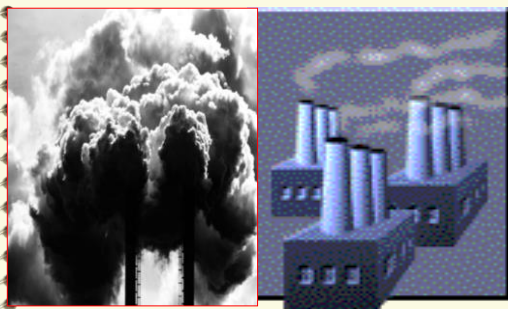


## Air Pollution Control Techniques



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## Open Elective Course

L T P

▣ Lecture Scheme 3 0 0

▣ Faculties Involved

Dr. Sandip Sharma

Dr. Mamta Saiyad

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## Blog:

▣ <http://2ch002ss.wordpress.com>

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## Syllabus

- What is an air Pollution?
- History of air Pollution
- Air Pollution disasters & Accidents
- Concepts & classification of pollutants
- Sources of Air Pollution
- Effect of Air Pollution

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- Ambient Air Sampling
- Collection of Gaseous pollutants
- Collection of Particulate Pollutants
- Analysis of Air Pollutants
- Air Quality Criteria & Standards

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- Control of Air Pollutants
- Control of Gaseous / Particulate Emission
- Indoor Air Pollutants
- Removal of Odors
- Control of Pollution from Mobile Sources
- Control of Pollution from Stationary Sources

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## Introduction to Air Pollution

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## Introduction

- Air pollution may be described as contamination of the atmosphere by gaseous, liquid, solid wastes or by-products that can endanger life, attack materials and reduce visibility.
- Air pollution worldwide is a threat to human health and the natural environment.
- It may also be defined as the presence of matter in atmosphere at concentrations, durations, and frequencies that adversely affect human health and environment.

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## Introduction

- Air pollution can be caused due to the burning of wood, coal, oil, petrol, or by spraying pesticides.
- Some of the questions which might come to mind while thinking about air pollution are:
  - Are we doing something about solving these problems?
  - Do we know enough about the conditions under which a pollution episode occurs?
  - What are the regulations?
  - How to control emissions?

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## Eras of Air Pollution



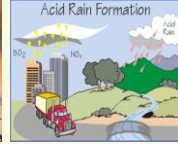
Early-Industrial Era



Pre-Industrial Era



Early 20<sup>th</sup> Century



Late 20<sup>th</sup> Century



Global Climate Change

Early 21<sup>st</sup> Century

## History of Air Pollution

- 1272 - King Edward I of England bans use of "sea coal"
- 1377 – 1399 - Richard II restricts use of coal
- 1413 – 1422 - Henry V regulates/restricts use of coal

1661 - By royal command of Charles II, John Evelyn of the Royal Society publishes "Fumifugium; or the Inconvenience of the Air and Smoke dissipated; together with Some Remedies Humbly Proposed"

1784—Watt's steam engine; boilers to burn fossil fuels (coal) to make steam to pump water and move machinery

Smoke and ash from fossil fuels by power plants, trains, ships: coal (and oil) burning = smoke, ash

1907 - Formation of the predecessor to the Air & Waste Management Association

1930 - 1950's - Air Pollution Episodes

1955 First Federal Air Pollution Control Act - funds for research (USA)

1960 Motor Vehicle Exhaust Act - funds for research (USA)

1963 Clean Air Act (USA)

-Three stage enforcement

-Funds for state and local agencies

1965 Motor Vehicle Air Pollution Control Act (USA)

-Emission regulations for cars to begin in 1968

- 1967 Air Quality Act (USA)
  - Criteria documents
  - Control technique documents
- 1970 Clean Air Act Amendments (USA)
  - National Ambient Air Quality Standards
  - New Source Performance Standards


[illegible]


# Why to study air pollution ?

[illegible]

- **Early 1900s** The City of Chicago, Illinois passes an ordinance to reduce the “smoke” emitted by local factories.
- **1940s** Los Angeles, California becomes one of the first cities in the U.S. to experience severe air pollution problems then called “gas attacks.” L.A.’s location in a basin like area ringed by mountains makes it susceptible to accumulation of auto exhaust and emissions from local petroleum refineries

[illegible]

 **1948** Air pollution kills in Donora, Pennsylvania. An unusual temperature inversion lasting six days blocks dispersal of emissions from zinc smelting and blast furnaces. Out of a total population of 14,000 people, 20 die, 600 others become ill, and 1400 seek medical attention.

 **1950** A chemist at the California Institute of Technology proposes a theory of smog (or ozone) formation in which auto exhaust and sunlight play major roles.

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 **1954** An early public protest against air pollution takes place in East Greenville, Pennsylvania. Homemakers march on the town council to demand that a local casket manufacturer be required to stop polluting. Their complaint is that clean laundry hung out to dry became dirtier than before it was washed because of high levels of soot (or particulates) in the air.

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 **1962** Silent Spring is published. Rachel Carson's powerful book draws the attention of the American public to the potential consequences of the increasing ability of human activities to significantly and even permanently alters the natural world.

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1966 In New York City, a three-day temperature inversion over Thanksgiving weekend is blamed for the deaths of 168 people.

1969 Millions of Americans watch via satellite, as Neil Armstrong becomes the first person to walk on the moon. The same weekend, a very different news story startles the nation. Sulfur dioxide pollution emitted by industries near Gary, Indiana and East Chicago becomes potent acid rain that burns lawns, eats away tree leaves, and causes birds to lose their feathers.

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1969 A vivid color photographs of Earth from space, widely distributed, shifts human perceptions of our planet. The Earth no longer seems vast but is recognized as a small, fragile ball of life in the immense infinitude of cold, black space.

1970 The first Earth Day becomes part of American history. Millions of students and citizens attend rallies to learn about environmental concerns and speak for environmental protection.

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1972 Representatives of 113 nations, gather on 5th June at a United Nations Conference on the Human Environment in Stockholm to develop plans for international action to protect the world environment.

1978 Rainfall in Wheeling, West Virginia is measured at a pH of 2, the most acidic yet recorded and 5000 times more acidic than normal rainfall.

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**1981** Air pollution enters international politics when the Quebec Ministry of the Environment notifies the U.S. that 60 percent of the acid rain (sulfur dioxide pollution) damaging air and waters in Quebec, Canada comes from the U.S. industrial sources in the Midwestern and Northeastern U.S.

**1982** The National Center for Health Statistics releases a study indicating that four percent of all U.S. schoolchildren, including about 12 percent of all African-American preschoolers, have high levels of lead in their blood

About 675,000 children are at risk of kidney damage, brain damage, anemia, retardation, and other ills associated with lead poisoning. It is recognized that children absorb this lead by breathing air laden with lead pollution, primarily from leaded gasoline.

**1985** The U.S. EPA estimates 50,000 streams in the U.S. and Canada are dead or dying because of acid rain pollution.

**1986** The National Academy of Sciences reports that the burning of coal, gasoline, and other fossil fuels is definitely linked to acid rain and the death of trees, fish, and lake ecosystems in both the U.S. and Canada.

 **1992** The Earth Summit in **Rio de Janeiro**, Brazil is the most comprehensive international conference on the environment to date. Representatives from **188 countries** and 35,000 participants attend. Two treaties are signed by all except the **U.S.** One, on global warming recommending curbing emissions of greenhouse gases. The second, on making inventories of plants and wildlife and strategies to protect endangered species.

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## Air Pollution Episodes

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## Air Pollution Disasters

- 1) Meuse Valley (Belgium), 1930
- 2) Donora (Pennsylvania USA) 1948
- 3) London 1952
- 4) New York (USA)
- 5) Los Angeles (USA)
- 6) Tokyo, Japan

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## Meuse Valley (Belgium), 1930

- During the eighteenth and nineteenth centuries, the air pollution disasters had been taking place because of Volcanoes or by smoke.
- Occurred in Meuse Valley in Belgium in 1930 **killing more than 60 people**.

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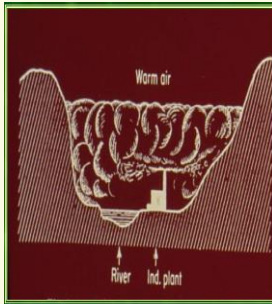
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It is deep with hills 80 – 120 m high on either side, narrow and highly industrialized (Steel works, Sulphuric acid plants, glass factories, zinc works and a Fertilizer plant) valley of the Meuse river.



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Beginning from **December 1, 1930** in the winter, the adverse meteorology for 5 days with inversion and windless conditions resulted in the **accumulation of smoke and abnormal pollutant levels** in the valley over the population.

- By the third day many people became ill and started dying.
- Most of the death occurred on the 4<sup>th</sup> and 5<sup>th</sup> day.

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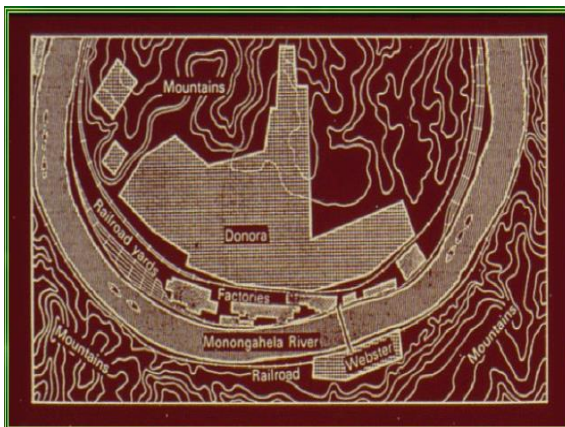
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- Though **the people of all sex and age** were affected but most of the deaths occurred in **older people** suffering previously with heart of lung trouble.
- Cattle, Birds and even rats** were reported to be killed.
- The concentration of the sulfure dioxide :  $25-100 \text{ mg/m}^3$

### Donora (Pennsylvania USA) 1948

- Donora lies in a horseshoe shaped valley of the Monongahela River near Pittsburg.
- Industries:** Steel mill, a Zinc plant and a sulphuric acid plant.
- It had a small population of about **141000 people**.





Due to adverse meteorological conditions of windlessness and temperature inversions started from **26<sup>th</sup> October 1948**, the **smoke and pollutants along with the fog** started to buildup in the atmosphere over the city for about 5 days.

Everything was black with gas and soot.

This resulted in the **death of 20 people, 43 % of the population became sick, out of which 10 % were severely affected.**

The symptoms of illness included irritation of eye, nose and throat, pulmonary trouble with coughing and respiratory irritation, vomiting and headache.

No actual measurements of pollutants were taken during the time of disaster (**Sulphur dioxide, sulphuric acid aerosol, particulates and some oxidation products**)

## London, 1952

London situated on the banks of river Thames.

- ☞ The city used large quantities of **high sulphur coal** for domestic heating, electricity generation (Thermal power plant) and other industries **generating smoke and sulphur dioxide**.

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- ☞ The problem started with the development of adverse meteorological conditions with temperature inversions and windlessness for **nearly 5 days from 4<sup>th</sup> December to 8<sup>th</sup> December 1952** during the winter.

- ☞ **Smoke and sulphur oxides started to build up** in the atmosphere and the white fog accumulated over the city turned black forming "**Pea soup smog**" with almost **zero visibility**.

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- ☞ Within two days of the formation of the smog, people started suffering from pulmonary disorders, cough, nasal discharges, sore throat, vomiting and irritation of bronchi and eyes which finally lead to excess death of people.

- ☞ The maximum suffers were elderly people having history of heart and respiratory troubles.

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Responsible Pollutant: **Sulphur Dioxide, soot.**

Similar adverse meteorological conditions in London after 1952 resulted further in **January 1955 (240 excess deaths), January 1956 (1000 excess deaths), December 1956 (400 excess deaths), December 1957 (800 excess deaths), January 1959 (200 Excess deaths) and December 1962 (850 excess deaths).**

## New York (USA)

The state of New York in USA has experienced several episodes of air pollution occurred as a result of the formation of a high pressure **anticyclonic weather** system over the area causing almost motionless wind conditions during **November 1953, November 1962 and November 1966.**

During November 1966, one such **high pressure area** developed in the New York State causing about **168 excess deaths of people.**

**SO<sub>2</sub>** was responsible for it.

## Los Angeles (USA)

Los Angeles basin is situated in the Southern California in USA having mountains on north and east of the city.

During 1940s it was realized that a **grey haze** develops frequently in the atmosphere which obstruct the mountain view causes irritation and watering in the eyes and mottling and wilting of the crops and flowers.

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It was thought that the problems are mainly due to particulate and sulphur dioxide from the oil refineries.

In 1947 regulations were passed to limit the levels of  $\text{SO}_2$  and particulates.

The problems start from production of higher quantities of auto exhaust pollutants due to plying of large number of motor vehicles.

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Oxides of nitrogen and hydrocarbons in the presence of sunlight (photo chemically) are converted into various oxidants which are responsible for symptoms of eye watering and mottling of crops.

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## Tokyo, Japan

- ☞ Tokyo is one of the most populous cities of the world having a very large number of motor vehicle.
- ☞ The monitoring of air in the city indicates the rising level of air pollutants especially oxidants, during the day caused by **photochemical reaction** involving the pollutants from auto exhaust.

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- ☞ **On 18 June, 1970** a thick **fog** was reported in the morning which disappears by noon, but the visibility still remained quite low.
- ☞ During noon, people complained of eye irritation and several school children suffered from smarting of eyes and sore throat associated with difficulty in breathing.

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- ☞ More than **6000 people** were treated for smog poisoning.
- ☞ **Responsible pollutant:** Large scale formation of photochemical oxidants.  $\text{SO}_2$  : 0.39 ppm

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## Air Pollution Accidents:

- 1) Poza Rico (Mexico)
- 2) Seveso (Italy)
- 3) Bhopal (India)
- 4) Chernobyl Nuclear Disaster, 1986

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## Poza Rico (Mexico)

- Poza Rico is a town in Mexico (Oil refining and Gas production).
- On November 24, 1950 there was an accidental release of Hydrogen sulphide gas from the oil refinery which left 22 people dead and more than 300 suffering from typical  $H_2S$  poisoning with symptoms of loss of sense of smell, cough, irritation, nausea and headache.

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- The source of the spillage was closed within half an hour, the gas had already spread by the time and the adverse meteorological condition facilitated its accumulation in the atmosphere for a long time.

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- Single source– high sulfur crude oil
- Hydrogen sulfide ( $H_2S$ )
- Flare went out
- Inversion in valley
- 22 sudden deaths, 320 hospitalized All ages
- Forerunner of Bhopal

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### Seveso (Italy)

- On July 10, 1976, an accident occurred at Seveso near Milan in Italy when an explosion took place in a chemical factory manufacturing Hexachlorophene and 2,4,5 trichlorophenoxy acetic acid. i.e. HERBISIDES.
- In Run away reaction approximately 2 kg of an extremely toxic compound 3, 4, 7, 8 tetradibenzene paradiioxine was released. resulting in release of a white cloud of poisonous gas containing dioxin (TCDD).

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- The gas cloud was settled over the city.
- The whole episode resulted in severe illness and death of some people and small animals.
- About 187 people showed skin chloracne (boils and pimples), 46 showed other skin and liver complications, a few reported abortions and many newly born children were found to have certain deformities.
- Soil was contaminated in large area.

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## Bhopal (India)

On the **night of 3/4 December 1984**, Bhopal became internationally famous when a poisonous gas, **methyl isocyanate (MIC)** - **Dangerous chemical, lighter than water but twice as heavy as air.**

It has **vigorous heat producing reactions with many substances including water.** In the presence of catalyst it can react with itself producing a **violent runaway reaction** was released from **Union Carbide India Ltd.**, a subsidiary of Union Carbide, a multinational company based in USA.

About **40 tons** of lethal **MIC** escapes the tanks in the refinery and was released into the atmosphere causing panic, death and havoc unparalleled in the world history. The gas quickly spread and caused severe eye, lung irritation and vomiting.

People started running helter-skelter and thousands lay dead in the streets of Bhopal in the morning and another 50,000 reported to various hospitals for minor to serious ailments. The worst effect was on poor slum dwellers living close to the factory.

The Indian Government figure is **2352** but people's guess vary from **3000 to 20000**. About **200000** people have been seriously affected. Their woes ranging from **temporary blindness to permanent disability**. A large number of cases of **abortion and stillbirth** were reported. Even after many years people were suffering from various ailments.

It causes serious **socio-economic problems** with thousands losing their livelihood.



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Thousands of cattle also perished in the disaster. In plants, MIC competes with  $\text{CO}_2$  in photosynthesis resulting in suppression of growth.

Several **structural changes** were reported in plant species like **coriander, carrot, cabbage, cauliflower**. The **reproduction and setting of fruits** were also affected.

The gas has also affected the **soil micro flora** as well as **water bodies**

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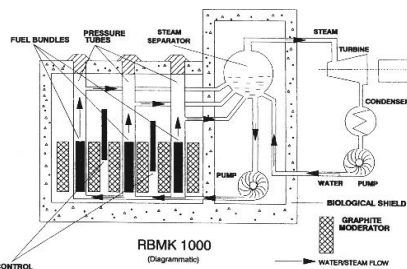
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## Chernobyl Nuclear Disaster

- Chernobyl nuclear reactor is located at Chernobyl, 128 km north of Kiev in Ukraine.



- A series of operator actions, including the disabling of automatic shutdown mechanisms, preceded the attempted test early on 26 April.
- By the time that the operator moved to shut down the reactor, the reactor was in an extremely unstable condition.
- A peculiarity of the design of the control rods caused a dramatic power surge as they were inserted into the reactor.

• The interaction of very hot fuel with the cooling water led to fuel fragmentation along with rapid steam production and an increase in pressure.

• The design characteristics of the reactor were such that substantial damage to even three or four fuel assemblies can – and did – result in the destruction of the reactor.

• The overpressure caused the 1000 t cover plate of the reactor to become partially detached, rupturing the fuel channels and jamming all the control rods, which by that time were only halfway down.

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• Intense steam generation then spread throughout the whole core (fed by water dumped into the core due to the rupture of the emergency cooling circuit) causing a steam explosion and releasing fission products to the atmosphere.

• About two to three seconds later, a second explosion threw out fragments from the fuel channels and hot graphite. There is some dispute among experts about the character of this second explosion, but it is likely to have been caused by the production of hydrogen from zirconium-steam reactions.

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• The Chernobyl accident in 1986 was the result of a flawed reactor design that was operated with inadequately trained personnel.

• The resulting steam explosion and fires released at least 5% of the radioactive reactor core into the atmosphere and downwind.

• Two Chernobyl plant workers died on the night of the accident, and a further 28 people died within a few weeks as a result of acute radiation poisoning.

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UNSCLEAR says that apart from increased thyroid cancers, "there is no evidence of a major public health impact attributable to radiation exposure 20 years after the accident."

Resettlement of areas from which people were relocated is ongoing.

\* **United Nations Scientific Committee on the Effect of Atomic Radiation**

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## World-wide Air Pollution Episode

November 27-December 10, 1962

Thousands of excess deaths in many cities including NYC, London, Boston, Paris

New Orleans Oct-Nov 1958 asthma deaths.

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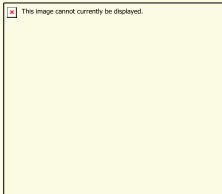
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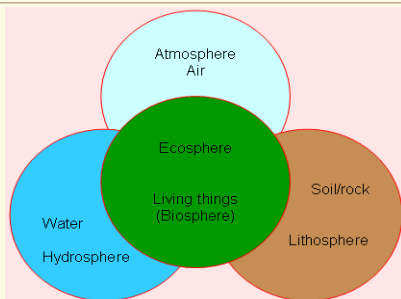
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## The Earth's Great Spheres



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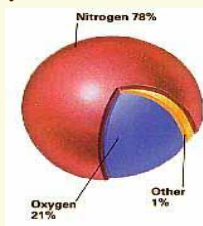
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## Atmosphere

The atmosphere contains all the air in Earth's system



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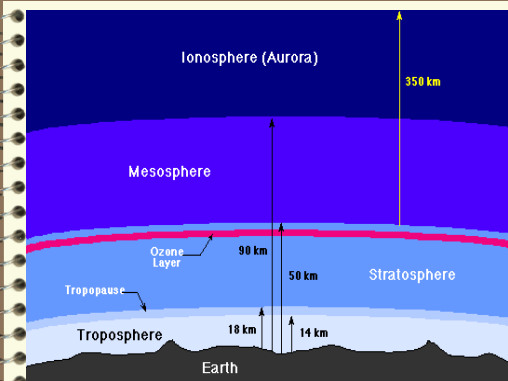
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## Troposphere

- It is the layer closest to the Earth, approximately 11km high.
- Weather occurs only in the troposphere because it is this layer that contains most of the water vapour. Weather is the way water changes in the air, and so without water there would be no clouds, rain, snow or other weather features.

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## Stratosphere

- It is the second layer of air above the Earth's surface and extends to a height of 50km.
- It is here that we find the *ozone layer*.
- The ozone layer absorbs much of the sun's harmful radiation that would otherwise be dangerous to plant and animal life.

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## Mesosphere

- Beyond the stratosphere the air is very thin and cold.
- This area is known as the *mesosphere*, and is found between 50km and 80km above the Earth's surface.

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## Thermosphere

- ▣ The *thermosphere* is the fourth layer in the atmosphere, between 80km and 110km above the Earth.
- ▣ Space shuttles fly in this area and it is also where the aurora lights are found.
- ▣ Auroras are wispy curtains of light caused when the sun strikes gases in the atmosphere above the Poles.

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## Exosphere

- ▣ Above a height of about 500km is the *exosphere*, a layer where the atmosphere merges into space. Satellites are stationed in this area, 500km to 1000km from Earth.

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## Pollutant



- ▣ There are many substances in the air which may impair the health of plants and animals (including humans), or reduce visibility.
- ▣ These arise both from natural processes and human activity.
- ▣ Substances not naturally found in the air or at greater concentrations or in different locations from usual are referred to as 'pollutants'.

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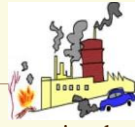
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## Air Pollution



### Perkins (1974) Defines

■ Air pollution means the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odor, smoke or vapor in quantities or characteristics and of duration such as to be injurious to human, plant or animal life or to property or which unreasonably interferes with the comfortable enjoyment of life and property.

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■ The presence in the atmosphere of a substance or substances added directly or indirectly by an act of man (**Arora 1999**)

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■ According to **Bureau of Indian Standards IS 4167 (1980)** air pollution is the presence in ambient atmosphere of substances generally resulting from the activities of man in sufficient concentration present for a significant time and under circumstances such as to interfere with comfort, health or welfare of persons or with reasonable use of enjoyment of property.

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 **The Air Act of Govt. of India (amendment 1987)** defines air pollution as “Air pollution means any solid, liquid or gaseous substances present in the atmosphere in such concentration that may tend to be injurious to human beings or other living creatures or plants or property or enjoyment.

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OR

 It may be defined as any atmospheric condition in which certain substances are present in such concentrations that they can produce undesirable effects on man and its environment.

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