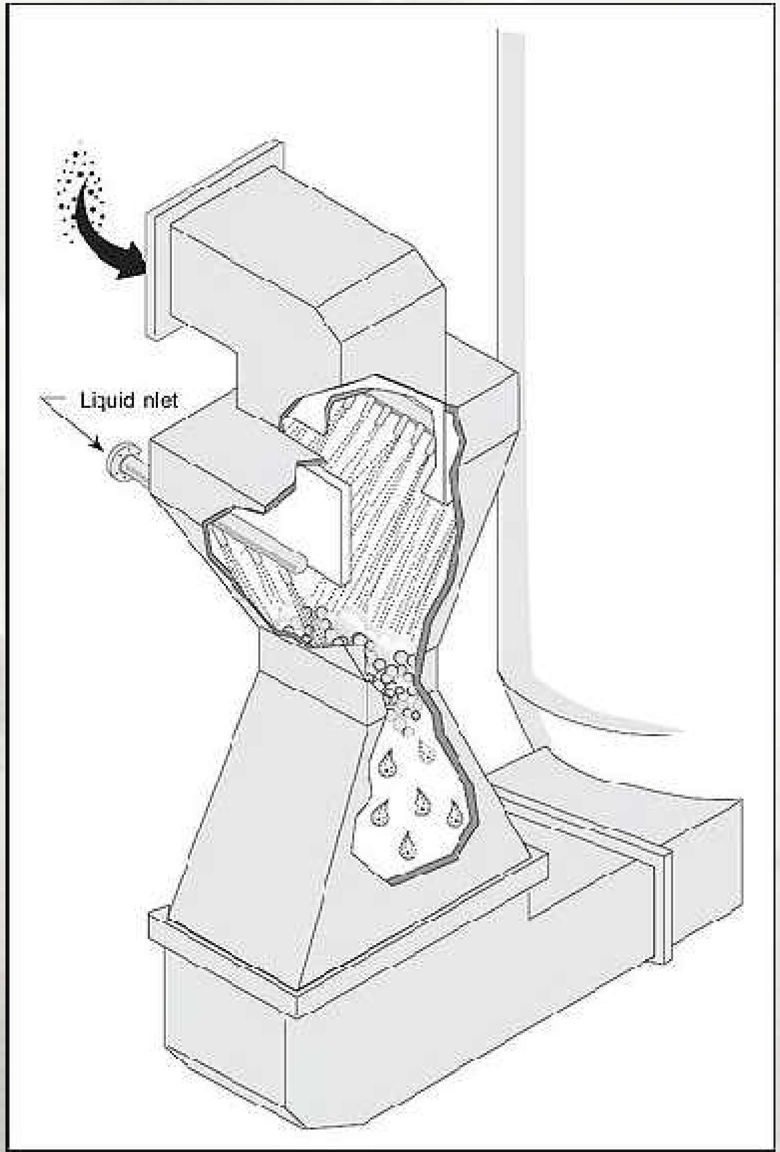
• These throats are susceptible to solids buildup when the throat is dry.

• They are also susceptible to abrasion by dust particles.

• These venturis are best used when the inlet stream is cool and moist.

• These venturis are referred to as having a non-wetted approach.

VENTURI SCRUBBER: RECTANGULAR THROAT VENTURI SCRUBBER



Venturi Scrubber: Rectangular Throat Venturi Scrubber

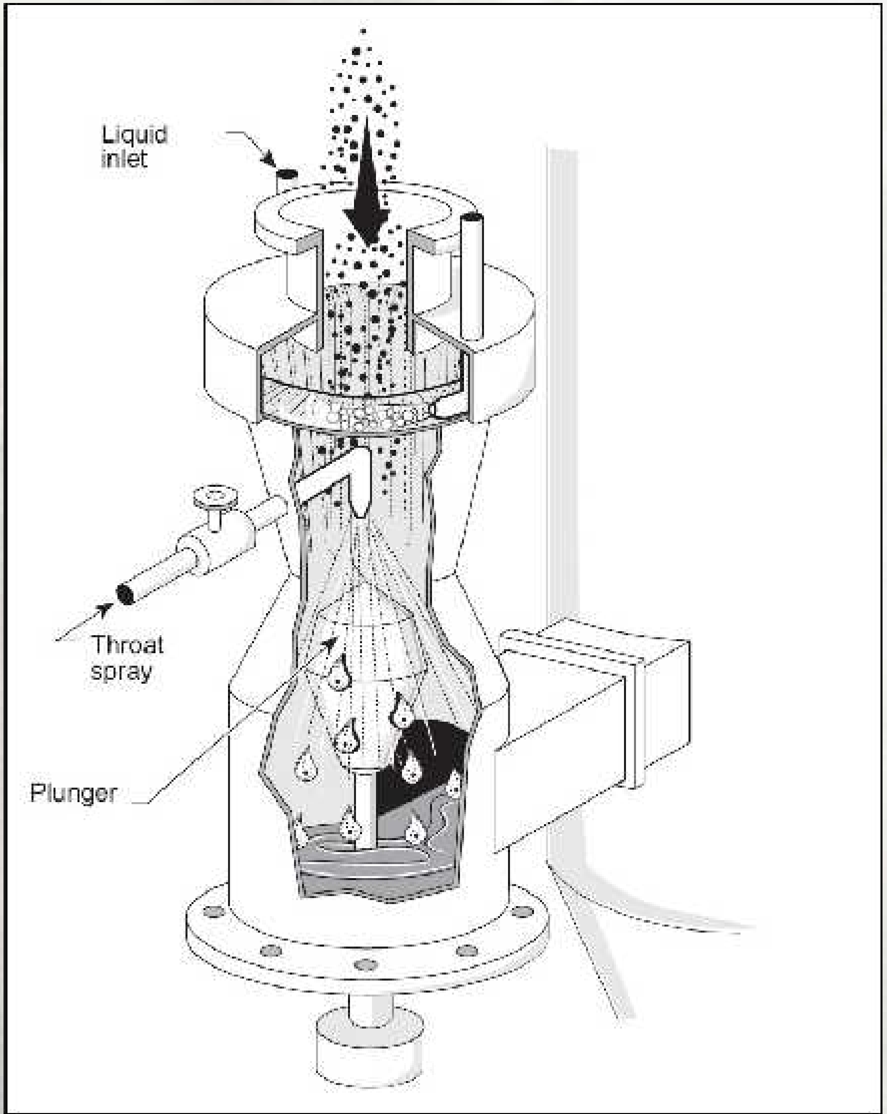
- Venturis scrubbers with round throats can handle inlet flows as large as 88,000 m^3/h (40,000 cfm) (*Brady and Legatski 1977*).

- At inlet flow rates greater than this, achieving uniform liquid distribution is difficult, unless additional weirs or baffles are used.

- To handle large inlet flows, scrubbers designed with long, narrow, rectangular throats have been used.

VENTURI SCRUBBER: ADJUSTIBLE THROAT VENTURI SCRUBBER

with movable plunger



Venturi Scrubber: Adjustible Throat Venturi Scrubber

with movable plunger

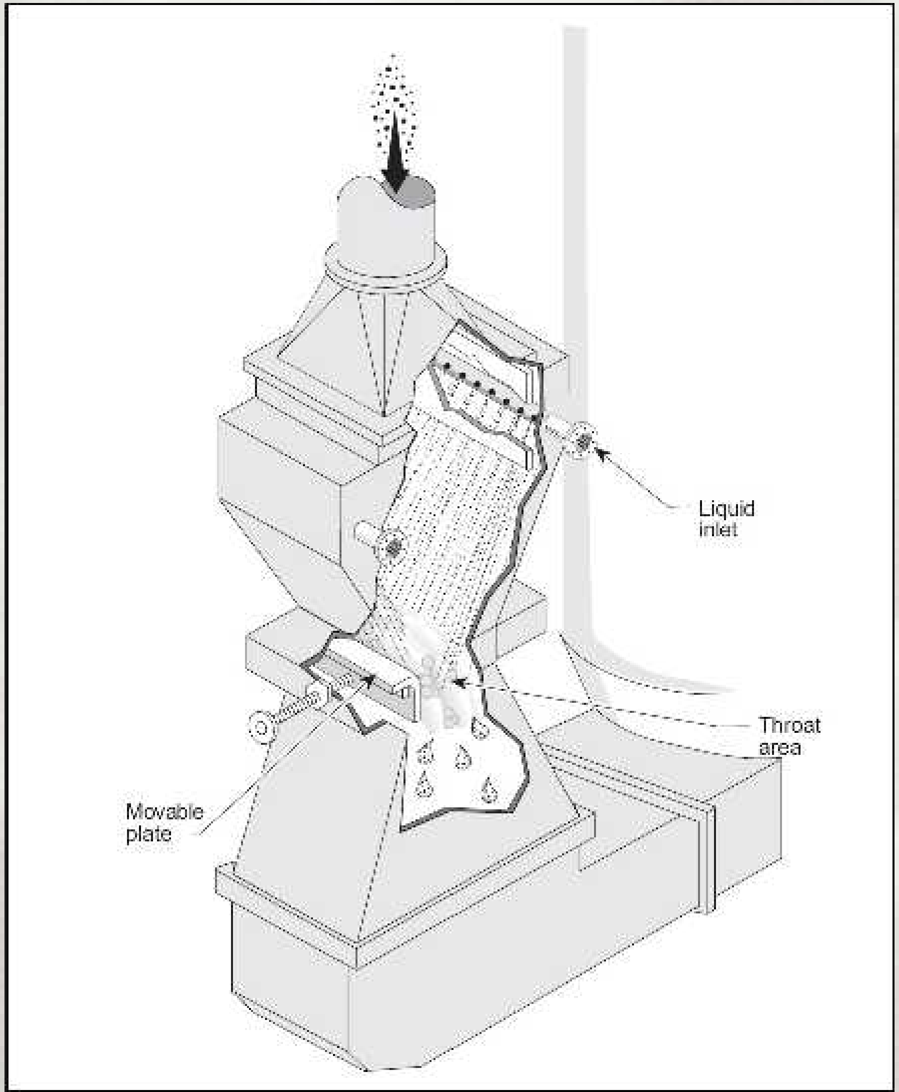
Simple venturi scrubbers have fixed throat areas and cannot be used over a wide range of gas flow rates. Manufacturers have developed other modifications to the basic venturi scrubber design to maintain scrubber efficiency by changing the throat area for varying inlet gas rates.

Certain types of orifices (throat areas) that create more turbulence than a true venturi were found to be equally efficient for a given unit of energy consumed (*McIlvaine Company 1974*). Results of these findings led to the development of the annular-orifice, or adjustable-throat venturi scrubber.

The size of the throat area is varied by moving a plunger, or adjustable disk, up or down in the throat, thereby decreasing or increasing the annular opening. Gas flows through the annular opening and atomizes liquid that is sprayed onto the plunger or swirled in from the top.

VENTURI SCRUBBER: **ADJUSTIBLE THROAT VENTURI SCRUBBER**

with movable plate



In this scrubber, the throat area is varied by using a movable plate.

A water-wash spray is used to continually wash collected material from the plate.

Case Study: Bhopal Gas Tragedy

- **Bhopal gas tragedy** was a gas leak incident in India, considered the world's worst industrial disaster.
- It occurred on the night of 2–3 December 1984 at the Union Carbide India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh.
- Over 500,000 people were exposed to methyl isocyanate (MIC) gas and other chemicals. The toxic substance made its way into and around the shanty towns located near the plant.

CASE STUDY: BHOPAL GAS TRAGEDY

- The cause of the disaster remains under debate.
- The Indian government and local activists argue that slack management and deferred maintenance created a situation where routine pipe maintenance caused a backflow of water into a MIC tank triggering the disaster.
- Union Carbide Corporation (UCC) contends water entered the tank through an act of sabotage.

Case Study: Bhopal Gas Tragedy

The Immediate Aftermath:

• Estimates vary on the death toll. The official immediate death toll was 2,259.

•The government of Madhya Pradesh confirmed a total of 3,787 deaths related to the gas release.

• A government affidavit in 2006 stated that the leak caused 558,125 injuries, including 38,478 temporary partial injuries and approximately 3,900 severely and permanently disabling injuries.

• Others estimate that 8,000 died within two weeks, and another 8,000 or more have since died from gas-related diseases

CASE STUDY: BHOPAL GAS TRAGEDY

Long Term Effects:

Eyes: Chronic conjunctivitis, scars on cornea, corneal opacities, early cataracts

Respiratory tracts: Obstructive and/or restrictive disease, pulmonary fibrosis, aggravation of TB and chronic bronchitis

Neurological system: Impairment of memory, finer motor skills, numbness etc.

Psychological problems: Post traumatic stress disorder (PTSD)

Children's health: Peri- and neonatal death rates increased. Failure to grow, intellectual impairment, etc.


Thank you!