Lecture 7. Environmental pollution: Causes, effects and control of air

India today is one of the first ten industrialized countries of the world. Today we have a good industrial infrastructure in core industries like metals, chemicals, fertilizers, petroleum, food etc. what has come out of these? Pesticides, detergents, plastics, solvents, fuels, paints, dyes, food additives etc. are some examples. Due to progress in atomic energy, there has also been an increase in radioactivity in the biosphere. Besides these, there are a number of industrial effluents and emissions particularly poisonous gases in the atmosphere. Mining activities also added to this problem particularly as solid waste.

Thus, pollution is a necessary evil of all development. Due to lack of development of a culture of pollution control, there had resulted a heavy backlog of gaseous, liquid and solid pollution in our country. It is to be cleaned. Thus pollution control in our country is a recent environmental concern.

What is pollution ? Pollution is an undesirable change in the physical, chemical or biological characteristics of air, water and soil that may harmfully affect the life or create a potential health hazard of any living organism. Pollution is thus direct or indirect changes in any component of the biosphere that is harmful to the living component(s), and in particular undesirable for man, affecting adversely the industrial progress, cultural and natural assets or general environment.

What are pollutants? Any substance which causes pollution is called a pollutant. A pollutant may thus include any chemical or geochemical (dust, sediment, grit etc.) substance, biotic component or its product, or physical factor (heat) that is released intentionally by man into the environment in such a concentration that may have adverse harmful or unpleasant effects.

Environmental Pollutants

The various principal pollutants which pollute our air, water, land are as follows :

(1) Deposited matter – soot, smoke, tar, dust, grit etc.
(2) Gases – Oxides of nitrogen (NO, NO_2), sulphur (SO_2), carbon monoxide, halogens, (chlorine, bromine, iodine),
(3) Acids droplets – sulphruric, acid nitric acid etc.
(4) Fluorides
(5) Metals – Mercury, lead, iron, zinc, nickel, tin, cadmium, chromium etc.

(6) Agrochemicals – Biocides (pesticides, herbicides, fungicides, nematicides, bactericides, weedicides etc), and fertilizers.

(7) Complex organic substances – Benzene, ether, acetic acid, benzopyrenes etc.

(8) Photochemical oxidants – Photochemical smog, ozone, peroxyacetyl nitrate (PAN), peroxybenzoil nitrate (PBzN), nitrogen oxides, aldehydes, ethylene etc.

(9) Solid wastes

(10) Radioactive waste

(11) Noise

Kinds of Pollution

Various types of pollutions are classified in different ways. On the basis of the type of environment being polluted, we may recognize air pollution, water pollution, land soil pollution, marine pollution etc. on the basis of the kind of pollutant involved, we may have sulphur dioxide pollution, fluoride pollution, carbon monoxide pollution, smoke pollution, lead pollution, mercury pollution, solid waste pollution, radioactive pollution, noise pollution etc. Of the variety of pollutants, we recognize the following two basic types of pollutants: non degradable and biodegradable.

(1) Nondegradable pollutants

These are the materials and poisonous substances like aluminium cans, mercuric salts, long-chain phenolics, DDT etc. that either do not degrade or degrade only very slowly in nature. They are not cycled in ecosystem naturally but by subsequent movement in food chains and biogeochemical cycles.

(2) Biodegradable pollutants

They are the domestic wastes that can be rapidly decomposed under natural condition. They may create problems when they accumulate (i.e. their input into the environment exceeds their decomposition).

Atmosphere

The earth's vertically extended atmosphere, an envelope of gases is divided into the following layers : (i) troposphere (up to 5 km) – the lowest atmosphere in which temperature decreases with height bounded by land or sea surface below and by tropopause above, (ii) stratosphere (5 to 45 km) - the region above the troposphere, in which temperature increases up to 90^0C with height. This is limited by stratopause, (iii) mesosphere (45 to 80 km) – the part between stratosphere and thermosphere (ionosphere). Temperature again decreases up to – 80^0C. (iv) thermosphere (ionosphere) – above 80 km, the upper part in which temperature increases with height. There is no boundary between the atmosphere and void of outer space. About 75% of the earth's atmosphere lies within 16 km. of the surface and 99% of the atmosphere lies below an altitude of 30 km.

The atmosphere is an insulating blanket around the earth. It is source of essential gases, maintains a narrow difference of day and night temperatures and provides a medium for long-distance radio communication. It also acts as shield around the earth against lethal UV radiations and meteors. Without atmosphere, there will be no lightening, no wind, no clouds, no rains, no snow and no fire.

Normal composition of clean air at or near sea (1990) is as follows:

Gases	**Percent (by Volume)**
Nitrogen	78.084
Oxygen	20.9476
Argon	0.934
Carbon dioxide	0.0314
Methane	0.0002
Hydrogen	0.00005
Other gases	minute

Air is necessary for the survival of all higher forms of life on Earth. On an average, a person needs at least 30 lb of air every day to live, but only about 3 lb of water and 1.5 lb of food. A person can live about 5 weeks without food and about 5 days without water, but only 5 minutes without air. Naturally, every one likes to breathe fresh, clean air. But the atmosphere, that invisible yet essential Ocean of different gases called air, is as susceptible to pollution from human activities as are water and land environments.

Air Pollution

It is defined as the excessive concentration of foreign material in the atmosphere , which affects the health of individuals and also causes damage to the property.

Air pollution episodes

- ***London smog*** : $SO_2 \rightarrow H_2SO_3$ vapours in the atmosphere. When automobile exhausts are trapped by this smog and exposed to sunlight, it produces photochemical smog.
- ***Bhopal gas tragedy*** **:** The poisonous gas, methyl isocyanate (MTC) leakage in the pesticide manufacturing plant of Union Carbide of India Ltd., (UCIL), Bhopal, Madhya Pradesh on December 3, 1984. 46 tons of MIC was released spreading to 40 km. *Effects* : About 65,000 people suffered from various disorders in eyes, lungs, stomach, heart, etc. The immediate symptom is bronchospasm which causes coughing, chest pain and abdominal pain. Nearly 3000 people died within a short span of time, 1600 domestic animals died and crop yields were reduced .
- **Darkening effect of Taj Mahal**

  Taj Mahal is a white marble stone mausoleum. Recently it was observed that the walls of Taj Mahal has become darkened and disfigured due to air pollution from nearby Mathura Oil refinery.

  $H_2O + SO_2 \rightarrow H_2SO_3$, $SO_2 + O_2 \rightarrow SO_3$; $SO_3 + H_2O \rightarrow H_2SO_4$.

  The acid rain reacts with marble stone ($CaCO_3$) to produce calcium sulphate, causing darkening and disfigurement.

Types, sources and effects of air pollution

Air pollution may be simply defined as the presence of certain substances in the air in high enough concentrations and for long enough duration to cause undesirable effects. “Certain substances” may be any gas, liquid or solid, although certain specific substances are considered significant pollutants because of very large emission rates are harmful and unwanted effects. “Long enough durations” can

be anywhere from a few hours to several days or weeks; on a global scale, durations of months and years are of concern.

Sources

Air pollution results from gaseous emission from mainly industry, thermal power stations, automobiles, domestic combustion etc.

1. **Industrial chimney wastes**: There are a number of industries which are source of air pollution. Petroleum refineries are the major source of gaseous pollutants. The chief gases are SO_2 and NO_x. Cement factories emit plenty of dust, which is potential health hazard. Stone crushers and hot mix plants also create a menace. Food and fertilizers industries which emit gaseous pollutants. Chemical manufacturing industries which emit acid vapours in air.
2. **Thermal power stations:** There are a number of thermal power stations and super thermal power stations in the country. The National thermal power corporation (NTPC) is setting up four mammoth coal-powered power stations to augment the energy generation. These are at Singrauli in U.P., Korba in M.P., Ramagundam in Andhra Pradesh and Farakka in W. Bengal. The coal consumption of thermal plants is several million tones. The chief pollutants are fly ash, SO_2 and other gases and hydrocarbons.
3. **Automobiles**: The toxic vehicular exhausts are a source of considerable air pollution, next only to thermal power plants. The ever increasing vehicular traffic density posed continued threat to the ambient air quality. Chief sources of emission in automobiles are (i) exhaust system, (ii) fuel tank and carburettor and (iii) crankcase. The exhaust produces many air pollutants including unburnt hydrocarbons, CO, NO_x and lead oxides. There are also traces of aldehydes, esters, ethers, peroxides and ketones which are chemically active and combine to form smog in presence of light. Evaporation from fuel tank goes on constantly due to volatile nature of petrol, causing emission of hydrocarbons. The evaporation through carburettor occurs when engine is stopped and heat builds up, and as much as 12 to 40 ml of fuel is lost during each long stop causing emission of hydrocarbons.

Criteria Air Pollutants

The five primary criteria pollutants include the gases- Carbon Monoxide (CO), nitrogen oxides (NO_x) , sulfur dioxide (SO_2), and solid or liquid particulates (smaller than 10 μm), and particulate lead.

a) Carbon Monoxide

- CO is a colourless, odourless and tasteless gas.
- It is produced when carbonaceous fuels are burned under less than ideal conditions.
- Incomplete combustion, yielding CO instead of CO_2, results when any of the following variables are not kept sufficiently high:
    i. Oxygen supply
    ii. flame temperature
    iii. gas residence time at high temperature and
    iv. combustion chamber turbulence.
- Most of the CO emissions are from the transportation sector. Hourly atmospheric concentrations of CO often reflect city driving patterns. Peaks occur on week days during the morning and late afternoon rush hours.
- The CO, at levels that occur in urban air has no detrimental effect on materials or plants; but adversely affects human health.
- CO interferes with the blood's ability to carry oxygen to the cells of the body. When inhaled, it readily binds to hemoglobin in the blood stream to form carboxyhemoglobin (COHb).
- Even small amounts of CO can seriously reduce the amount of oxygen conveyed throughout the body → brain function is affected and heart rate increased in an attempt to offset the oxygen deficit.

b). Oxides Of Nitrogen

- 7 oxides of nitrogen are known to occur – NO, NO_2, NO_3, N_2O, N_2O_3, N_2O_4 and N_2O_5.
- Nitric oxide (NO) and Nitrogen dioxide (NO_2) are important in air pollution study.
- There are two sources of nitrogen oxides (or NO_x):
    i. *Thermal NO_x* are created when nitrogen and oxygen in the combustion air are heated to a high enough temperature (> 1000 K) to oxidise nitrogen.
    ii. *Fuel NO_x* result from the oxidation of nitrogen compounds that are chemically bound in the fuel molecules themselves. Natural gas almost has no nitrogen in them and some coal can have 3% N by weight. Fuel NO_x is often the dominant source of NO_x.
- Almost all NO_x emissions are in the form of NO, which has no adverse health effects.
- However, NO can oxidise to NO_2, which in turn may react with hydrocarbons in the presence of sunlight to form photochemical smog, which is injurious.

- NO_2 also reacts with hydroxyl radical (HO) in the atmosphere to form nitric acid (HNO_3) and results in acid rain.
- NO_2 is an acute irritant at higher concentrations. Prolonged exposure to relatively low concentrations is linked to increased bronchitis in children. It can also damage plants. When converted to nitric acid it causes corrosion of metal surfaces.
- NO is a colourless gas, but NO_2 gives smog its reddish brown colour.
- Reductions in NO_x emissions have been harder to achieve.
- When mobile source controls are introduced, modifications to the combustion process that improve emissions of CO tend to make the NO_x problem worse and vice-versa. To control CO, it helps to increase the combustion air supply and to raise the temperature. To control NO_x, the opposite is true.

The NO-NO_2–O_3 photochemical reaction sequence

- NO is formed during combustion

  $N_2 + O_2 \rightarrow 2\ NO$

- The nitric oxide thus emitted, can oxidise to NO_2.

  $2\ NO + O_2 \rightarrow 2\ NO_2$.

- If sunlight is available, NO_2 can photolyse, and the freed atomic oxygen can then help to form ozone:

  $NO_2 + hv \rightarrow NO + O$

  $O + O_2 + M \rightarrow O_3 + M$

where hv represents a photon ($\lambda < 0.38\ \mu m$) and M represents a molecule (usually O_2 or N_2) whose presence is necessary to absorb excess energy from the reaction.

- Ozone can then convert NO back to NO_2 :

  $O_3 + NO \rightarrow NO_2 + O_2$

- Thus, NO concentrations rise as early morning traffic emits its load of NO. Then as morning progresses, there is a drop in NO and a rise in NO_2 as NO gets converted to NO_2. As the sun's intensity increases toward noon, the rate of photolysis of NO_2 increases; thus NO_2 begins to drop while O_3 rises. Ozone is so effective in its reaction with NO that as long as O_3 is present, NO

concentrations do not rise through the rest of the afternoon, even though there may be new emissions.

If only NO_2 photolytic cycle is involved, O_3 can not accumulate in sufficient quantity in photochemical smog to account for the actual measured data. The introduction of hydrocarbons upsets the balance in production and destruction of ozone, thus allowing more O_3 to accumulate.

Photochemical smog and ozone

- When oxides of nitrogen, various hydrocarbons and sunlight come together, they initiate a complex set of reactions that produce a number of secondary pollutants known as photochemical oxidants.
- Ozone (O_3) is the most abundant photochemical oxidant responsible for chest constriction and irritation of the mucous membrane in people, cracking of rubber products and damage to vegetation.
- Other components of the photochemical smog viz., formaldehyde, peroxy benzoyl nitrate (PBzN), peroxy acetyl nitrate (PAN) and acrolein cause eye irritation.
- The formation of photochemical smog can be expressed in the simples terms as : Hydrocarbons + NO_x + sunlight → photochemical smog.

C). Oxides of sulfur

- Over 80% of anthropogenic sulfur oxide emissions are the result of fossil fuel combustion in stationary sources. Of that, almost 85% is released from electric utility power plants. Only about 2% comes from highway vehicles.
- The only significant non combustion sources of Sulfur emissions are associated with petroleum refining, copper smelting and cement manufacture.
- Oil and coal generally contain appreciable quantities of sulfur (0.5-6%), either in the form of inorganic sulfides or as organic sulfur. When these fuels are burned, the sulfur is released mostly as sulfur dioxide (SO_2), but also with small amounts of sulfur trioxides (SO_3).
- SO_2, once released, can convert to SO_3 in a series of reactions which, once again, involve a free radical such as OH**.**

$$SO_2 + OH. \longrightarrow HO\,SO_2.$$

$$HO\,SO_2. + O_2 \longrightarrow SO_3 + HO_2.$$

- The HO_2 radical can then react with NO to return the initial OH. ($HO_2. + NO \rightarrow NO_2 + OH.$).

- Sulfur trioxide reacts very quickly with H_2O to form sulfuric acid, which is the principal cause of acid rain.

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

- Sulfuric acid molecules rapidly become particles by either condensing on existing particles in the air or by merging with water vapour to from $H_2O - H_2SO_4$ droplets.
- Often a significant fraction of particulate matter in the atmosphere consists of such sulfate (SO_4^{2-}) aerosols.
- The transformation from SO_2 gas to sulfate particles is gradual, taking a matter of days. In either form, sulfur can be deposited during precipitation (wet deposition) or by slow continuous removal processes that occur without precipitation (dry deposition).
- Most sulfate particles in urban air have en effective size of less than 2 μm, with most of them being in the range of 0.2 μm. Their size allows deep penetration into the respiratory system.
- SO_2 is highly water soluble (much more than any of the other criteria pollutants). As a result, when it is inhaled it is most likely to be absorbed in the most passages of the upper respiratory tract, the nose and upper air ways.
- However, when sulfur is entrained in an aerosol, the aerodynamic properties of the particles themselves affect the area of deposition and it is possible for sulfur oxides to reach far deeper into the lungs.
- The combination of particulate matter and sulfur oxides can than act synergistically, with the effects of both together being much more detrimental than either of them separately.
- Sulfur oxides can damage vegetation. Sulfur pollutants can discolour paint, corrode metals and cause organic fibres to weaken. Airborne sulfates significantly reduce visibility and discolour the atmosphere.
- Prolonged exposure to sulfates causes serious damage to building marble, lime stone ($CaCO_3$) and mortar, as the carbonates in these materials are replaced by sulfates.

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$$

The calcium sulfate (gypsum) produced by this reaction is water soluble and easily washes away, leaving a pitted, eroded surface.

d).Lead

- Most lead emissions in the past have been from motor vehicles burning gasoline containing the antiknock additive, tetraethyl lead, $(C_2 H_5)_4$ Pb.
- Lead is emitted to the atmosphere primarily in the form of inorganic particulates.
- Much of this is removed from the atmosphere by settling in the immediate vicinity of the source.
- Air borne lead may affect human populations by direct inhalation, in which case people living nearest to highways are at greatest risk, or it can be ingested after the lead is deposited onto food stuffs.
- Most of human exposure to airborne lead is the result of inhalation. It has been estimated that about one third of the lead particles inhaled are deposited in the respiratory system and that about half of those are absorbed by the blood stream.
- The NAAQS standard for lead – 1.5 $\mu g/m^3$.
- Lead poisoning can cause aggressive, hostile and destructive behavioral changes as well as learning disabilities, seizures, severe and permanent brain damage and even death. Children and pregnant women are at greatest risk.
- Blood lead levels associated with neurobehavioral changes in children appear to begin at 50-60 μg per decilitre (μg/dL). Encephalopathy, with possible brain damage or death occurs at levels some what 80 μg / dL.
- Sources of lead exposure $\rightarrow$ air emissions, drinking water (lead can be leached out of lead solder used in copper piping systems), ingestion of lead in food and leaded paint.

e).Particulate Matter

Atmospheric *particulate matter* is defined to be any dispersed matter, solid or liquid, in which the individual aggregates are larger than single small molecules (about 0.0002μm in diameter), but smaller than 500μm.

- Particulate matter is diverse and complex.
- The ability of the human respiratory system to defend itself against particulate matter is, to a large extent, determined by the size of the particles.

Particles larger than 10μm

- Large particles that enter respiratory system can be trapped by the hairs and lining of the nose. Once captured, they can be driven out by a cough or sneeze.

- Smaller particles that make it into the tracheobronchial system can be captured by mucus, worked back to the throat by tiny hair like cilia, and removed by swallowing or spitting.

Particles smaller than 10μm

- These particles may make it into the lungs, but depending on their size, they may or may not he deposited there.
- Some particles are so small that they tend to follow the air stream into the lungs and then right back out again.
- Particles roughly between 0.5 and 10μm may be large enough to be deposited in the lungs by sedimentation. Sedimentation is most effective for particles between 2 and 4μm.
- Particulates <10μm are most important from view of adverse health effects on humans.
- High particulate concentration in the atmosphere, especially in conjunction with oxides of sulfur→ respiratory infection, cardiac disorders, bronchitis, asthma, pneumonia …
- Some particles are toxic. Many carbonaceous particles, especially those containing polycyclic aromatic hydrocarbons (PAHs) are suspected carcinogens.
- Particulate emissions have decreased substantially in the past few decades, due to tremendous reductions in combustion emissions (especially by electric utilities).

Indoor Air Quality

- People tend to spend more time indoors than out, and in many circumstances, the air we breathe indoors is even more polluted than outdoor air.

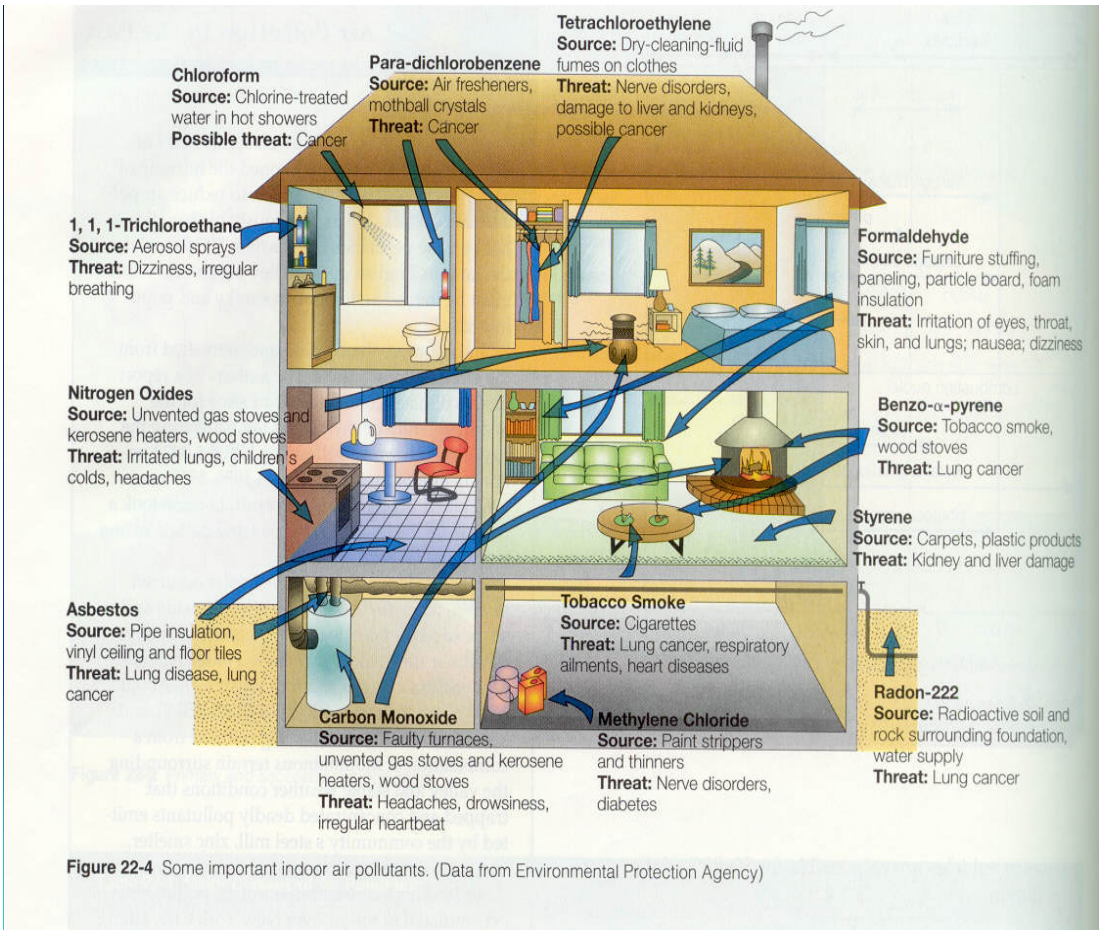


Figure 22-4 Some important indoor air pollutants. (Data from Environmental Protection Agency)

Sources of indoor air pollution

- Combustion (to heat water, cook and space heating) can produce elevated levels of CO and NO_X.
- Certain photocopying machines emit ozone.
- Formaldehyde emissions from particle board, plywood, urea – formaldehyde foam insulation.
- Asbestos used for fireproofing and insulation.
- Various volatile organics emitted from household cleaning products.
- Many pollutants, such as cigarette smoke and radon when emitted indoors can be concentrated, leading to harmful exposure levels.
- Tobacco smoke contains numerous known or suspected carcinogens, including benzene, hydrazine, benzo - α-pyrene (BaP) and Nickel.
- Smoke particles are small, averaging about 0.2 µm, so they are easily carried into the deepest regions of the lungs.

- A single cigarette smoke gives off on the order of 1012 smoke particles, most of which are released while the cigarette is simply smoldering in the air (*sidestream smoke*) rather than when a smoker takes a puff (*mainstream smoke*).
- Hence non smokers are also exposed to significant amount of smoke particles.
- Other indoor air pollutants arising from tobacco smoke include carbon monoxide, nicotine, nitrosamines, acrolein and other aldehydes.
- Another potentially important source of indoor air pollution is caused by wood-burning stoves and fireplaces.
- Wood combustion produces CO, NO_X, hydrocarbons and respirable particles and some emissions that are suspected carcinogens like benzo - α-pyrene.

Effects of air pollution

Air pollution is known to have many adverse effects, including those on human health, building facades and other exposed materials, vegetation, agricultural crops, animals, aquatic and terrestrial ecosystems, and the climate of earth as a whole.

a)Health effects

Perhaps the most important effect of air pollution is the harm it causes to human health. Generally, air pollution is most harmful to the very old and the very young. Many elderly people may already suffer from some form of heart or lung disease, and their weakened condition can make them very susceptible to additional harm from air pollution. The sensitive lungs of new born infants are also susceptible to harm from dirty air. But it is not just the elderly or the very young who suffer; healthy people of all ages can be adversely affected by high levels of air pollutants. Major health effects are categorized as being acute, chronic, or temporary.

There is much evidence linking lung cancer to air pollution, although the actual cause-and –effect relationship is still unknown. Typical effects of sulfur dioxide, oxides of nitrogen, and ozone include eye and throat irritation, coughing and chest pain. Nitrogen dioxide is known to cause pulmonary edema, an accumulation of excessive fluids in the lungs. Ozone, a highly irritating gas, produces pulmonary congestion; symptoms of ozone exposure may include dry throat, headache, disorientation, and altered breathing patterns.

b)Effect on Materials

Every year , air pollutants cause damage worth billions of rupees. Air pollutants breakdown the exterior paint in cars and houses. Air pollutants have discolored irreplaceable monuments, historic buildings, marble statues and other heritage and natural beauty sites.

c)Effect on plants.

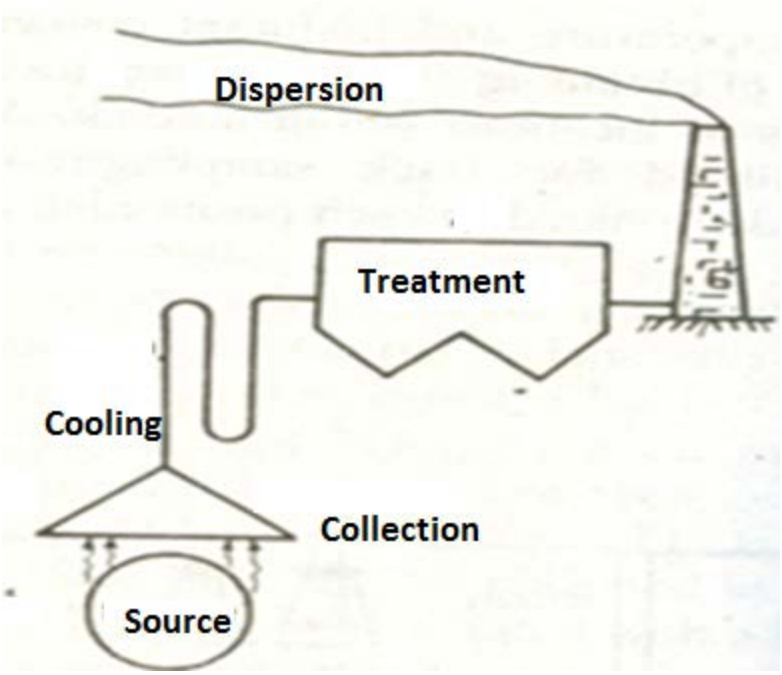
Some gaseous pollutants enter leaf pores and damage the crop plants. Chronic exposure of leaves to air pollutants damages waxy coating, leads to damage from diseases, pests, drought and frost. Such exposure interferes with photosysthesis and plant growth, reduces nutrient uptake and causes leaves to turn yellow, brown or drop off. At higher concentrations of SO_2 most of the flower buds become stiff and hard and fall off. Prolonged exposure to higher levels of air pollutants from Iron smelters, coal burning power plants and industries, vehicles can damage trees and plants.

d)on Stratosphere

Ozone is continuously being created in the stratosphere by the absorption of short-wavelength UV radiation, while at the same time it is continuously being removed by various chemical reactions that convert it back to molecular oxygen. The rates of creation and removal at any given time and location dictate the concentration of ozone present. The balance between creation and removal is being affected by increasing stratospheric concentrations of chlorine, nitrogen and bromine, which acts as catalysts, speeding up the removal process. CFCs are predominant.

Management of Air Pollution

For ages man has been dumping wastes into the atmosphere, and these pollutants have disappeared with the wind. We have seen that the main sources of air pollution are (i) motor vehicles, (ii) industries-particularly their chimney wastes, (iii) fossil-fuel (coal) based plants, as thermal power plants. Steps are to be taken to control pollution at source (prevention) as well as after the release so pollutants in the atmosphere. There is an urgent need to prevent the emissions from the above said major sources of air pollution. The control of emissions can be realized in number of ways



1. Source Correction: There are several approaches or strategies for air pollution control. The most effective control would be to prevent the pollution from occurring in the first place. Complete source shutdown would accomplish this, but shutdown is only practical under emergency conditions, and even then it causes economic loss. Nevertheless, state public health officials can force industries to stop operations and can curtain highway traffic if an air pollution episode is imminent or occurring.

An important approach for air pollution control is to encourage industries to make fuel substitutions or process changes. For example, making more use of solar, hydroelectric, and geothermal energy would eliminate much of the pollution caused by fossil fuel combustion at power generating plants. Nuclear power would do the same, but other problems related to high level radioactive waste disposal and safety remain to be solved. Fuel substitutions are also effective in reducing pollution from mobile sources. For example, the use of reformulated gasoline or alternative fuels such as liquefied petroleum gas, compressed natural gas, or methanol for highway vehicles would help to clear the air. The use of correct operation and maintenance practices is important for minimizing air pollution and should not be overlooked as an effective control strategy.

2. Collection of pollutants:

Often the most serious problem in air pollution control is the collection of the pollutants so as to provide treatment. Automobiles are most dangerous, but only because the emissions can not be readily collected. If we could channel the exhausts from automobiles to some central facilities, their treatment would be much more reasonable than controlling each individual car. One success in collecting pollutants has been the recycling of blowby gases in the internal combustion engine. By reigniting these gases and emitting them through the car's exhaust system, the need of installing a separate treatment device for the car can be eliminated.

3. Cooling: The exhaust gases to be treated are sometimes too hot for the control equipment and the gases must first be cooled. This can be done in three general ways: dilution, quenching, or heat exchange coils. Dilution is acceptable only if the total amount of hot exhaust is small. Quenching has the additional advantage of scrubbing out some of these gases and particulates. The cooling coils are perhaps the most widely used, and are especially appropriate when heat can be conserved.

4. Treatment

The selection of the correct treatment device requires the matching of the characteristics of pollutant and features of the control device. It is important to realize that the sizes of air pollutants range many orders of magnitude, and it is therefore not reasonable to expect one device to be effective for all pollutants. Although, any new devices may appear any day in the market, the following are the most widely used:

(a) **Setting chambers** are nothing more than large places in the flues, similar to settling tanks in water treatment. These chambers remove only the large particulates.

(b) **Cyclones** are widely used for removing large particulars. The dirty air is blasted into a conical cylinder, but off the centerline. This creates violent swirl within the cone, and the heavy solids migrate to the wall of the cylinder where they slow down due to friction and exit at the bottom of the cone. The clean air is in the middle of the cylinder and exits out the top. Cyclones are widely used as pre-cleaners to remove the heavy material before further treatment.

(c) **Bag filters** operate like the common vacuum cleaner. Fabric bags are used to collect the dust which must be periodically shaken out of the bags. The fabric removes nearly all particulates. Bag filters are widely used in many industries, but are sensitive to high temperature and humidity.

(d) **Wet collectors** come in many shapes and styles. The simple spray tower is an effective method for removing large particulates. More efficient scrubbers promote the contact between air and water by violent action in a narrow throat section into which the water is introduced.

(e) **Electrostatic precipitators** are widely used in power plants. The particulate matter is removed by first being charged by electrons jumping from one high voltage electrode to the other, and then migrating to the positively charged electrode. The particulates will collect on the pipe and must be removed by banging the pipes with hammers. Electrostatic precipitators have no moving parts, require electricity, and are extremely effective in removing submicron particulates. They are expensive.

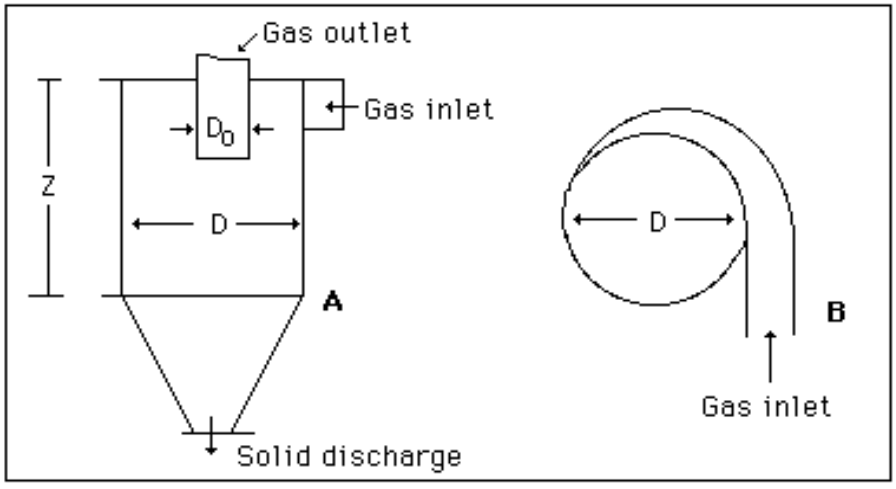
(f) **Gas scrubbers** are simply wet collectors as described above but are used for dissolving the gases.

(g) **Absorption** is the use of the material such as activated carbon to capture pollutants. Such adsorbers may be expensive to regenerate. Most of these work well for organics and have limited use for inorganic pollutants.

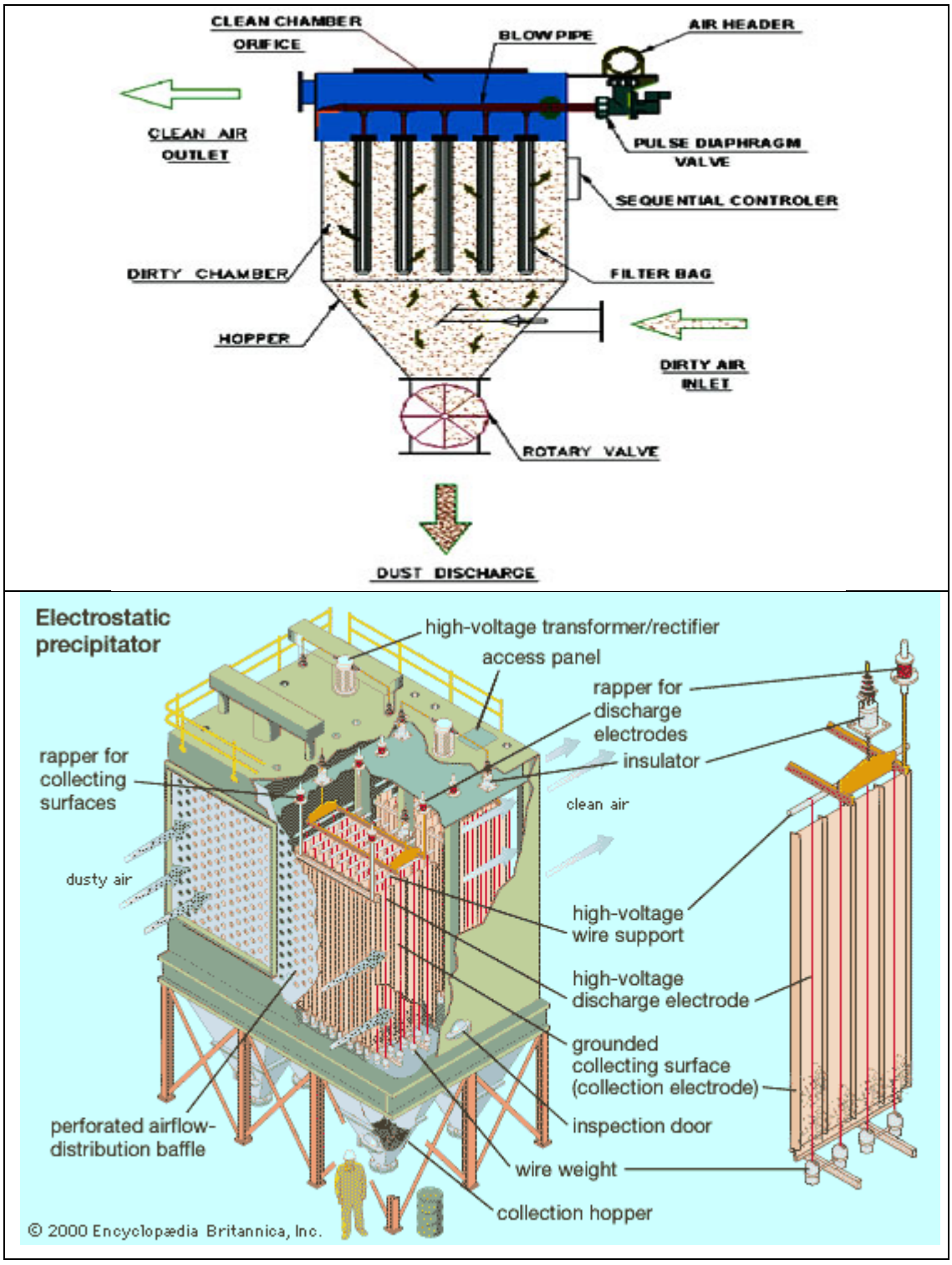
(h) **Incineration** is a method for removing gaseous pollutants by burning them to CO_2, H_2O and inerts. This works only for combustible vapours.

(i) **Catalytic combustion** involves the use of a catalyst to adsorb or chemically change the pollutants.

Cyclone separator



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
Electrostatic precipitator
high-voltage transformer/rectifier
access panel
rapper for discharge electrodes
insulator
rapper for collecting surfaces
clean air
dusty air
high-voltage wire support
high-voltage discharge electrode
grounded collecting surface (collection electrode)
perforated airflow-distribution baffle
inspection door
wire weight
collection hopper
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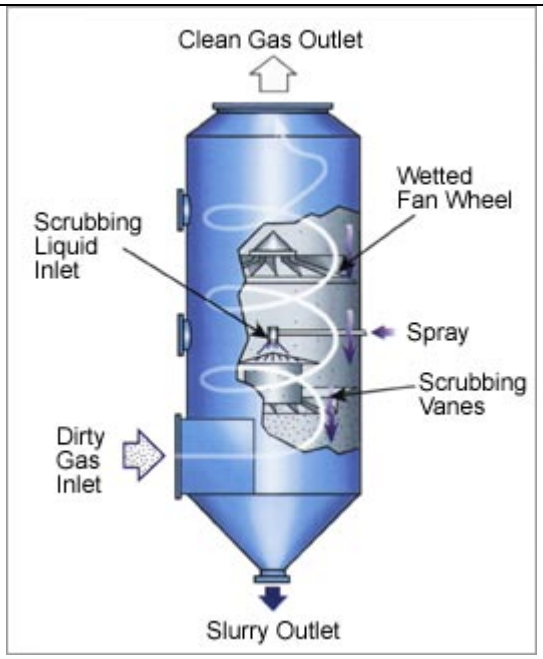

5. Dispersion

The concentration of the pollutants at the recipient is affected by atmospheric dispersion, or how the pollutant is diluted with clean air. This dispersion takes place horizontally as well as vertically. Earth rotation presents new areas for the sun to shine upon and to warm air. Accordingly a pattern of winds is set up around the world, some seasonal (e.g. hurricanes) and some permanent.

Diffusion is the process of spreading out the emission over a large area and thus reducing the concentration of the specific pollutants. The plume spread or dispersion as told above is horizontal as well as vertical. We assume that the maximum concentration of pollutants is in the plume centerline, i.e. in the direction of the prevailing wind. As we move further from the centerline, the concentration becomes lower. If we assume that the spread of a plume in both directions is approximated by a Gaussian probability curve, we can calculate the concentration of a pollutant at any distance X downwind from the source.

Ambient Air quality Standards

Area	**SPM (μg /m^3)**	**SO_2(μg /m^3)**	**CO(μg /m^3)**	**NO_x(μg /m^3)**
Industrial and Mixed use	500	120	5000	120

Residential and Rural	200	80	2000	80
Sensitive	100	3	1000	30

Integrated approach for air pollution Control

- Putting greater emphasis on pollution prevention rather than Control
- Reducing the use of Fossil fuels
- Improving quality of vehicular fuel
- Increasing the use of renewable energy

Lecture 7. Environmental pollution: Causes, effects and control of air

1.	Emission of ---------- cause acid rain	
	a) NO_3	**b) SO_2 and NO_3**
	c) SO_2	d) Green house gases
2.	Bhopal gas tragedy was due to	
	a) CO	b) SO_2
	c)MIC	d) H_2S
3.	Photochemical smog is a pollutant formed in	
	a)Excessive SO_2 Atmosphere	b)High temperature
	c) low temperature	d)Excessive Nitrogen
4.	Electrostatic precipitators are used to remove	
	a)Heavy metals	**b) Particulate pollutants**
	c) Sulfur compunds	d) Dioxins
5.	Byssinosis is an Occupational disease found in workers of	
	a)Coal mine	**b)Textile Industry**
	c)Slaughter house	d)Galvanizing Industries
6.	PAN is ---------- Pollutant	
	a)Primary Pollutant	**b)Secondary Pollutant**
	c)Water Pollutant	d)Soil pollutant t
7.	Smog is	
	a)Fog + Smoke	b)Smoke + Rain
	c)Smoke + CO_2	d)Fog + CO_2
8.	Photo chemical smog is formed during	
	a)Early Morning	b)Afternoon
	c)Rainfall	**d)Early afternoon**
9.	Peak SO_2 concentration was	
	a)13 ppm and smoke 40 mg/M^3	b)0.1 ppm and smoke 400 mg/M^3
	c)0.3 ppm and smoke 0.4 mg/M^3	**d) 1.3 ppm and smoke 4 mg/M^3**
10.	Which of the following pollutant reacts with marble stone (CaCO3) to produce calcium sulphate, causing darkening and disfigurement of Taj Mahal	
	a)Acid Rain	b)Smog
	c)CO_2	d)O_3
11	Planet earth along with the atmosphere that sustains life is known as	
	a)Hydrosphere	**b)Biosphere**
	c)Atmosphere	d)Lithosphere
12.	Stratosphere is rich in ----------	
	a)Ozone.	b)Chlorine
	c)Helium	d)Freon

13.	Lead poisoning affects the function of	
	a)Liver	b)Kidney
	c)Lungs	d)Heart
14.	Microbes involved in methane oxidation are ----------	
	a)Acidophiles **c)Thermophiles**	**b)Methanotrophs** d)Methanogens
15.	The silent killer gas, which has more affinity towards haemoglobin of the blood	
	a) NO_2	b)CO_2
	c)SO_2	**d)CO**
16.	Time taken by sunlight to reach the earth	
	a)20 seconds	b)45 minutes
	c) 8 seconds	**d)8 minutes.**
17.	The unit of measurement of ozone thickness is	
	a)Decibel	**b)Dobson**
	c)Richter	d)Decimal
18.	Which satellite recorded the presence of ozone hole?	
	a)Landsat-3	**b) Nimbus**
	c)GOES	d)TRIPS-N.
19.	The part of human body first to be affected due to vehicular pollution?	
	a) Kidney	b)Liver
	c)Lungs	d) Brain
20.	Black lung disease occurs among	
	a) Quarry workers	b)Refinery workers
	c)Coal miners	d) Smokers
21.	One per cent reduction in O_3 increases the UV radiation on earth by	
	a)1%	**b)2%**
	c)10%	d) 5%.
22.	Plumbism in nothing but	
	a)Cd poisoning	b)Hg poisoning
	c) Pb poisoning	d)Cr poisoning.
23.	The most prominent inorganic oxidant in atmosphere	
	a)O_3	b) O_2
	c)OH	d)NO_2.
24.	Mesothelima is a type of cancer which occur due to	
	a)Asbestos	b)Copper
	c)Silver	d) Iron
25.	White lung disease is common among	
	a)Coal miners	b)Farmers
	c) Traffic police	**d)Textile workers**.

26.	Heavy duty diesel powered vehicles contribute more of	
	a)NOx and Particulate matte	b)CO & HC
	c)CO&CO_2	d) SO_2 & NO_2
27.	Ozone at ground surface is responsible for the formation of a hazardous pollutant namely,	
	a)Smoke	b)Fog
	c) Smog	d)SPM
28.	The major element responsible for photochemical smog is	
	a)SO_2	b)CO
	c)CO_2	**d)NO_2.**
29.	The most obvious toxic product of combustion of plastic is	
	a)SO_2	b)CO .
	c)CO_2	**d) Dioxins**
30.	The more toxic gaseous component released due to burning of fossil fuel	
	a)CO	b)CO_2
	c)SO_2	d) NO_2