AIR POLLUTION AND CONTROL

(23HPE011b)

LECTURER NOTES

III-B.TECH & I-SEM

Prepared by:

Dr. P. Sri Chandana

M.Tech, Ph.D. (National Taiwan University, Taipei, TAIWAN)

Visiting Professor, GIEE, NTU, Taipei, Taiwan

Professor and Head of Dept

Dean Research and Development

UGC Research Awardee

Department of Civil Engineering

ANNAMACHARAYA INSTITUTE OF TECHNOLOGY & SCIENCES

(AUTONOMOUS)

Utukur (P), C. K. Dinne (V & M), Kadapa, Andhra Pradesh-516003

Web Site: www.aitskadapa.ac.in

CIVIL ENGINEERING					
III B.Tech – I Semester					
Course Code	**AIR POLLUTION AND CONTROL (PE – I)**	**L**	**T**	**P**	**C**
23HPE011b		3	0	0	3

Course Objectives:

The objectives of this course are to make the student to:

1. Understand the sources, classification, and effects of air pollution on humans and the environment.
2. Analyze meteorological factors influencing air pollution and dispersion modeling.
3. Design and evaluate control measures for particulate pollutants.
4. Apply techniques for controlling gaseous pollutants through chemical and physical processes.
5. Assess vehicular and indoor air pollution and propose control strategies.

Course Outcomes (COs):

After successful completion of this course, students will be able to:

1. Explain the sources, classification, and global effects of air pollution.
2. Analyze meteorological parameters affecting air pollution dispersion.
3. Design control systems for particulate matter using appropriate removal techniques.
4. Apply suitable technologies for gaseous pollutant removal through adsorption, absorption, and combustion.
5. Evaluate vehicular and indoor air pollution sources and suggest mitigation strategies.

CO – PO Articulation Matrix:-

Course Outcomes	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO1	PSO2
CO -1	2	1	-	-	-	2	3	-	-	1	-	1	1	1
CO -2	2	2	-	2	2	3	3	-	-	-	-	1	2	2
CO -3	2	2	3	2	2	3	3	-	-	-	-	1	2	2
CO -4	2	1	2	2	3	3	3	-	-	-	-	1	2	2
CO -5	2	2	2	2	2	3	3	2	-	-	-	1	2	2

UNIT – I

Air Pollution:

Definition - Sources &Classification of Air Pollutants - Effects of Air Pollution On Humans, Plants and Materials- Global Effects - Air Quality and NAAQS - National Clean Air Programme- Sampling of Pollutants in Ambient Air - Stack Sampling

UNIT – II

Meteorology and Air Pollution:

Factors Influencing Air Pollution, Wind Rose, Mixing Depths, Lapse Rates and Dispersion - Atmospheric Stability, Plume Rise and Dispersion, Prediction of Air

Quality, Box Model - Gaussian Model - Dispersion Coefficient - Application of Tall Chimney for Pollutant Dispersion.

UNIT – III
Control of Particulate Pollutants:
Properties of Particulate Pollution - Particle Size Distribution - Control Mechanism - Dust Removal Equipment - Design and Operation of Settling Chambers, Cyclones, Wet Dust Scrubbers, Fabric Filters &ESP.

UNIT – IV
Control of Gaseous Pollutants:
Process and Equipment for The Removal By Chemical Methods - Design and Operation of Absorption and Adsorption Equipment - Combustion and Condensation Equipment.

UNIT – V
Automobile and Indoor Pollution:
Vehicular Pollution – Sources and Types of Emission – Effect of Operating Conditions- Alternate Fuels and Emissions-Emission Controls and Standards, Strategies to Control Automobile Pollution– Causes of Indoor Air Pollution-Changes in Indoor Air Quality- Control and Air Cleaning Systems-Indoor Air Quality

TEXT BOOKS:

1. Rao, M. N. and Rao H. V. N., Air Pollution, Tata McGraw-Hill, New Delhi, 2007
2. Khare M, Sharma P, Kota, S.H, Sumanth C, Air Pollution Science Engineering and Management Fundamentals, CRC Press, 2024.
3. Noel, D. N., Air Pollution Control Engineering, Tata McGraw Hill Publishers, 1999.

REFRENCE BOOKS:

1. Fundamentals of Air Pollution by Dr. B.S.N. Raju, Oxford & I.B.H
2. Air Pollution Control Engineering by Nevers, , McGraw-Hill, Inc., 2000.
3. Rao, C. S., Environmental Pollution Control Engineering, New Age International, New Delhi, 2006.
4. Mahajan S. P., Pollution Control in Process Industries, Tata McGraw-Hill Publishing Company, New Delhi, 1991.
5. Peavy H. S., Rowe D. R. and Tchobanoglous G.,Environmental Engineering, McGraw Hill, New York, 1985.

Online Learning Resources: **https://archive.nptel.ac.in/courses/105/107/105107213/**

UNIT – I Air Pollution: Definition - Sources &Classification of Air Pollutants - Effects of Air Pollution On Humans, Plants and Materials- Global Effects - Air Quality and NAAQS - National Clean Air Programme- Sampling of Pollutants in Ambient Air - Stack Sampling

UNIT – I

Definition of Air pollution: It is the presence of substances in air in sufficient concentration and for sufficient time, so as to be, or threaten to be injurious to human,plant or animal life, or to property, or which reasonably interferes with the comfortable enjoyment of life and property.

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 concentrations that maytend to be injurious to human beings or other living creatures or plants orpropertyorenjoyment".

Perkins (1974) defined air pollution as "air pollution means the presence in the outdoor atmosphere of one or more contaminants such as dust, fumes, gas, mist, odor, smoke or vaporinquantitiesorcharacteristicsandofdurationsuchastobe injuriousto human, plant or animal life or to property or which unreasonably interferes with the comfortable enjoyment of life and property."

Atmosphere can be defined as the thin blanket of air surrounding the earth. The clean dry air has following average composition:-

Component	*By volume*	*By weight*
Nitrogen	78.084%	75.51%
Oxygen	20.946%	23.15%
Argon	0.934%	1.28%
Carbon dioxide	0.033%	0.046%
Neon	18.180 ppm	12.50 ppm
Helium	5.240 ppm	0.72 ppm
Krypton	1.190 ppm	2.90 ppm
Xenon	0.087 ppm	0.36 ppm
Nitrous oxide	0.500 ppm	1.50 ppm
Methane	2.0 ppm	1.2 ppm
Hydrogen	0.5 ppm	0.03 ppm
Ozone	0.01 ppm	

Definition of Air pollutants: Substances introduces into the air, natural or manmade, in concentrations detrimental to human, plant or animal life, or to property.

MajorClassificationofAirPollutants:

1] Primary– Secondary
2] Natural – Manmade

Primary pollutants and secondary pollutants: Primary pollutants are substances that are directly emitted into the atmosphere from sources. Primary pollutants are those that areemitted directlyfromidentifiable sources. Secondaryair pollutants arethosethat areproduced in the airby the interaction of two or more primary airpollutant.

PrimaryAirpollutants:-

(i) Fine(lessthan100µ) andcoarse(morethan100µ) suspended particulatematter
(ii) Oxides ofsulfur
(iii) Oxides ofnitrogen
(iv) Carbon monoxide
(v) Halogens
(vi) Organic compounds
(vii) Radioactive compounds

SecondaryAirpollutants:-
(i) Ozone
(ii) PAN(peroxiaceylnitrate)
(iii) Photochemicalsmog
(iv) Acidmists

Airpollutantsarise frombothmanmadeand naturalprocesses. Theambient airqualitymaybe defined bythe concentrationofa set ofpollutants which may be present inthe ambient air we breathe in. These pollutants may be called **criteria pollutants**.

Natural Contaminants: Pollen is important natural contaminant because of its peculiar properties of irritation and allergy sometimes leading to bronchitis, asthma and dermatitis. Pollen grains are the male gametophytes of gymnosperms and angiosperms and they are discharged intothe atmosphere fromplantsetc.The airtransported pollengrainsrange mainly between10and50microns. Manmade refersto anypollutant producedto influence oraction ofhumans.

Aerosols: Aerosolsrefertothedispersionofsolid orliquidparticlesofmicroscopic size inthe air. It can also be defined as a colloidal system in which the dispersion medium is gas and the dispersed phase is solid or liquid. The term aerosol is applicable until it is in suspension and after settlement due to its own weight or byaddition with other particles (agglomeration) it is nolonger an air pollutant. The diameter of the aerosol may range from 0.01 (or less)micron to 100 micron.

Thevariousaerosolsareasfollows:-

(i) **Dust:** Dust is producedby the crushing, grinding and natural sources like windstorms. Generally the dust particles are over 20 micron in diameter. Theydo not flocculate butsettle under gravity, but smaller particles like 5 micron form stablesuspensions.

(ii) **Smoke:** Smoke is made up of finely divided particles produced by incompletecombustion. Generally it consists of carbon particles of size less than 1.0micron.

(iii) **Mists:** Mist is a light dispersion of minute water droplets suspended in the atmosphere ranging from 40 to 400 micron insize.

(iv) **Fog:** Fog is made up of dispersion of water or ice near the earth's surface reducing visibilityto less than 500 m. In natural fog the size of particles range from1.0 to 40micron.

(v) **Fumes:** Fumes are solid particles generated by condensation from the gaseous state after volatilization from melted substances. Fumes flocculate and sometimes coalesce.

Followingarethe**main airpollutantgases**

(i) **Sulphur dioxide:** It is a major air pollutant gas produced by the combustion of fuels like coal. The main source of electricity production is by burning of fossil fuels in India and the whole world. The sulphur content of the coal varies from 1 to 4% and fortunately the Indian coal is low in sulphur content. SO2 is also produced in the metallurgicaloperations.

(ii) **Oxides ofnitrogen:** Oxides ofnitrogenareproduced either inthe productionofnitric acid or in the automobile exhausts and as the effluent of power plants. Out of the seven oxidesof Nitrogen (N_2O, NO, NO_2, NO_3, N_2O_3, N_2O_4, N_2O_5) only nitric oxide and nitrogen dioxide are classified as the main pollutants. All the oxides of nitrogen are collectively known as NOX.

(iii) **Carbon monoxide:** It is produced because of the incomplete combustion of coal andother petroleum products. It is produced in the exhaust of automobiles. In the pollution check of vehicles mainly CO and unburnt hydrocarbons are measured.

(iv) **Hydrogen sulphide:** Hydrogen Sulphide is an obnoxious (bad-smelling) gas. It is produced mainly by the anaerobic (in absence of air) decomposition of organic matter. Other air polluting sulfur compoundsare methylmercaptan(CH_3SH) and dimethylsulphide (CH_3-S-CH_3)etc.

(v) **Hydrogen fluoride:** It is an important pollutant even in very low concentrations. It is produced in the manufacturing of phosphatefertilizers.

(vi) **Chlorine and hydrogen chloride:** It is mixed in the air either from the leakages from water treatment plants or other industries where it is produced or used. Hydrogen chloride is also evolved in various industrial chemical processes. The main effect of chlorine isrespiratory irritation which may befatal.

(vii) **Ozone:** It is a desirable gas in the upper layers of atmosphere as it absorbs the UV radiation of sunlight. But near the earth surface it is a poisonous gas. It makes poisonous chemicals by photochemicalreactions.

(viii) **Aldehydes:** They are produced by the incomplete oxidation of motor fuels and lubricating oil. They may also be formed because ofphotochemical reactions. Formaldehydes are irritatingto the eyes.

Classificationaccordingtochemicalcomposition:(Organic–inorganic)

1. Sulfur-containing compounds.
2. Nitrogen-containing compounds.
3. Carbon-containingcompounds.
4. Halogen-containingcompounds.
5. Toxicsubstances(anyofabout).
6. Radiativecompounds.

Classificationaccordingtophysicalstate:

1. Gaseous.
2. Liquid(aqueous).
3. Solid.

Criteria air pollutants are six major pollutants defined by EPA (Environmental Protection Agency) for which ambient air standards have been set to protect human health and welfare. These include:

1. Ozone,O3.
2. Carbonmonoxide,CO.
3. Sulfurdioxide, SO2.
4. Nitrogenoxides,NOx.
5. Lead,Pb.
6. Particulates,PM10.

Pollutant	Description	Sources	HealthEffects	WelfareEffects
Carbon Monoxide (CO)	Colorless, odorlessgas	Motor vehicle exhaust,indoor sources include kerosene or wood burning stoves.	Headaches reduced mental alertness, heart attack, cardiovascular diseases,impaired fetal development, and death.	Contribute to the formation of smog.
Sulfur Dioxide (SO2)	Colorless gas thatdissolvesin water vapor to form acid, and interact with other gases and particlesin theair.	Coal-fired power plants, petroleum refineries,manufacture of sulfuric acid and smelting of ores containingsulfur.	Eye irritation, wheezing, chest tightness, shortness of breath, lung damage.	Contribute to the formation of acid rain, visibility impairment, plant and water damage, aesthetic damage.
Nitrogen Dioxide (NO2)	Reddishbrown, highly reactive gas.	Motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fuels.	Susceptibility to respiratory infections, irritation of the lung and respiratory symptoms (e.g., cough, chest pain, difficulty breathing).	Contribute to theformationof smog,acidrain, water quality deterioration, globalwarming, and visibility impairment.
Ozone(O3)	Gaseous pollutantwhen itisformedin thetroposphere.	Vehicle exhaust and certain other fumes. Formedfromotherair pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead(Pb)	Metallicelement	Metal refineries, lead smelters, battery manufacturers, ironand steel producers.	Anemia, high blood pressure, brain andkidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.
Particulate Matter(PM)	Very small particles ofsoot, dust, or other matter, includingtiny dropletsof liquids.	Diesel engines, power plants, industries, windblown dust, wood stoves.	Eye irritation, asthma, bronchitis, lung damage, cancer, heavy metal poisoning,cardiovascular effects.	Visibility impairment, atmospheric deposition, aesthetic damage.

EmissionSources

MajorClassificationofAirPollutionSources:

1] BasedonOrigin:NaturalandManmade

While man-made air pollutiondoes present healthhazards, naturalsources ofair pollutioncan be equally dangerous at times. These sources include dust picked up by wind erosion, the emissionof methane by livestock, and smoke from wildfires. Volcanic eruptions are perhaps the largest single source of air pollution, natural or man-made, that humans have ever dealt with. Thesecanproducecloudsofabrasive volcanicashand other harmful substancessuchas chlorineand sulfur.

2] Basedon Position:Stationary andMobile

The sources of air pollution may be classified as stationarypoint sources (generally industrial in origin), diffuse or area sources and mobile sources (mainly cars and trucks).

3] Basedon AixofRelease: Horizontalaxis(Roadwaystraffic)

VerticalAxisrelease(IndustrialStacks)

4] BasedonIntensity/frequencyofrelease: Continuousrelease(IndustrialStacks)

Instantaneousrelease(Roadwaystraffic)

StationarySources

Thestationaryindustrialsourcesareusuallyclassified by processtypeor sub-type. Thusanoil refining plant also includes large industrial boilers as a sub-type. Small and medium scale plants such as garment or food processing plants may include industrial boilers, a common source of air pollution. The quality and type of fuel used for energy production are important determinants of the air pollution potential of a plant. Each type of plant or activity generally emits more than one pollutant, and the pollutant emission rate depends on the fuel type and quality, the design of the plant (and whether fitted with air pollution control devices or not), and the activity rate or output of the plant.

(i) Pointsource(powerplantstacks)

(ii) Areasource(forest fires,openburning)

(iii) LineSource(highwayvehicleexhausts)

Mobile Sources Refer mainly to emissions from cars, trucks, minibuses and buses. The fuel source may be petrol or diesel, and emissions include exhaust emissions and fugitive emissions. Vehicle (mobile) source emissions depend on a number of factors, including vehicle size, fuel type, speed and vehicle technology. Total vehicle emissions depend on the vehicle population on the road at a giventime.

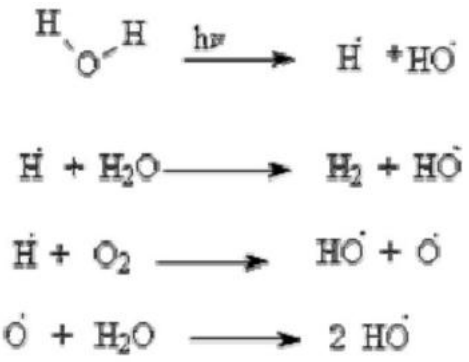
ChemicalReactions intheAtmosphere

Substances in the top layer of the geosphere, known as the lithosphere, tend to become more reduced over time. Biomass (CH_2O) for example is slowly transformed to substances which have no oxygen atoms through a sequence of steps, then to compoundswithsuccessively larger carbon to hydrogen ratios and finally to products with a formofpure carbon. However, atmospheric chemical reactions have the opposite effect on substances, causing an atomto become more oxidized over time in the atmosphere. Atmospheric gases that are found in their reduced states are oxidized stepwise to form ionic substances that are washed out of the atmosphere in rainfall. Example, dissolution of atmospheric hydrogen sulfide by rain to form sulfatemolecule.

$$H_2S + H_2O\ (rain) \rightarrow \ SO_4^{2-}$$

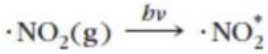
Chemical reactions in the atmosphere can occuras gas phase collisions between molecules, onthe surfaces of solid particles or in aqueous solution (in water droplets); predominantly acid-base reactions. Particles spend short residence time in the atmosphere. Dueto this, reactionsthat occur on particle surfaces are of minor importance in most cases. Gas phase reactions dominate the chemical changes that occur to substances in theatmosphere.

The most important single species in atmospheric chemistry is the hydroxyl radical (HO·).This radical isformedby severalreactions.However,theprimaryprocess is onewherean O-H bondof the water molecule is broken to form a hydrogen atom (H·) and a hydroxyl radical (HO·). The hydrogenatomcanthenreact withanother water molecule to formhydrogenand a second hydroxyl radical, or with an oxygen molecule (O2) to form a second hydroxyl radical and an oxygen atom. The new oxygen atom can then react with another water molecule toform two new hydroxylradicals.



Molecules in the atmosphere are continually moving and colliding with one another, as described by the kinetic-molecular theory. The atmosphere is also continually illuminated during daylight hours. As a result, absorption of light energy by atmospheric molecules can cause photochemical reactions, reactions that would not occur at normal atmospheric temperatures in the absence of light. Such reactions play an important role in determining the composition of the atmosphere itself and the fate of many chemical species that contribute to airpollution.

Nitrogen dioxide, NO2, is one of the most photochemically active species in the atmosphere. The NO2 molecule is an example of a free radical because it contains an unpaired electron, represented by a next to its formula. When an NO2 molecule absorbs a photon of light with energy, the molecule is raised to a higher energy level; it becomes an electronically excited molecule, designated by an asterisk(*).



The excited molecule may quickly re-emit a photon of light, or the energy may break an N-O bond to form a nitrogen monoxide (NO) molecule and an oxygen atom (O). Both NO and O are free radicals, because they have one or more unpaired electrons each denoted byadot.

$$\cdot NO_2^*(g) \xrightarrow{h\nu} \cdot NO(g) + \cdot O\cdot(g)$$

Photodissociation is another mechanismof formationofradicals, inwhicha molecule absorbs an ultraviolet photon and produces two free radicals as products. Molecular oxygen can photodissociate to form two oxygen atoms.

$$O_2(g) \xrightarrow{h\nu} \cdot O\cdot(g) + \cdot O\cdot(g)$$

Some free radicals, such as an oxygen atom, react with another atom or molecule almost immediately. Others, suchasanNO2 molecule, arenot quitesoreactiveandarestableenough to exist for a somewhat longer time. Most radicals are highly reactive and short-lived.

Fate ofairpollutants intheatmosphere

1]NO_x,Hydrocarbons,Ozone,Mist:-Formationofphotochemical smog 2]

SO_2, NO_x: - Formation of Acid Mist / Rain

3]SO_2,CO,Mist:-Formationofcoalinduced smog 4] [O],

NOx, OH^- - Formation of Ozone

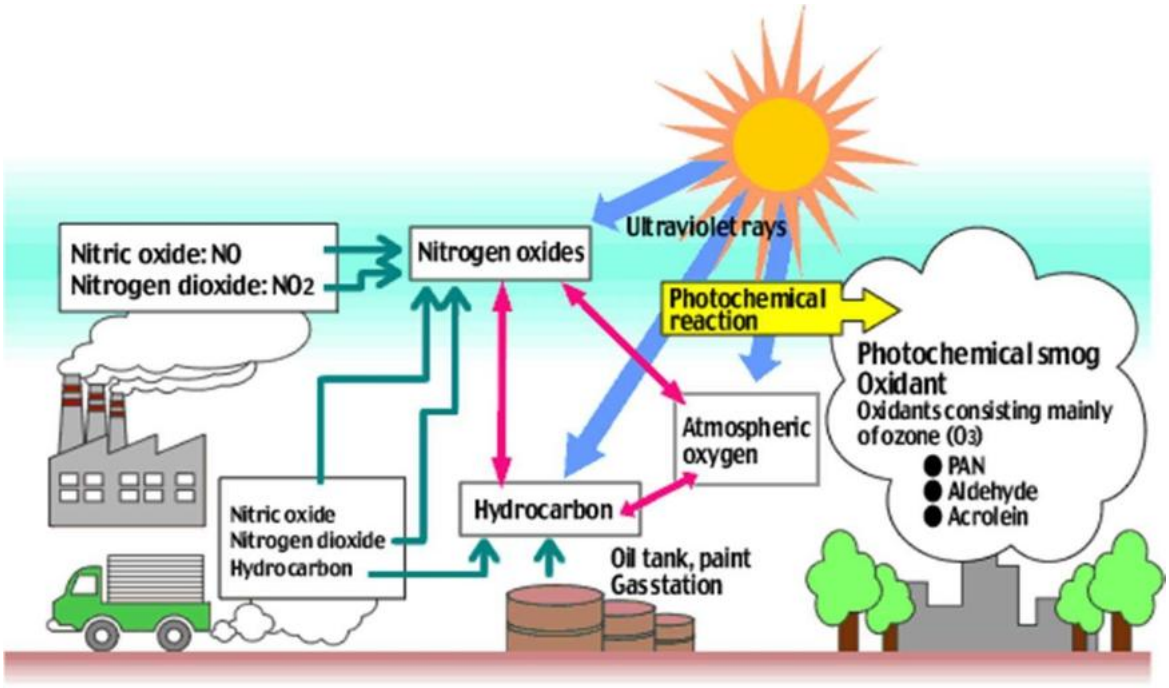
PHOTOCHEMICALSMOG

Photochemical smog was first described in the 1950s. It is the chemical reaction ofsunlight, nitrogenoxidesandvolatileorganiccompoundsintheatmosphere,whichleavesairborne

particles and ground-level ozone. This noxious mixture of air pollutants can includes Aldehydes, Nitrogen oxides, such as nitrogen dioxide, Peroxyacyl nitrates

Tropospheric ozone, Volatile organic compounds etc. All of these chemicals are usuallyhighly reactive and oxidizing. Photochemical smog is considered to be a problem of modern industrialization. It is present in all modern cities, but it is more common in cities with sunny, warm, dryclimates and a large number of motor vehicles. Because it travels with the wind, it can affect sparsely populated areas as well.

VOCs+NOx+sunlight→photochemicalsmog



To beginthe chemical processofphotochemicalsmog development the following conditions must occur:

- Sunlight.
- The productionofoxides ofnitrogen(NOx).
- Theproductionofvolatileorganiccompounds(VOCs).
- Temperaturesgreaterthan18degreesCelsius.

Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle's engines. Nitrogen oxide is an essential ingredient of photochemical smog that is produced during the high temperatures associated with combustion of vehicle's engines.

Formation

Sunlight canbreakdownnitrogendioxidebackintonitrogenoxide. NO2 +

sunlight »»» NO + O

Theatomicoxygenformed intheabovereactionthenreactswithoneoftheabundantoxygen molecules producing ozone.

O+ O2 »»»O3

Nitrogendioxide canalso react withradicals produced fromvolatile organic compounds ina series of reactions to form toxic products such as peroxyaceyl nitrates.

NO2 + R»»»productssuchasPAN

Notethe symbolR represents a hydrocarbon(a molecule composed ofcarbon, hydrogenand other atoms) which is primarily created from volatile organic compounds.

Steps

1) Nitrogenoxidesgenerateoxygenatoms

2) Oxygenatomsformhydroxylradicals

3) Hydroxylradicalsgenerate hydrocarbon radicals

4) Hydrocarbonradicalsformhydrocarbonperoxides

5) Hydrocarbonperoxidesformaldehydes

6) Aldehydes formaldehydeperoxides

7) Aldehydeperoxidesform peroxy-acyl-nitrates

Health effects

It cancause eye and nose irritationand it dries out the protective membranes ofthe nose and throat and interferes with the body's ability to fight infection, increasing susceptibility toillness.

COALINDUCEDSMOG

IntroductiontoSmog

Smog is a recent compound word from "smoke" and "fog",and was coined by HaroldAntoine des Voeux, a doctor, in1905. Smog refers to locally highconcentrations ofacids, dry acid-forming compounds, particulates, orother pollutantsinstagnant,stable air. Smog's form whenemissions areprevented fromdispersing bystableor sinking air masses. Theywere very prevalent in European and North American cities during first part of 20th Century.London smog's were infamous in the 19th and early 20th centuries and formed every autumn and winter due to sulphur emissions from coal burning industries and domestic fires. The most severe London smog was on 4-10th December 1952, when cold, high-pressure conditions trapped coal smoke in foggy air. The output of smoke was increased by the cold weather, due to the large numbers of domestic fires. Sooty smoke produced peak daily concentrations of black smoke of 5000 mgs/m3 (WHO 24 hr. max limit of 100-150), and daily average SO2 levels of 3000-4000 mg/m3 (WHO 24 hr. max limit of 100-150). Sulphuric acid droplets resulted in pH estimatedas to 1.9: as acidic as car batteryacid.

$$HSO_{2(g)} + HO_{2} \rightarrow HSO_{4(aq)}$$

$$SO_{2(g)} + HO_{2(l)} \rightarrow HSO_{3(aq)}$$

Chemistry

These are produced by high outputs of SO2, which are converted to acids on contact with atmospheric moisture. Usually, sulphuroussmog's also contain elevated concentrations of suspended soot.

Impacts

Visibility was reduced to 5m at times, and London buses had to be guided through the streetby men with lanterns during daylight hours. The smog lasted for 5 days, eventually extending over a 50km radius. Approx. 4,000 excess deaths occurred as a result of inhaling pollution, mainly old and sick and those with chest problems. Respiratory diseases alone accounted for 59 per cent of the increase in deaths registered in the week ending 13 December and 76 per cent inthefollowing week. Bronchitis and emphysema were the two conditions that stood out in the coroner's records as showing the greatest increase. Cardiovascular diseaseaccounted for 22 per cent of the increased number of deaths in the firstweek and 16 per centin the week ending 20 December. The disaster ultimately led to the introduction of the Clean AirActs.

ACIDMIST/RAIN

Definition

Normal Rain water p^H is slightly acidic due to certain concentration of CO_2dissolvedas rainwater trickles downatmosphere,

$CO_2+H_2O \rightarrow HCO^{3-}+H^+$

Acidrainisdefinedasanytypeofprecipitationwithap^{H}thatisunusuallyloworlowerthan
5.7. Acidrainwas first found inManchester,England. In1852, Robert AngusSmithfoundthe relationship between acid rain and atmospheric pollution. Though acid rain was discovered in 1852, it wasn't until the late 1960s that scientists began widely observing and studying the phenomenon.

Causes

The principal natural phenomena that contribute acid-producing gases to the atmosphere are emissions from volcanoes and those from biological processes that occur on the land,in wetlands, and in the oceans. The major biological source of sulfur containing compounds is dimethylsulfide.

The principalcause ofacid rain is sulfuric and nitrogencompounds fromhumansources, such as electricity generation, factories and motor vehicles. Coal power plants are one of the most polluting. The gases can be carried hundreds of kilometres in the atmosphere before they are converted to acids and deposited. Factories used to have short funnels to let out smoke, butthis caused many problems, so now, factories have longer smoke funnels. The problem with this is those pollutants get carried far off, where it creates more destruction.

Sulfur dioxide contributes to about seventypercent ofacid rain while nitrogen oxides provide the remaining thirtypercent. The sourcesofsulfur inthe atmosphere include coalcombustion, smelting, organic decay, and oceanspray. Approximatelyninetypercent ofatmospheric sulfur results from human activities.

In the atmosphere, sulfur dioxide combines with water vapor to form hydrogen sulfite

gas: $SO_2 + H_2O + 1/2O_2 \rightarrow H_2SO_4$

Next, hydrogen sulfite reacts with oxygen to form sulfuric acid, a major component of acid

rain: $H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$

The sources of nitrogen oxides include the combustion of oil, coal and natural gas, forest fires, bacterial action in soil, volcanic gases, and lighting-induced atmospheric reactions.

Intheatmosphere,nitrogenmonoxidereactswithoxygengastoform nitrogendioxide gas: NO +

$1/2O_2 \rightarrow NO_2$

Then, nitrogen dioxide reacts with water vapor in the atmosphere to form hydrogen nitrite and hydrogen nitrate:

$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$

Henceforth, acid rain is a mixture of HNO_3, H_2SO_4+ HCl. however conditions needed to favor formation of these are sunlight, temperature, humidity, hydrocarbons, NO_X, SO_2.

Effects

Both the lower p^H and higher aluminum concentrations in surface water that occur as a result of acid rain can cause damage to fish and other aquatic animals. At p^H lower than 5 most fish eggs will not hatchand lower p^H cankilladult fish. As lakes become more acidic biodiversity is reduced. Soil biology can be seriously damaged by acid rain. Some tropical microbes can quickly consume acids but other microbes are unable to tolerate low p^H and are killed.

Acid rain can slow the growth of forests, cause leaves and needles to turn brown and fall off and die. In extreme cases trees or whole areas of forest can die. The death of trees is not usuallyadirect result ofacid rain;often it weakenstreesand makesthemmoresusceptibleto otherthreats. Some scientists have suggested direct links to humanhealth, but none have been proven. However, fine particles, a large fraction of which are formed from the same gases as acid rain (sulfur dioxide and nitrogen dioxide), have been shown to cause illness and premature deathssuch as cancer and other deadlydiseases

Toxic metals released into the environment by acid rain may enter water supplies or accumulatein fish and crops. Acid deposition also destroys statues, headstones, buildings,and fountains. Limestone structures are especially susceptible because they dissolve easily in acidicsolutions.

Acid rain canalso cause damage to certainbuilding materials and historical monuments. Acid rain can cause weathering on ancient and valuable statues and has caused considerable damage. This is because the sulfuric acid in the rain chemically reacts with the calcium compounds in the stones (limestone, sandstone, marble and granite) to create gypsum, which then flakes off. Acid rain also causes an increased rateof oxidation foriron.

Control

- Designmoreefficientautomobileengines inordertoreducenitrogenoxide emissions.
- Increaseefficiencyofpower plantsthat burncoal inordertoreducewastethat contains sulfur dioxide and nitrogen oxide.
- Increasepenaltiesonindustriesthatdonotmeetairpollution guidelines.

- Increasetaxincentivestoindustriesthat domeetguidelines.
- Usealternativeenergysources,Increasefundingforalternativeenergysources;for example, give tax incentives to buyers of hybrid cars.
- Providetaxincentivestocompaniesthatusealternativeenergy sources.
- Add $CaCO_3$(calcium carbonate) to lakes suffering from acid deposition;calcium carbonate actsasabuffer, resisting a change in $p^H$and lessening the negative effectsof acid rain.

OZONE DEPLETION

Definition

Ozone layer is anumbrella24km[15 miles] fromearthsurface, anessentialcomponent ofthe stratospherethat absorbs short wavelengthultraviolet radiationfromthesun, heatingthegases of the stratosphere in the process. World ozone day is celebrated on Sept, 16of every year.

Stratospheric ozone is measured in Dobson units [DU] named after G.M.B Dobson who pioneered the study; [I Dobson unit = 0.01 mm thickness of stratospheric ozone], Average ozone thickness in stratosphere is 300 DU, & when it falls below 200DU, it's considered as Ozonehole. It is thinnest around equator and thickest near the poles.

Stratospheric ozone depletion is the termappliedto the loss of stratospheric ozone molecules (O_3)andthe disruptionofOxygen-Ozone concentrationequilibriuminstratosphere [i.e., when chlorine atoms upset the natural O_2/O_3equilibrium in the stratosphere]. Oxygen molecules interact with the intense solar radiation present at this elevation to form oxygen atoms. The oxygen atoms thus generated react with other oxygen molecules to form ozone(O_3).

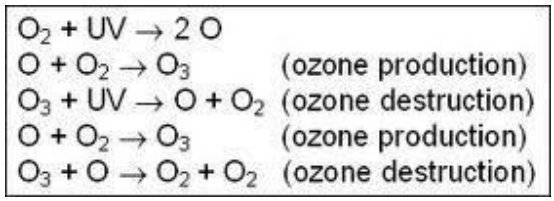
Causes

Ozone depletion is caused by the release of chlorofluorocarbons (CFC's) and other ozone-depleting substances (ODS), which were used widely as refrigerants, insulating foams, and solvents. Thediscussionbelow focusesonCFCs, but isrelevantto allODS[NO, NO_2(aircraft exhaust), Br^-, UV rays, [O] Atomic oxygen etc].

Although CFCs are heavier than air, they are eventually carried into the stratosphere in a processthat cantakeaslong as2 to 5 years. When CFCsreachthestratosphere,theultraviolet radiation fromthe sun causes themto break apart and release chlorine atoms which react with ozone, startingchemicalcyclesofozonedestructionthat depletetheozone layer. One chlorine atom can break apart more than 100,000 ozone molecules.

Other chemicals that damage the ozone layer include methyl bromide (used as apesticide), halons (used in fire extinguishers), and methyl chloroform (used as a solvent in industrial processes). As methyl bromide and halons are broken apart, they release bromine atoms,whichare 40 times more destructive to ozone molecules than chlorine atoms.

Chapman'sReaction



OzoneDepletionbyCFC's

Effects

Effect ofozone hole include cataract, genetic mutation, constriction of blood vessels, reduced crop yield, leukemia, breast cancer, damage to crop, aqua culture,etc.,

The higher energy UV radiation absorbed by ozone is generally accepted to be a contributory factorto skin cancer. In addition, increased surface UV leads to increased tropospheric ozone, which is a health risk to humans such as Snow Blindness [photo keratosis], i.e., inflammation ofcornea (outer coating ofeyeball). The most common forms ofskin cancer in humans, basal and squamous cell carcinomas have been strongly linked to UVB exposure. Another form of skin cancer, malignant melanoma, is much less common but far more dangerous, being lethal in about 15% - 20% ofthe cases diagnosed. In India there is no standard for Ozone. However WHO standard is 100 ppm for 8 hrs. – avg.

ControlMeasures

The Montreal Protocol, an international agreement signed by 139 nations, banningthe production of CFCs by the year 2000. We can't make enough ozone to replace what's been destroyed, but provided that we stop producing ozone-depleting substances, natural ozone production reactions should return the ozone layer to normal levels by about 2050. It is very important that the world comply with the Montreal Protocol; delays in ending productioncould result in additionaldamage and prolong the ozone layer's recovery. Control mechanism stresseson replacement of the banned chemical by ammonia, steam, helium, etc.

AIRQUALITYMANAGEMENT

Air pollutants are added in the atmosphere from variety of sources that change the composition of air and affect the biotic environment. The concentration of air pollutants depend not only on the quantities that are emitted from air pollution sources but also on the ability of the atmosphere to either absorb or disperse these emission. The pollution concentrations vary spatially and temporarily causing the air pollution pattern to change with different locations and time due to changes in meteorological and topographical condition. Thesourcesofairpollutants includevehicles, industries, domesticandnatural sources. The presence of air pollutants inthe ambient air adversely affects the health of the population. In order to prevent and control air pollution, the Air (Prevention and Control of Pollution) Act was enacted in1981. The responsibility has been further emphasized under Environment (Protection) Act, 1986. It is necessary to assess the present and anticipated air pollution through air quality survey/monitoring programs. Therefore, Central Pollution Control Board had started National Ambient Air Quality Monitoring (NAAQM) Network during 1984 - 85 at national level and gradually the number of stations has increased over the years. The programmed was later renamed as National Air Quality Monitoring Programme (NAMP).The ambient air quality monitoring network involves measurement of a number of air pollutants at different locations in the country. Air quality monitoring requires propers election of pollutants, selection of locations, frequency and duration of sampling, sampling techniques, infrastructural facilities, man power and operationandmaintenance. The areas selected for monitoring are based on high traffic density, industrial growth, human population and its distribution, emission source, public complaints, the land use pattern etc. Generally, the basis

of a network design are the pollution source and the pollutants present. The criteria pollutants measured are Suspended Particulate Matter (SPM), Respirable Suspended Particulate Matter(RSPM), Sulphur dioxide (SO2), Oxides of Nitrogen (NOx), and Carbon Monoxide(CO) etc.

The quality of the air that we breathe affects our health and quality of life. It can also have major impacts on the ecosystem. Measuring and understanding air pollution provides a sound scientific basis for its management and control. Historically, air pollution problem has typically been high levels of smoke and sulphur dioxide arising from the combustion of sulphur-containing fossil fuels such as coal for domestic and industrial purpose. However, now the major threat to clean urban air is posed by vehicular emission. A variety of pollutants are emitted by petrol and diesel- enginemotor vehicles. These include carbon monoxide (CO), oxides ofnitrogen(NOx),volatile organic compounds (VOCs) and particulates (PM10 and PM2.5). The sources of particulate matter levels are vehicles, engine gensets, small scale industries, biomass incineration, boilers and emission from power plants, re-suspension of traffic dust, commercial and domestic use of fuels, etc. Fine particles containmicroscopicsolids or liquid droplets that are very small and they can penetrate deep into the lung sand cause serious health problems. Generally, coarse particles are directly emitted and fine particles can be formed in the atmosphere. Photochemical reactions resulting from the action of sunlight on nitrogen dioxide (NO2) and VOCs from vehicles leads to the formation of ozone. Ozone is a secondary long-range pollutant, which affects areas far fromtheoriginalemissionsite.Thereportpresentsresultsofambientairqualitymonitoringcarriedout duringtheyear 2008atvariousmonitoringstationsunder NAMP. Four criteria pollutants namely sulphurdioxide, nitrogen dioxide, respirable suspended particulate matter, and suspended particulate matter, have been monitored regularlyat various monitoring locations. The air quality is described in terms of low, moderate, high and critical levels based on an exceedance factor. The pollutants that are exceeding the standards in many cities are suspended particulate matter and respirable suspended particulate matter. Results of additional pollutants such as benzene and carbon monoxide monitored inDelhi and ammonia insix cities have also been presented. The next few chapters present details of the National Air Quality Monitoring Programme and major findings during the year 2008. Also detailed are the initiatives taken for air pollution control.

Air(Preventionand ControlofPollution)Act 1981

Government of India enacted the Air (Prevention and Control of Pollution) Act 1981 to arrest the deterioration in the air quality. The act prescribes various functions for the Central Pollution Control Board (CPCB) at the control level and State Pollution Control Boards at the state level. The main functions of the Central Pollution Control Board are as follows:

• To advise the Central Government on any matter concerning the improvement of the quality of the air and the prevention, control and abatement of air pollution.

• To planand cause to beexecuted a nation-wide programme for the prevention, control andabatementofairpollution.•To providetechnicalassistanceandguidancetotheState Pollution Control Board.

• To carryout and sponsorinvestigationsand researchrelatedto prevention, controland abatement of air pollution.

• Tocollect, compileandpublishtechnicalandstatisticaldatarelatedtoairpollution; and

• To laydown standards for the quality of air. The main functions of the State Pollution Control Boards are as follows:

• Toplanacomprehensiveprogrammeforprevention,controlandabatementofair pollution and to secure the execution thereof.

• ToadvisetheStateGovernmentonanymatterconcerningprevention,controland abatement of air pollution.

• Tocollectanddisseminate informationrelatedtoair pollution.

• TocollaboratewithCentralPollutionControlBoardinprogrammerelatedtop revention, control and abatement of air pollution; and

• Toinspectairpollutioncontrolareas,assessqualityofairandtotakestepsforprevention, control and abatement of air pollution in such areas.

NationalAmbientAirQualityStandards(NAAQS)

The ambient airqualityobjectives/standards are pre-requisite for developing programme for effective management of ambient air quality and to reduce the damaging effects ofair pollution. The objectives of air quality standards are:

• Toindicatethelevelsofairqualitynecessarywithanadequatemarginofsafetyto

Protectthepublichealth, vegetationand property;

• Toassistinestablishingprioritiesforabatement andcontrolofpollutant level;
• Toprovideuniformyardstickforassessingairqualityatnationallevel; and
• Toindicatetheneed andextentofmonitoring programme

Measurementofdustfallandmetallic compoundsindustfall

Twofundamentallydifferentmethodsareusedtocollectdustfall:

· samplingincollecting vessels

· samplingonadhesive surfaces.

A popular procedure for measuring dustfall (deposited dust) is the so-called Bergerhoff procedure. In this procedure the entire atmospheric precipitation (dry and wet depositions) is collected over 30± 2 days in vessels about 1.5 to 2.0 metres above the ground (bulk deposition). Then the collecting vessels are taken to the lab and prepared (filtered, water evaporated, dried, weighed). The result is calculated on the basis of the surface area of the collecting vessel and exposure time in grams per square meter andday (g/m^2d). The relative detection limit is 0.035 g/m^2d.

Additional procedures for collecting dustfall include the Liesegang-Löbner device and methods which collect the deposited dust on adhesive foils.

All measurement results for dustfall are relative values that depend on the apparatus used, as the dust separation is influenced by the flow conditions at the device and other parameters. The differences in the measurement values obtained with the different procedures can reach 50 per cent.

Also important is the composition of the deposited dust, such as the content of lead, cadmium and other metallic compounds. The analytical procedures used for this are basically the same as those used for suspendeddust.

Measuringspecialmaterialsindustform

Special materials in dust form include asbestos and soot. Collecting fibres as air pollutants is important since asbestos has been classified as a confirmed carcinogenic material. Fibres with a diameter of $D \leq 3mm$ and a length of $L \geq 5mm$, where $L:D \geq 3$, are considered carcinogenic. Measurement procedures for fibrous materials consist of counting, under the microscope, fibres that have been separated on filters. Only electron microscopic procedures can be considered for outside air measurements. The fibres are separated on gold-coated porous filters. Prior to assessment in an electron scan microscope, the sample is freed of organic substances through plasma incineration right on the filter. The fibres are counted on part of the filter surface, randomly chosen and classified by geometry and type of fibre. With the help of energydispersive x-ray analysis (EDXA), asbestos fibres, calcium sulphate fibres and other inorganic fibres can be differentiated on the basis of elemental composition. The entire procedure is extremely expensive and requires the greatest care to achieve reliable results.

Soot in the form of particles emitted by diesel motors has become relevant since diesel soot was also classified as carcinogenic. Because of its changing and complex compositionand because of the factthat variousconstituentsare also emitted fromother sources,there isnomeasurement procedurespecificto dieselsoot.Nevertheless, inorder to saysomething concrete about the concentrations inambient air, soot isconventionally defined as elemental carbon, as a part of total carbon. It is measured after sampling and anextractionstep and/orthermaldesorption. Determinationofthe carboncontent ensues through burning in an oxygen stream and coulometric titration or non-dispersive IR detection of the carbon dioxide formed in theprocess.

The so-called aethalometer and the photoelectric aerosol sensor are also used for measuring soot, in principle.

MeasuringWet Depositions

Together with dry deposition, wet deposition in rain, snow, fog and dew constitute the mostimportant means by which harmful materials enter the ground, water or plant surfaces from the air.

In order to clearly distinguish the wet deposition in rain and snow (fog and dew present specialproblems)fromthemeasurementoftotaldeposition(bulkdeposition,seesection —Measurement of dustfall and metallic compounds‖ above) and dry deposition, rain catchers, whose collection opening is covered when there is no rain (wet-only sampler), are used for sampling. With rain sensors, which mostly work on the principle of conductivity changes, the cover is opened when it starts to rain and closed again when the rain stops.

The samples are transferred througha funnel(openarea approx. 500 cm^2 and more) into a darkened and if possible insulated collection container (of glass or polyethylene for inorganic components only).

In general, analysing the collected water for inorganic components can be done without sample preparation. The water should be centrifuged or filtered if it is visibly cloudy. Theconductivity, pH value and imp4ortant anions (NO_3^- , SO^{2-} , Cl^-) and cations (Ca^{2+}, K^+, Mg^{2+}, Na^+,$NH^+$and
so on) are routinely measured. Unstable trace compounds and intermediate states like H_2O_2or HSO_3– are also measured for research purposes.

For analysis, procedures are used that are generallyavailable for aqueoussolutions such as conductometry for conductivity, electrodes for pH values, atom adsorption spectroscopyfor cations(seesection—Measuringspecialmaterialsindust form‖,above) and, increasingly, ion exchange chromatography with conductivity detection for anions.

Organic compounds are extracted from rain water with, for example, dichloromethane,or blownout with argon and adsorbed with Tenax tubes (only highly volatile materials). The materials are then subjected to a gas chromatographic analysis (see —Measurement procedures for organic air pollutants‖, below).

Dry deposition correlates directly with ambient air concentrations. The concentration differences of airborne harmful materials in rain, however, are relatively small, so that for measuring wet deposition, wide-mesh measuring networks are adequate. Examples include the European EMEP measurement network, in which the entry of sulphate and

nitrate ions, certain cations and precipitation pH values are collected in approximately90 stations. There are also extensive measurement networks in North America.

UNIT II

UNIT – II Meteorology and Air Pollution: Factors Influencing Air Pollution, Wind Rose, Mixing Depths, Lapse Rates and Dispersion - Atmospheric Stability, Plume Rise and Dispersion, Prediction of Air Quality, Box Model - Gaussian Model - Dispersion Coefficient - Application of Tall Chimney for Pollutant Dispersion.

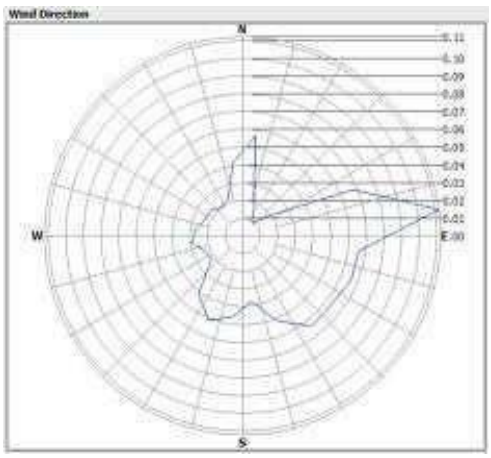
AirPollutionandMeteorology

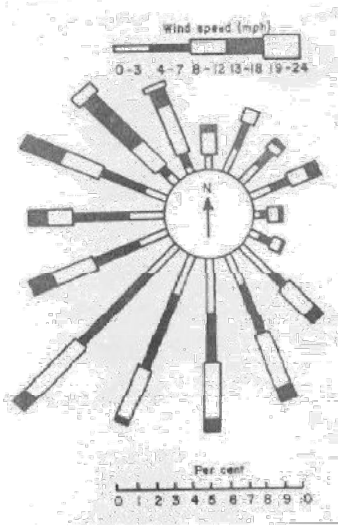
Thescienceofmeteorologyhasgreat bearingonair pollution. Anair pollution probleminvolves three parts: the source, the movement of the pollutant and the recipient. All meteorological phenomena are a result of interaction of the elemental properties of the atmosphere, heat, pressure, wind and moisture.

Wind

Wind is simply air in motion. On global or macroscale wind patterns are set up due to unequal heating of earth surface by solar radiation at the equator and the polar regions, rotation of the earth and the difference between conductive capacities of land and ocean masses. Secondary or mesoscale circulation patterns develop because of the regional or local topography. Mountain ranges, cloud cover, waterbodies, deserts, forestation, etc., influence wind patternsonscales ofa few hundred kilometers. Accordingly, a pattern of wind is setup, some seasonal and some permanent. Microscale phenomenon occurs over areas of less than 10 km extent. Standard wind patterns may deviate markedly due to varying frictional effects of the earth surface, such as,ruralopen land, irregular topographyand urban development, effect of radiant heat fromdeserts and cities, effect of lakes, etc. The movement ofair at the mesoscale and microscale levels is of concern in control of air pollution. A study of air movement over relatively small geographical regions can help in understanding the movement of pollutants.

It is obviously important in predicting pollutant dispersion to know the direction of wind. The wind direction and speed data may be collected every hour in a month and classified accordingto speed and direction. It is then summarized in the form of a polar diagram called *wind rose*. Figure shows a hypothetical wind rose. The position of the spokes show the direction fromwhich the wind was blowing, the length of various segments of the spokes show the percent of time the wind wasofthe designated speed. Thus fromthe diagram, most often(12% oftime) the wind was from SE; the strongest wind (9-11 m/s) was from NW andNNW.



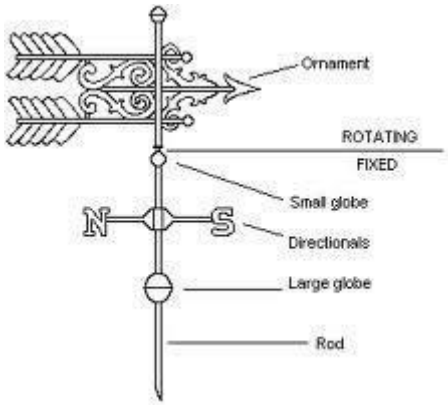


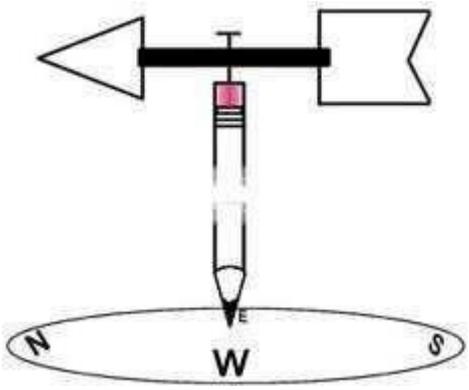
Importanceofwindroseinairpollution studies

A wind rose is a graphic tool used by meteorologists to give a succinct view of how wind speed and direction are typically distributed at a particular location. It assists in cityplanning and siting of industries.

An anemometer is a device for measuring wind speed, and is a common weather station instrument.Anemometerscanbedividedintotwoclasses:thosethatmeasurethewind'sspeed,

and those that measure the wind's pressure; but as there is a close connection between the pressure and the speed, an anemometer designed for one will give information about both. A simple type of anemometer, consists of four hemispherical cups each mounted on one end offour horizontal arms, which in turn were mounted at equal angles to each other on a verticalshaft. The air flow past the cups in any horizontaldirectionturned the cups in a manner that was proportional to the wind speed. Therefore, counting the turns of the cups over a set time period producedtheaveragewindspeed forawiderange ofspeeds. Onananemometerwithfourcups it is easy to see that since the cupsare arranged symmetrically on the end of the arms, the wind always has the hollow of one cup presented to it and is blowing on the back of the cup on the opposite end of the cross.





A weather vane (or weathercock) is an instrument for showing the direction of the wind . They aretypicallyusedasanarchitecturalornament tothe highest point of abuilding. Althoughpartly functional, weather vanes are generally decorative, often featuring the traditionalcockereldesign with letters indicating the points of the compass. Other common motifs include ships, arrows, and horses.

The design of a wind vane is such that the weight is evenly distributed on each side of the surface, but the surface area is unequallydivided, so that the pointer can move freelyon its axis. The side with the larger surface area is blown away fromthe wind direction, so that the smaller side, with the pointer, is pivoted to face the wind direction. Most wind vanes have directional markers beneath the arrow, aligned with the geographic directions.

Wind vanes, especially those with fanciful shapes, do not always show the real direction of a very gentle wind. This is because the figures do not achieve the necessary design balance: an unequal surface area but balanced in weight. To obtain an accurate reading, the wind vane must be located well above the ground and away from buildings, trees, and other objects which interfere with the true wind direction. Changing wind direction can be meaningful when coordinated with other apparent sky conditions, enabling the user to make simple short range forecasts. From the street level the size of many weathercocks is deceptive.

The meanwindspeed variationwithaltitude istheplanetaryboundarylayercanberepresented by a simple empirical power.

$$\frac{U}{U1} = \left[\frac{Z}{Z1}\right]\alpha \text{ ---------(2.11)}$$

Where: U is the wind at altitude Z

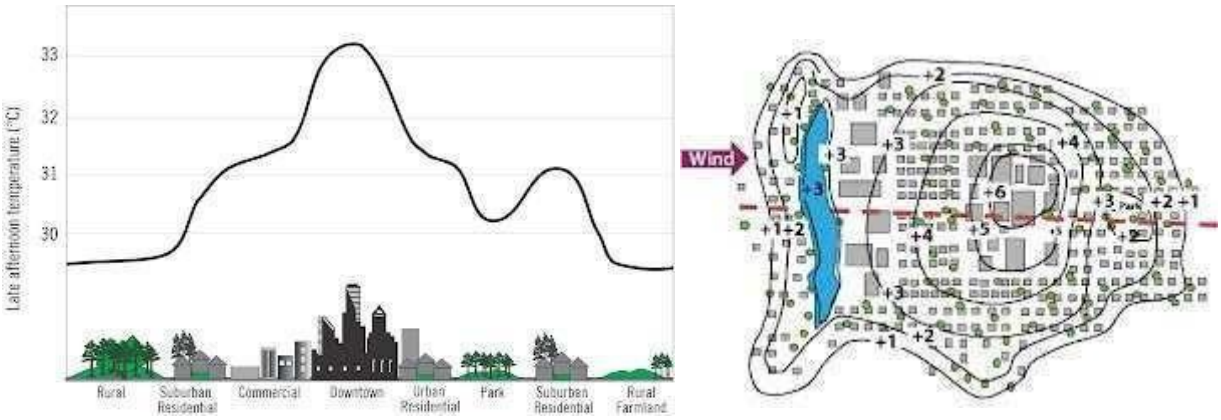
U_1 is the wind speed at altitude Z_1

α The exponent varies between 0.14 and 0.5 depending on the roughness of the ground surface as well as on the temperature stability of the atm.

α = 0.25 for unstable atmosphere

= 0.5 for stable condition

UrbanHeatIslands



Urbanization negatively impacts the environment mainly by the production of pollution, the modification of the physical and chemical properties of the atmosphere, and the covering of the soil surface. Considered to be a cumulative effect ofallthese impacts is the UHI, defined as the rise in temperature of any man-made area, resulting in a well-defined, distinct "warm island" among the "cool sea" represented by the lower temperature of the area's nearby natural landscape.

Though heat islands may form on any rural or urban area, and at any spatial scale, cities are favoured, since their surfaces are prone to release large quantities of heat. Nonetheless, the UHI negatively impacts not only residents of urban-related environs, but also humans and their associated ecosystems located far awayfromcities. In fact, UHIs have been indirectlyrelated to climate change due to their contribution to the greenhouse effect, and therefore, to global warming.

It is well-known that the progressive replacement of natural surfaces by built surfaces, through urbanization, constitutes the main cause of UHI formation. Natural surfaces are often composed of vegetation and moisture-trapping soils. Therefore, they utilize a relatively large proportion of the absorbed radiation in the evapotranspiration process and release water vapour thatcontributes to cool the air in their vicinity. In contrast, built surfaces are composed of a high percentage of non-reflective and water-resistant construction materials. As consequence, they tend to absorb a significant proportion of the incident radiation, which is released asheat.

Vegetation intercepts radiation and produces shade that also contributes to reduce urban heat release. The decrease and fragmentation of large vegetated areas such as parks, not only reduces these benefits, but also inhibits atmospheric cooling due to horizontal air circulation generatedby the temperature gradient between vegetated and urbanized areas (i.e. advection), which is known as the park cool island effect. On the other hand, the narrow arrangement of buildings along the city's streets formurban canyons that inhibit the escape ofthe reflected radiation from most of the three-dimensional urban surface to space. This radiation is ultimately absorbed bythe building walls (i.e. reduced sky view factor), thus enhancing the urban heat release. Additional factors such as the scattered and emitted radiation fromatmospheric pollutants to the urban area, the production ofwaste heat fromair conditioning and refrigeration systems, as well from industrial processes and motorized vehicular traffic (i.e. anthropogenic heat), and the obstruction of rural air flows by the windward face of the built-up surfaces, have beenrecognized as additional causes of the UHIeffect

As it would be expected, the characteristic inclination towards warming of urban surfaces is exacerbated during hot days and heat waves, which reinforces the air temperature increase, particularly in ill-ventilated outdoor spaces or inner spaces of residential and commercial buildings withpoor thermal isolation. This increases the overallenergyconsumption for cooling (i.e. refrigerationand air-conditioning), hence increasing the energyproduction bypower plants, which leads to higher emissions of heat-trapping greenhouse gases such as carbon dioxide, as well as other pollutants such as sulfur dioxide, carbon monoxide and particulate matter. Furthermore, the increased energydemand means more costs to citizens and goverments, which in large metropolitan areas may induce significant economic impacts. On the other hand, UHIs promote highair temperaturesthat contribute to formationofozone precursors, whichcombined photochemically produce ground level ozone.

A direct relationship has been found between UHI intensity peaks and heat-related illness and fatalities, due to the incidence of thermal discomfort on the human cardiovascular andrespiratorysystems. Heatstroke, heat exhaustion, heat syncope,and heat cramps, are some ofthe main stress events, while a wide number of diseases may become worse, particularly in the elderlyand children. In a similar way, respiratoryand lung diseases have shown to be related to high ozone levels induced by heat events. Other meteorological impacts of the UHI are associated with reductions in snowfall frecuencies and intensities, as well as reductions in the diurnal and seasonal range of freezing temperatures. Lastly, high temperatures may produce physiological and phenological disturbances on ornamental plants and urbanforests.

There are two main UHI reduction strategies: first, to increase surface reflectivity (i.e. high albedo), in order to reduce radiation absorption of urban surfaces, and second, to increase vegetation cover, mainly in the form of urban forests and parks, in order to maximize the multiple vegetation benefits in controlling the temperature rises. Reflective surfaces simply results from light colored or white paint on the surface of a given construction material or from cover the construction material surface with a white membrane. Both techniques have been mainly applied on roofs and pavements. Cool roofs are specially important in commercial and residential buildings, where significant energy demand for cooling can be saved by reducingheat gain to the building. Cool pavements have mainly based on the use of whitened asphalt roads, a very warm material.

UrbanDustDomes

Urban dust domes are a meteorological phenomenon in which soot, dust, and chemicalemissions become trapped in the air above urban spaces. This trapping is a product of local air circulations. Calm surface winds are drawn to urban centers, they then rise above the city and descend slowly on the periphery of the developed core. This cycleis of ten a cause of smog through photochemical reactions that occur when strong concentrations ofthe pollutants in this cycle are exposed to solar radiation. These are one result of urban heat islands: pollutants concentrate in a dust dome because convection lifts pollutants into the air, where they remain because of somewhat stable air masses produced by the urban heat island.

AtmosphericStability

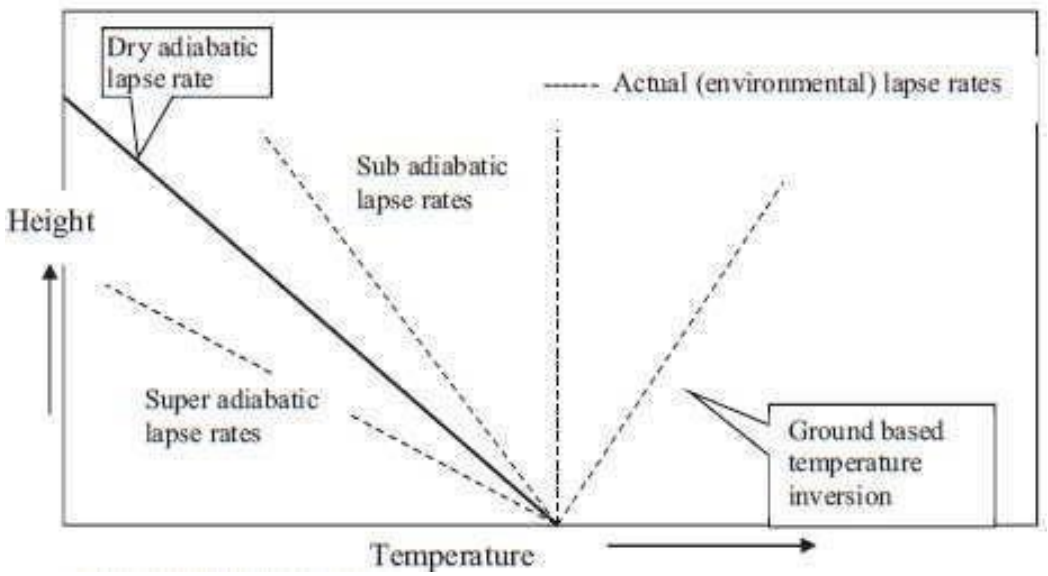
Theabilityoftheatmospheretodispersethepollutantsemittedintoit dependstoalargeextent onthedegreeofstability. Acomparisonoftheadiabatic lapseratewiththeenvironmentallapse rategives an idea ofstabilityofthe atmosphere. Whenthe environmentallapse rate and the dry adiabatic lapse rate are exactlythe same, a raising parcelofair willhave the same pressure and temperature and the densityof the surroundings and would experience no buoyant force. Such atmosphere issaid to be neutrallystable where a displaced massofair neither tendsto returnto its original position nor tends to continue its displacement

Lapserate

As a parcel of air rises in the earth's atmosphere it experiences lower and lower pressure fromthe surrounding air molecules, and thus it expands. This expansion lowers its temperature. Ideally, if it does not absorb heat from its surroundings and it does not contain any moisture, it cools at a rate of 1ºC/100 m rise. This is known as *dry adiabatic lapserate.*

Iftheparcelmovesdownit warmsup at thesame rate. For aparticular placeat aparticular time, the existing temperature can be determined by sending up a balloon equipped with a thermometer. The balloon moves through the air, and not with it. The temperature profile of the air, which the balloon measures, is called the *ambient lapse rate, environmental lapse rate,* orthe *prevailing lapserate.*

A super-adiabatic lapse rate also called a strong lapse rate occurs when the atmosphere temperature drops more than 1ºC/100m. A sub-adiabatic rate also called weak lapse rate, is characterized bydrop of less than 1ºC/100 m. A special case ofweaklapse rate is the inversion, a condition which has warmer layer above colderair.



During super-adiabatic lapse rate the atmospheric conditions are unstable. If a parcel of air at 500m elevation, at 20ºC is pushed upward to 1000m, its temperature will come down to 15ºC (according to adiabatic lapse rate). The prevailing temperature is however 10ºC at 1000m. The parcel of air will be surrounded by colder air and therefore will keep moving up.

Similarly if the parcel is displaced downwards, it will become colder than its surroundings and therefore will move down. Super-adiabatic conditions are thus unstable, characterized by a great deal of vertical air movement and turbulence. The sub-adiabatic condition shown in is by contrast a very stable system. Consider again a parcel of air at 500 m elevation at 20ºC. If the parcel is displaced to 1000 m it will cool by 5ºC to 15ºC. But the surrounding air would be warmer. It will therefore fall back to its point of origin. Similarly if a parcel of air at 500 m is pushed down, it will become warmer than its surrounding and therefore will rise back to its original position. Thus such systems are characterized by very limited verticalmixing.

Inversion

An inversion is an extreme sub-adiabatic condition, and thus the vertical air movement withinthe inversion is almost nill. The two most common kind of inversion are *subsidence inversion* and *radiation inversion.* The base of the subsidence inversion lies some distance above earth's surface. This type of inversion is formed due to adiabatic compression and warming of sinking air mass to a lower altitude in the region of a high pressure center. In the case of radiation inversion, the surface layers of the atmosphere during the day receive heat by conduction, convection and radiation from the earth's surface and are warmed. This resultsin a temperature

profile in the lower atmosphere, which is represented by a negative temperature gradient. On a clear night,thegroundsurfaceradiates heat andquicklycools. Theair layer adjacenttotheearth surface are cooled to atemperature below that ofthe layers ofair at higher elevations. This type ofthe inversionisstrongest just beforedaylight whenit mayextendto 500m. Itbreaksupasthe morning sun heats the ground.

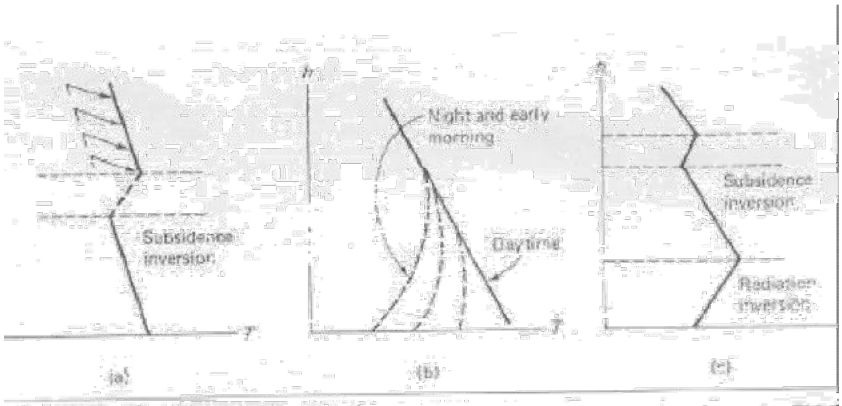


FIGURE 4 ILLUSTRATIONS OF SUBSIDENCE AND RADIATION INVERSIONS.

Maximummixingdepth

The dispersion of pollutants in the lower atmosphere is greatly aided by the convective and turbulent mixing that takes place. The vertical extent to which this mixing takes place depends on the environmental lapse rate which varies diurnally, from season to season and is alsoaffected by topographical features. The depth of the convective mixing layer in which vertical movement of pollutants is possible, is called the maximum mixing depth (MMD). Figure illustrates these MMDs for different lapse rate profiles.

These profiles are usually measured at night or early in the morning. An air parcel at a temperature (maximum surface temperature for the month) warmer than the existing groundlevel temperature rises and cools according to adiabatic lapse rate. The level where its temperature becomes equal to the surrounding air gives the MMD value. Urban air pollution episodes are known to occur when MMD is 1500 m orless.

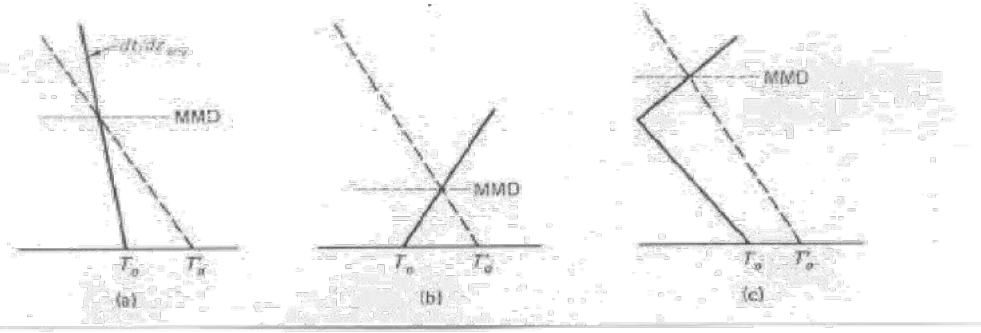
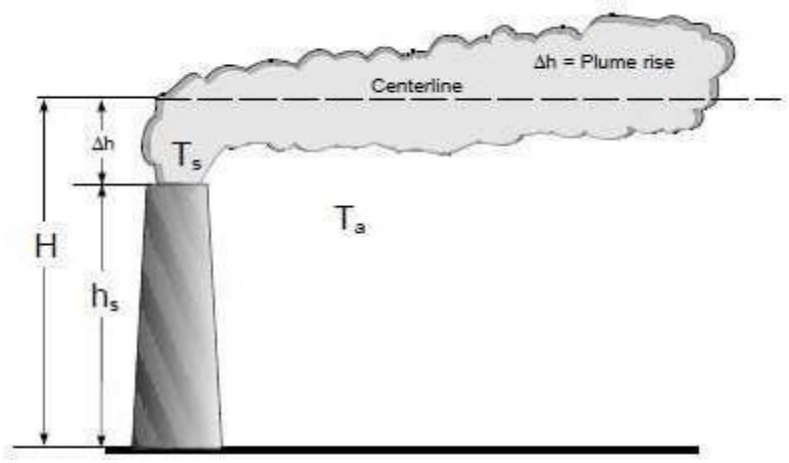


FIGURE 5 MAXIMUM MIXING DEPTH (MMD) UNDER VARIOUS ATMOSPHERIC CONDITIONS, (ADIABATIC PROFILE ------, ENVIRONMENTAL PROFILE————).

PlumeDispersion

Gasesthat areemittedfromstacksareoftenpushedout byfans. Astheturbulent exhaust gasesexit the stacktheymixwithambient air. This mixingofambient air into theplume is called entrainment. As the plume entrains air into it, the plume diameter grows as it travels downwind. These gases have momentum as they enter the atmosphere.

Often these gases are heated and are warmer than the outdoor air. In these cases the emitted gases are less dense than the outside air and are therefore buoyant. A combination of the gases' momentum and buoyancy causes the gases to rise. This is referred to as plume rise and allows air pollutants emitted in this gas streamto be lofted higher in the atmosphere. Since the plume is higher in the atmosphere and at a further distance from the ground, the plume will disperse more before it reaches groundlevel.



The final height ofthe plume, referred to asthe effective stack height (H), is the sumof the physical stack height (hs) and the plume rise (Δh). Plume rise is actually calculated as the distancetothe imaginarycenterline ofthe plume rather thantothe upperor lower edge of the plume (Figure 6-1). Plume rise depends on the stack's physical characteristics and on the effluent's (stack gas) characteristics. The difference in temperature between the stack gas (Ts) and ambient air (Ta) determines the plume density which affects plume rise. Also, the velocity of the stack gases which is a function of the stack diameter and the volumetric flow rate of the exhaust gases determines the plume’s momentum.

TheGaussianplume model

Thepresenttendencyistointerpretdispersiondataintermsoftheplume model. The standard deviations are related to the eddy diffusivities.

Ground level concentration

In this case Z=0

$$[\rho A](x,y,0,H)=\frac{Q}{\pi\bar{\sigma}y\bar{\sigma}Zu}\exp\left(\frac{-1}{2}\left(\frac{y}{\bar{\sigma}y}\right)^2\right).\exp\left[\frac{-1}{2}\left(\frac{H}{\bar{\sigma}Z}\right)\right]$$

Plume dispersion coordinate sysem, showing Gaussian distributions in the horizontal and vertical directions (Turner, 1970)

Dispersioncharacteristicsofstackplumes

Dispersion is the process of spreading out pollution emission over a large area and thus reducing their concentration. Wind speed and environmental lapse rates directly influence the dispersion pattern.

Coning

A *coning* plume, shown in, occurs under essentially neutral stability, when environmental lapse rate is equal to adiabatic lapse rate, and moderate to strong winds occur. The plume enlarges in the shape of a cone. A major part of pollution may be carried fairly far downwind before reaching ground.

Looping

Under super-adiabatic condition, both upward and downward movement ofthe plume is possible. Large eddies of a strong wind cause a *looping* pattern. Although the large eddies tend to disperse pollutants over a wide region, high ground level concentrations may occur close to the stack.

Fanning

A*fanning* plume occurs inthe presence ofa negative lapse rate when verticaldispersion is restricted. The pollutants disperse at the stack height, horizontally in the from of a fanning plume.

Fumigation

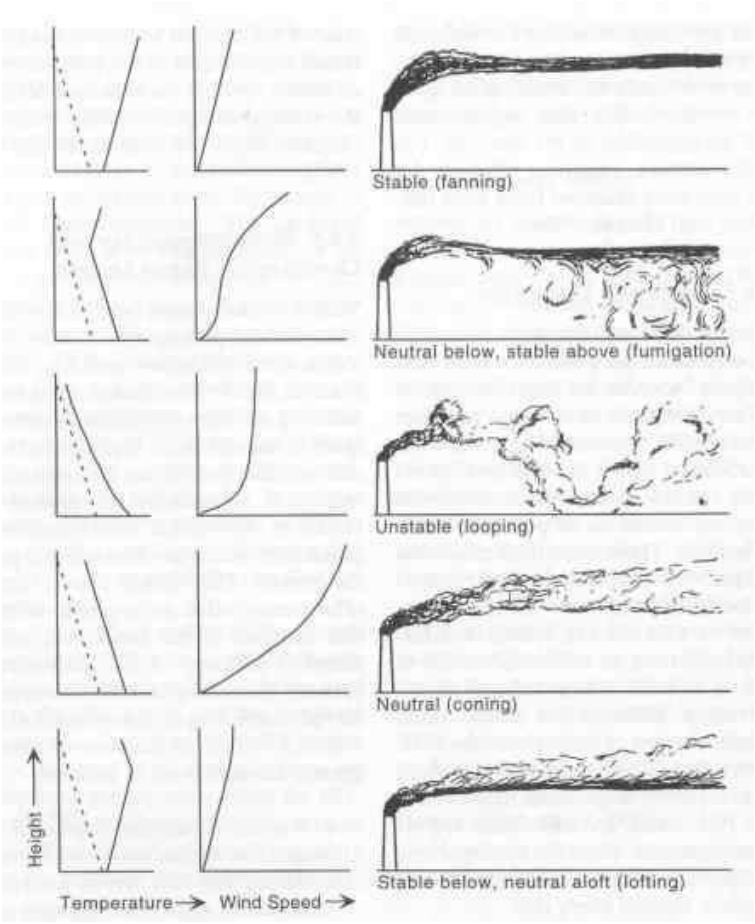
When the emission from the stack is under an inversion layer, the movement of the pollutants in the upward direction is restricted. The pollutants move downwards. The resulting *fumigation* can lead to a high ground level concentration downwind of the stack.

Lofting

When the stack is sufficiently high and the emission is above an inversion layer, mixing in the upward direction is uninhibited, but downward motion is restricted. Such *lofting* plumes do not result in any significant concentration at ground level. However, the pollutants are carried hundreds of kilometers from the source.

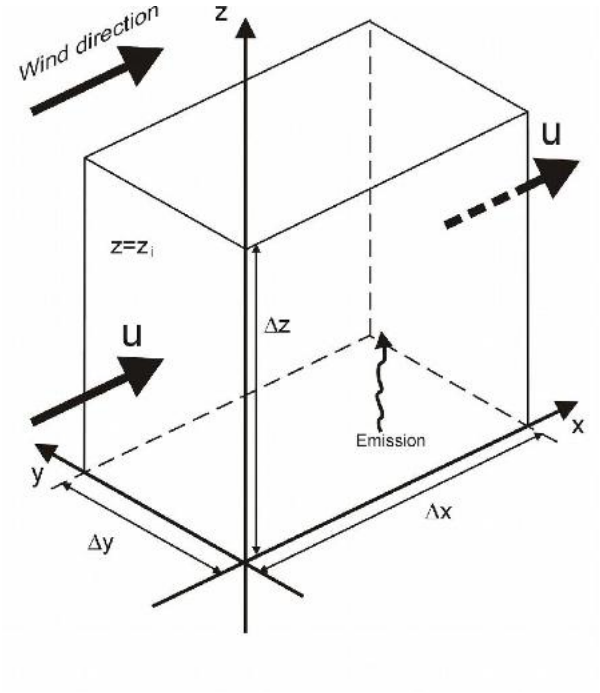
Trapping

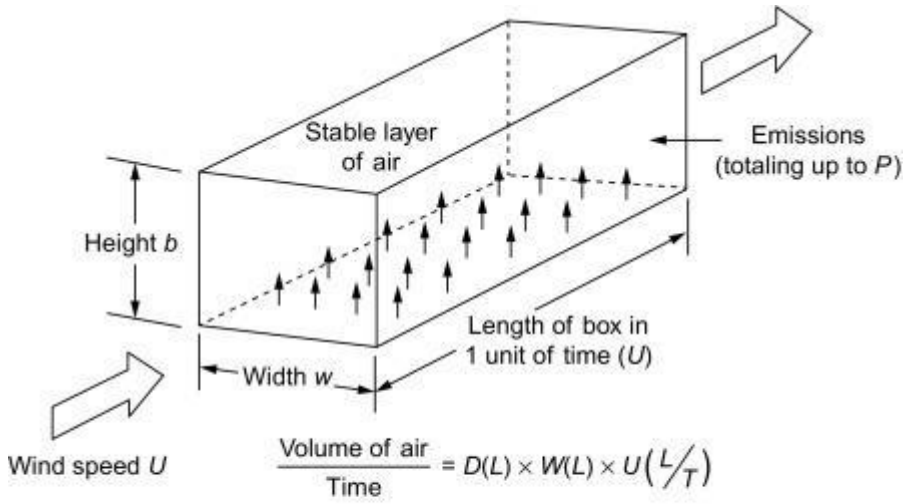
It occurs when the plume effluent is caught between two inversion layers. The diffusion of the effluent is severely restricted to the unstable layer between the two unstablelayers.



Box model, Gaussian model and dispersion coefficients of air pollution dispersion

Box model — The box model is the simplest of the model types. It assumes the airshed (i.e., a given volume of atmospheric air in a geographical region) is in the shape of a box. It also assumes that the air pollutants inside the box are homogeneously distributed and uses that assumption to estimate the average pollutant concentrations anywhere within the airshed. Although useful, this model is very limited in its ability to accurately predict dispersion of air pollutants over an airshed because the assumption of homogeneous pollutant distribution is much too simple.





The box dispersion model is a simplified approach in air pollution modeling that treats a geographical area as a rectangular box. It assumes that pollutants are uniformly mixed within this box, allowing for estimation of average pollutant concentrations. This method is computationally efficient and requires minimal input data, making it suitable for initial assessments of air quality impact.

Key Assumptions:

Box Shape:

The airshed (the area under consideration) is idealized as a rectangular box.

Homogeneous Mixing:

Pollutants are assumed to be evenly distributed throughout the box, meaning the concentration is uniform at any point within the box.

Steady State:

The model often assumes steady-state conditions, where emissions, wind speed, and other relevant parameters remain constant over time.

Complete and Instantaneous Mixing:

Pollutants are assumed to mix completely and instantaneously with the available air volume.

How it works:

1. Define the box:The model requires defining the dimensions of the box (length, width, and height).

2. Emission rate:The rate at which pollutants are emitted into the box is needed.

3. Wind speed and direction:The wind speed and direction are crucial for determining how

pollutants are transported within the box.

4. Background concentration:The concentration of pollutants already present in the area (background concentration) is also a factor.

Advantages:

Simplicity: The model is easy to understand and implement.

Computational efficiency: It requires minimal computational power and can be run quickly.

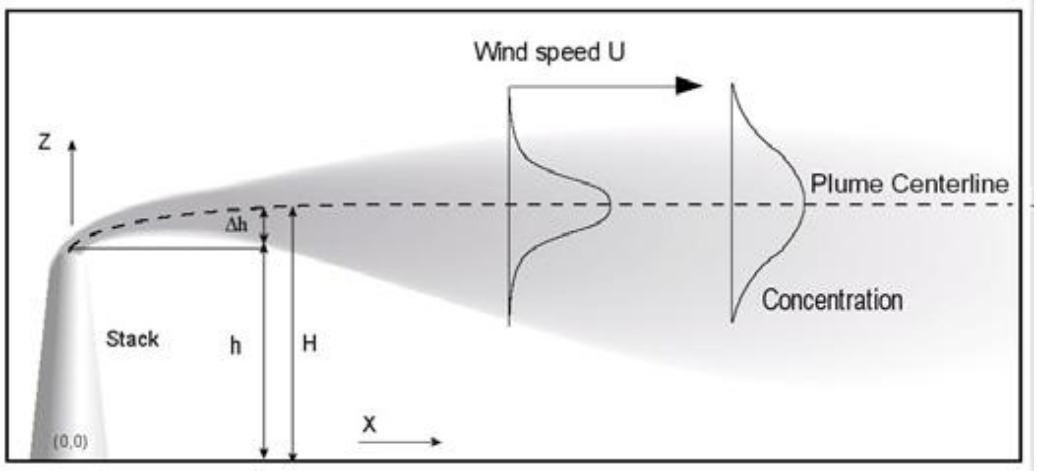
Fast simulation runtimes: Due to its simplicity, it can be used for rapid simulations.

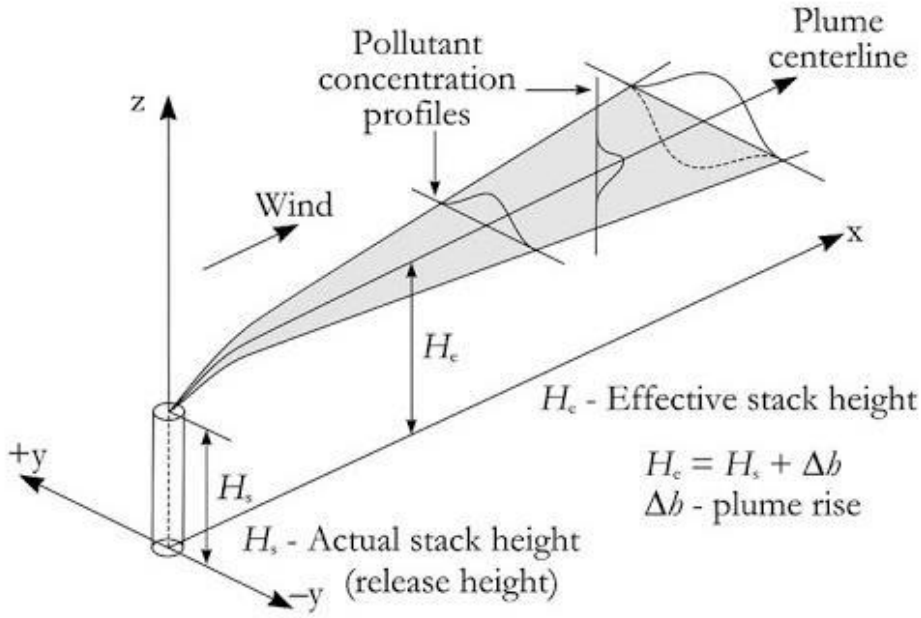
Low input data requirements: It requires relatively little input data compared to more complex models.

Limitations:

- Oversimplification: The assumption of homogeneous mixing is often unrealistic, especially for larger areas or complex terrain.
- Limited accuracy: The model's accuracy is limited due to its simplifying assumptions.
- Not suitable for all situations: It may not be appropriate for situations requiring detailed spatial or temporal resolution.

Gaussian model — The Gaussian model is perhaps the oldest and perhaps the most commonly used model type. It assumes that the air pollutant dispersion has a Gaussian distribution (distribution of concentration in both the horizontal and vertical directions), meaning that the pollutant distribution has a normal probability distribution. This model simplifies plume behavior by representing it as a bell-shaped curve, with the highest concentration at the center and decreasing outwards.





Key Concepts:

- Gaussian Distribution:

  The model relies on the Gaussian or normal distribution to describe how pollutant concentrations vary spatially.

- Plume Shape:

  The model visualizes the pollutant as a plume, with the concentration highest at the center and decreasing outwards both horizontally (crosswind) and vertically.

- Factors Affecting Dispersion:

  Several factors influence how the plume spreads, including wind speed, atmospheric stability (determined by factors like wind speed and solar radiation), and the source's emission rate.

- Empirical Model:

  The Gaussian model is considered an empirical model, meaning it incorporates relationships and parameters derived from observations and experiments.

  How it Works:

  1. Emission Source:The model starts with a source of pollutant emission (e.g., a smokestack).

  2. Meteorological Conditions**:**It takes into account wind speed, wind direction, and

atmospheric stability to determine how the plume will spread.

3. Dispersion Parameters (σy and σz):The model uses standard deviations (σy for horizontal and σz for vertical dispersion) to quantify the plume's spread at different distances from the source.

4. Concentration Prediction:Based on these factors, the model calculates the concentration of the pollutant at any given point downwind.

Advantages:

- Computational Simplicity:

  Gaussian models are relatively easy to implement and computationally efficient compared to more complex models.
- Wide Applicability:

  They can be used to predict concentrations over a range of distances from the source.
- Handles Boundary Reflections:

  The model can be adapted to account for phenomena like plume reflection off boundaries (e.g., the ground) or plume depletion due to processes like dry deposition.

Limitations:

- Simplifications:

  The Gaussian model makes simplifying assumptions about atmospheric conditions, which may not always accurately represent real-world scenarios.
- Complex Terrain:

  It can be less accurate in complex terrain or near obstacles, where wind flow is more complicated.

Assumptions:

1. A plume has a Gaussian distribution in both horizontal and vertical planes with standard deviations of the concentrations of the plume in horizontal cross wind and vertical directions respectively.
2. The mean speed affecting the plume is actually wind speed at the source level where dispersion starts
3. Uniform and continuous emission of pollutant takes place
4. Diffusion of pollutant in x direction is negligible compared to diffusion in crosswind direction. This is true if emission is continuous and if wind speed is more than 1 m/sec

5. Total reflection of the plume takes place at the earths surface. Also pollutants are inert and passive so that there is no gravity fallout and there are no atmospheric chemical reactions
6. Parameters governing the diffusion of the pollutant do not change in space and time, steady-state
7. The terrain underlying the plume is flat

Limitations:

1. It does ot consider the existence of various stability layers at different heights in the atmosphere
2. It does not consider the change in stability characteristics with time
3. It does not consider the terrain characteristics such as terrain roughness, existence of mountains and valleys, distribution of land and water masses
4. It does not consider the existence of free convection regions and strong wind shears like change of wind directions and change of wind speed with height
5. It can be applied only for shorter distances upto 10 km and of shorter travel time

Dispersion coefficients:

Dispersion coefficients σy, σz are defined as parameters which describe the growth of the dimensions of a Gaussian plume as a function of travel distance or travel time and atmospheric stability. They also depend on the source height and the sourface roughness.

UNIT – III Control of Particulate Pollutants: Properties of Particulate Pollution - Particle Size Distribution - Control Mechanism - Dust Removal Equipment - Design and Operation of Settling Chambers, Cyclones, Wet Dust Scrubbers, Fabric Filters &ESP.

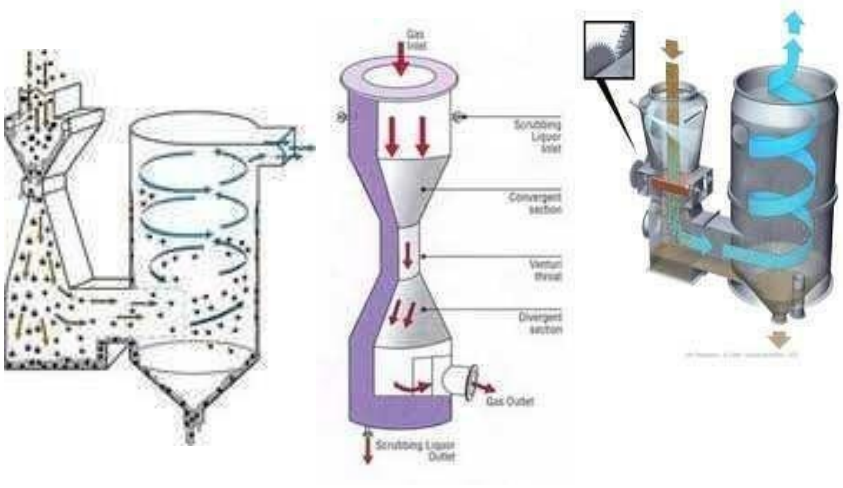
UNIT – III

CONTROLDEVICESFORPARTICULATEEMISSIONS

Particulate matter is any finely divided liquid or solid substance. Examples of particulate matter include smoke, dust, or some forms of fine mist and is entrained in effluent gas streams or suspended in ambient air. Any particulate less than 10 micrometers (μm) in diameter is defined as PM10 and is regulated as a criteria pollutant. The purpose of such regulation is to control smaller, respirable particles that can bypass the body's respiratory filtersand penetratedeeplyinto the lungs, whichcould cause harmto humanhealth. Toxic substances, such as sulfates, sulfites, nitrates, heavy metals, and polycyclic organic matter are predominantly carried by particles in this size range. Therefore, control devices used today, to prevent particles from reaching the ambient air, focus on capturing particulate matter ≤10μm in diameter. Several factors must be considered when selecting an appropriate particulate control device. Typically, particles must be captured from an effluent gas stream; therefore, characteristics of the particles and the gas stream will determine the appropriate control device. Characteristics that must be considered include the particle size and resistivity, exhaust flow rate, temperature, moisture content, and various chemical properties of the exhaust stream such as explosiveness, acidity,alkalinity, and flammability.

VENTURISCRUBBERS

Venturi scrubbers use a liquid stream to remove solid particles. A venturi scrubber accelerates the waste gas streamto atomize the scrubbing liquid and to improve gas-liquid contact. In a venturi scrubber, a "throat" section is built into the duct that forces the gas stream to accelerate as the duct narrows and then expands. As the gas enters the venture throat, both gas velocity and turbulence increase. Depending on the scrubber design, the scrubbing liquid issprayed intothegasstreambeforethegasencounterstheventurithroat, orinthethroat, orupwards against the gas flow inthe throat. The scrubbing liquid is then atomized into smalldropletsbythe turbulence inthe throat and droplet-particle interaction is increased. Some designs use supplemental hydraulically or pneumatically atomized sprays to augment droplet creation. However, the disadvantage of these designs is that clean liquid feed is required to avoid clogging. After the throat section, the mixture decelerates, and further impacts occur causing the droplets to agglomerate. Once the particles are captured by the liquid, the wetted PM and excess liquid droplets are then separated from the gas stream by an entrainment section, which usually consists of a cyclonic separator and/or a mist eliminator. Particle collection efficiencies of venturi scrubbers range from 70 to greater than 99 percent, depending on the application. Typically, venturi scrubbers are applied where it is necessary to obtain high collection efficiencies for fine PM. Thus, they are applicable to controlling emission sources with high concentrations of submicronPM.



AdvantagesofVenturi Scrubbers

• Capableofhandlingflammableandexplosive dusts
• Canhandlemistsinprocesses and exhausts
• Relativelylow maintenance
• Simpleindesignandeasyto install
• Collectionefficiencycan be varied
• Providescoolingforhot gases
• Neutralizescorrosivegasesanddusts

Disadvantagesof Scrubbers

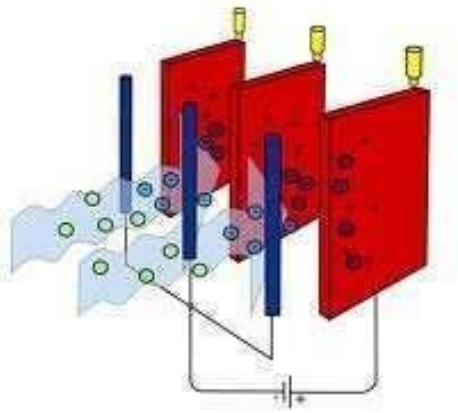
• Effluentliquidcancreatewater pollution problems
• Wasteproductcollectedwet
• Highpotentialforcorrosionproblems
• Requiresprotectionagainstfreezing
• Finalexhaustgasrequires reheatingtoavoidvisibleplume
• CollectedPM maybecontaminated, and notrecyclable
• Disposalofwastesludgemay be veryexpensive

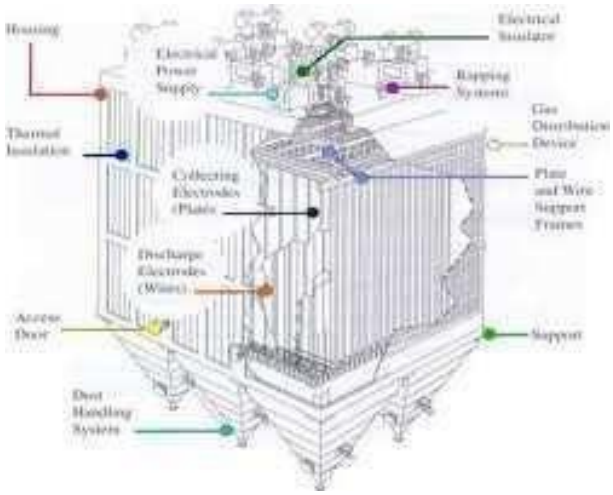
ELECTROSTATICPRECIPITATORS.

An ESP is a PM control device that uses electrical forces to move particles entrained within an exhaust stream onto collection surfaces. The entrained particles are given an electrical charge when they pass through a corona, a region wheregaseous ions flow. Electrodes in the center ofthe flow lane are maintained at high voltage and generate the electrical field that forces the particles to the collector plates. The high voltage electrodes are long wires or rigid "masts" suspended from a frame in the upper part ofthe ESP that run through the axis ofeach tube. Rigid electrodes are generally supported by both an upper and lower frame. The power supplies for the ESPconverttheindustrialACvoltagetopulsatingDCvoltageintherangeof20,000to100,000 volts as needed. The voltage applied to the electrodes causes the gas between the electrodes to break down electrically, an action known as a "corona." The electrodes are usually given a negative polarity because a negative corona supports a higher voltage

than does a positive corona
before sparking occurs. The ions generated in the corona follow electric field lines from the electrodetothecollectingpipe. Therefore, eachelectrode-pipecombinationestablishesacharging zone through which the particles mustpass.

As larger particles (>10µm diameter) absorb many times more ions than small particles (>1µm diameter),theelectrical forcesare muchstronger onthe largeparticles. Whenthecollectionplates are filled to capacity, the particulate is removed from the plates by "rapping," which is a mechanical means to dislodge the particulate. The collected particulate material slides downward into a hopper located below the unit. The collectionefficiencyofanESP isquite reliablyabout 99 percent for particles less than10 micrometers. ESPs, ingeneral, are veryexpensive tooperateand are not very well suited for use in industrial processes because they are too sensitive to fluctuations inthegasstream. TheElectrostaticPrecipitator(ESP) separatesparticles fromthegas stream by electrically charging the particles.





FABRICFILTER

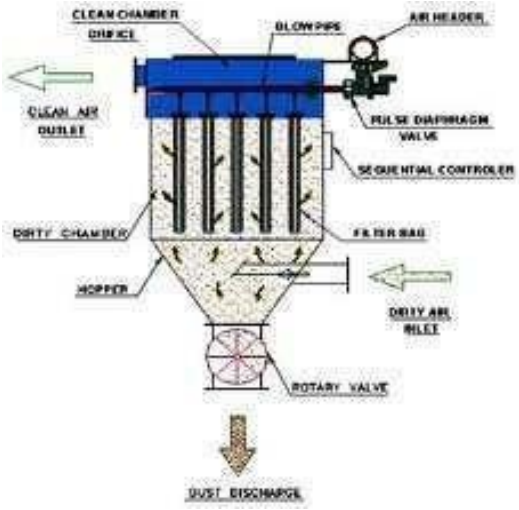
Ina fabric filter, fluegas ispassedthroughatightlywovenor felted fabric, causingPM inthe flue gas to be collected on the fabric by sieving and other mechanisms. Fabric filters may be in the form of sheets, cartridges, or bags, with a number of the individual fabric filter units housed together in a group. Bags are the most common type of fabric filter. The dust cake that forms on the filter from the collected PM can significantly increase collection efficiency. Fabric filters are frequently referred to as baghouses because the fabric is usually configured in cylindrical bags. Bags may be 6 to 9m (20 to 30 ft) long and 12.7 to 30.5 centimeters (cm) (5 to 12 inches) in diameter. Groups of bags are placed in isolable compartments to allow cleaning of the bags or replacement of some of the bags without shutting down the entire fabric filter). Operating conditions are important determinants of the choice of fabric. Some fabrics (i.e., polyolefins, nylons,acrylics,polyesters)areusefulonlyatrelativelylowtemperaturesof95°to150ºC(200°to 300ºF). For hightemperature flue gasstreams, more thermallystable fabricssuchas fiberglass,

Teflon, or Nomex must beused.

Thepracticalapplicationoffabric filtersrequirestheuseofa large fabric area inorderto avoidan unacceptable pressure drop across the fabric. Baghouse size for a particular unit is determined by the choice of air-to-cloth ratio, or the ratio of volumetric airflow tocloth area. The selection ofair-to-cloth ratio depends on the particulate loading and characteristics, and the cleaning method used. A high particulate loading will require the use of a larger baghouse in order to avoidforming too heavy a dust cake.Determinants of baghouse performance include the fabric chosen, the cleaning frequency and methods, and the particulate characteristics. Fabrics can be chosen which will intercept a greaterfraction of particulate. In order to accomplish this, some fabrics are coated with a membrane of very fine openings for enhanced removalof submicronparticulate. However, such fabrics tend to be more expensive. Cleaning intensity and frequency are important variables in determining removal efficiency because the dust cake can affect the fine particulate removal capability of a fabric. Cleaning procedures, which may be too frequent or too intense, will also lowerthe removal efficiency of the fabric filter. On the other hand, if removal is too infrequentortooineffective,thenthebaghousepressuredropwillbecometoohigh.

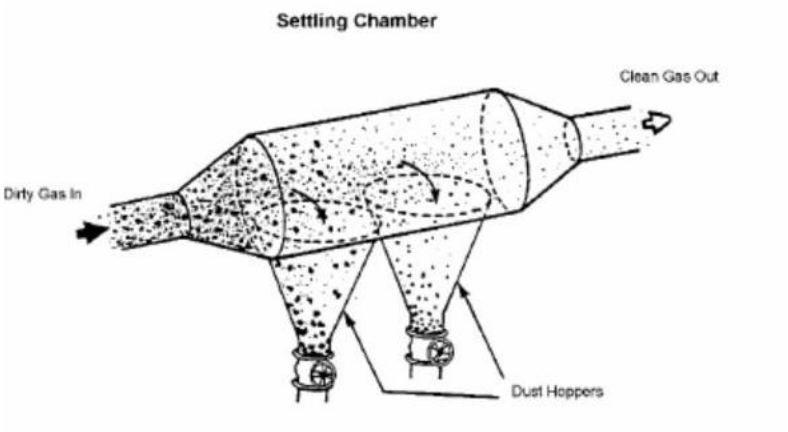
Mechanicalshaking ofthe bags has beena popular cleaning method for many years because of its simplicity as well as its effectiveness. In a typical operation, dusty gas enters an inlet pipe to the shaker. Very large particles are removed from the stream when they strike the baffle plate in the inlet duct and fall into the hopper. The particulate-laden gas is drawn from beneath a cell plate in the floor and into the filter bags. The gas proceeds from the inside of the bags to the outside and through the outlet pipe. The particles are collected on the inside surface of the bags and a filter cake accumulates. In mechanical shaking units, the tops of bags are attached to a shaker bar,which is moved briskly (usually in a horizontal direction) to clean the bags. The shaker bars are operated by mechanical motors or by hand, in applications where cleaning is not required frequently. Reverse-air cleaning is another popular fabric filter cleaning method that has beenused extensivelyand improved overthe years. Itis a gentler but sometimes lesseffective cleaning mechanismthan mechanicalshaking. Most reverse-air fabric filters operateina manner similar to shaker-cleaned fabric filters. Typically, the bags are open on bottom, closed on top, and the gas flows from the inside to the outside of the bags with dust being captured on the inside. However, some reverse-air designs collect dust on the outside ofthe bags. In either design, forcing clean air through the filters in the opposite direction of the dusty gas flow performs reverse-air cleaning. The change indirectionofthe gas flow causes the bag to flexand crack the filter cake. In internal cake collection, the bags are allowed to collapse to some extent during reverse-air cleaning. The bagsare usuallyprevented fromcollapsing entirely bysome kind ofsupport,suchasringsthat are sewn into the bags. The support enables the dust cake to fall off the bags and into the hopper.Cake release is also aided by the reverse flow of the gas because felted fabrics retain dust more than woven fabrics. Therefore, they are more difficult to clean. For this reason, felts are usually not used in reverse-air systems.

Fabric filtersingeneralprovide highcollectionefficienciesonbothcoarseand fine(submicron) particulates. Typical new equipment design efficiencies are between 99% and 99.9%.



SETTLINGCHAMBERS

This type of technology is a part of the group of air pollution controls collectively referred to as "precleaners." They are referred to as precleaners because they are often used to reduce the inlet loading of particulate matter (PM) to downstream collection devices by removing larger, abrasive particles. Settling chambers are also referred to as gravity settling chambers, gravity collectors, expansionchambers, and outfallchambers. This is becausesettlingchambersarequiteeffective in removing only large particles; therefore, they can be frequently used in combination with other control devices. Settling Chambers rely on simple gravitation to remove particles from a gas stream.



Settling chambers, which rely on gravitationalsettling as a collection mechanism are the simplest andoldestmechanicalcollectors.Settlingchambersaregenerallybuiltintheformoflong,horizontal, rectangular chambers with an inlet at one end and an exit at the side or top of the opposite end. Flow within the chamber must be uniform and without any macroscopic mixing. Uniform flow is

can be improved by flow straighteners at the inlet to the chamber. Hoppers are used to collect the settled-out material, though drag scrapers and screw conveyers have also been employed. The dust removal system must be sealed to prevent air from leaking into the chamber which increases turbulence, causes dust reentrainment, and prevents dust from being properly discharged from the device. There are two primary types of settling chambers: the expansion chamber and the multiple-tray chamber. In the expansion chamber, the velocity of the gas stream is significantly reduced as the gas expands in a large chamber. The reduction in velocity allows larger particles to settle out of the gas stream.

A multiple-tray settling chamber is an expansion chamber with a number of thin trays closely spaced within the chamber, which causes the gas to flow horizontally between them. While thegas velocity is increased slightly in a multiple-tray chamber, when compared to a simple expansion chamber, the collection efficiency generally improves because the particles have a much shorter distance to fall before theyare collected. Multiple-traysettling chambers have lower volume requirements than expansion-type settling chambers for the collection of small particles (<15µm). Settling chambers are most effective when collecting large or dense particles, but often fail when the chamber becomes plugged with collecteddust.

The most common failure ofsettling chambers is when chambers become plugged with collected dust. In expansion settling chambers the plugging can result from hopper bridging or hopper discharge seal failure. Multiple-traysettling chambers may experience plugging ofthe individual gaspassages. Such failurescan be preventedorminimized byuse ofhopper levelindicatorsorby continuous monitoringofthedust discharge. Scheduled internalinspectioncandetermineareasof air leakage and condensation, bothofwhich may cause hopper bridging. Normal instrumentation for a settling chamber generally includes only an indicator of differential static pressure. An increase in static pressure drop can indicate plugging

AdvantagesofSettlingChambers

- Lowcapital cost
- Verylow energy cost
- Nomoving parts
- Fewmaintenance requirements
- Lowoperating costs
- Excellent reliability
- Lowpressure dropthrough the device
- Devicenotsubjecttoabrasionduetolowgas velocity
- Provideincidentalcoolingofthe gas stream
- Drycollectionand disposal

DisadvantagesofSettling Chambers

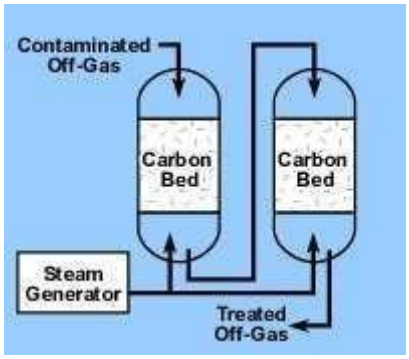
- RelativelylowPMcollection efficiencies
- Unableto handlestickyortacky materials
- Largephysical size
- Traysina multiple-traysettlingchambermay war

UNIT – IV
Controlofgaseouspollutantsfromstationary sources-Adsorption

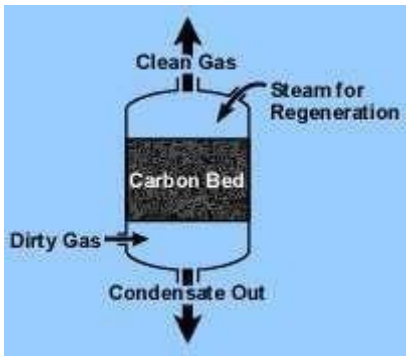
When a gas or vapor is brought into contact with a solid, part of it is taken up by the solid. The molecules that disappear fromthe gas either enter the inside ofthe solid, or remain on the outside attached to the surface. The former phenomenon is termed absorption (or dissolution) and the latter adsorption. Adsorption is the binding of molecules or particles to a surface. In this phenomenon molecules from a gas or liquid will be attached in a physical way to a surface. The binding to the surface is usuallyweak and reversible. The most common industrial adsorbents are activated carbon, silica gel, and alumina, because they have enormous surface areas per unit weight.

Activated carbon is the universal standard for purification and removal of trace organic contaminants from liquid and vapor streams. Carbon adsorption uses activated carbon to control and/or recover gaseous pollutant emissions. Incarbon adsorption, the gas is attracted and adheres totheporoussurfaceoftheactivatedcarbon. Removalefficienciesof95percent to 99percent can be achieved by using this process. Carbon adsorption is used in cases where the recovered organics are valuable. For example, carbon adsorption is often used to recover perchloroethylene, a compound used in the dry cleaning process.

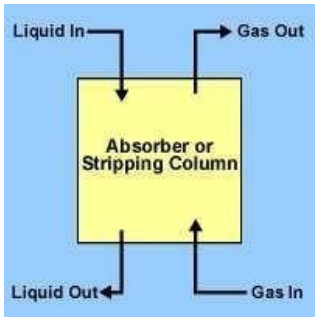
Carbon adsorption systems are either regenerative or non-regenerative. A regenerative system usually contains more than one carbon bed. As one bed actively removes pollutants, anotherbedis being regenerated for future use. Steam is used to purge captured pollutants from the bed to a pollutant recovery device. By "regenerating" the carbon bed, the same activated carbon particles can be used again and again. Regenerative systems are used when concentration of the pollutantin the gas stream is relatively high. Non-regenerative systems have thinner beds of activated carbon. Ina non-regenerative adsorber, the spent carbon is disposed ofwhen it becomes saturated with the pollutant. Because of the solid waste problem generated by this type of system, non-regenerative carbon adsorbers are usually used when the pollutant concentration is extremelylow.



RegenerativeCarbon Adsorption System



Non-RegenerativeCarbon Adsorption System



Typicalpackedcolumndiagram

Controlofgaseouspollutantsfromstationary sources– Absorption

The removal of one or more selected components from a gas mixture by absorption is probablythe most important operation in the control of gaseous pollutant emissions. Absorption is aprocess in which a gaseous pollutant is dissolved in a liquid. Water is the most commonly used absorbent liquid. As the gas stream passes through the liquid, the liquid absorbs the gas, in much the same way that sugar is absorbed in a glass of water when stirred. Absorption is commonlyused to recover products or to purify gas streams that have high concentrations of organic compounds. Absorption equipment is designed to get as much mixing between the gas and liquid as possible. Absorbers are often referred to as scrubbers, and there are various types ofabsorption equipment. The principal types of gas absorption equipment include spray towers, packed columns, spray chambers, and venture scrubbers. The packed column is by far the mostcommonly used for the absorption of gaseous pollutants. The packed column absorber has a column filled with an inert (non-reactive) substance, such as plastic or ceramic, which increases the liquid surface area for the liquid/gas interface. The inert material helps to maximize the absorption capabilityof the column.

In addition, the introduction ofthe gas and liquid at opposite ends of the column causes mixing to be more efficient because of the counter-current flowthrough the column. In general, absorbers can achieve removal efficiencies greater than 95 percent. One potential problem with absorption is the generation of waste-water, which converts an air pollution problem to a water pollutionproblem.

UNIT – V Automobile and Indoor Pollution: Vehicular Pollution – Sources and Types of Emission – Effect of Operating Conditions Alternate Fuels and Emissions-Emission Controls and Standards, Strategies to Control Automobile Pollution– Causes of Indoor Air Pollution-Changes in Indoor Air Quality Control and Air Cleaning Systems-Indoor Air Quality

UNIT – V

POLLUTION:

Themixingofunwantedandundesirablesubstancesintooursurroundingsthatcause undesirable effects onboth living and non-living things is knownas pollution.

AIRPOLLUTION:

Airpollutionisdefinedastheadditionofunwantedandundesirablethingstoour atmosphere that have harmful effect uponour planned life.

MAJORSOURCESOFAIRPOLLUTION:

1. Automotive Engines
2. Electricalpowergeneratingstations
3. Industrialanddomesticfuelconsumption
4. Refuseburningofindustrialprocessing,wastes etc.,

SOURCESOFPOLLUTANTSFROMGASOLINEENGINE:

Thereare fourpossiblesourcesof atmosphericpollutionfrom apetrolenginepowered vehicle. They are

1. FuelTank
2. Carburetor
3. Crankcase
4. Engine

Thenumberofpollutantscontributedbytheabove-mentionedsourcesareasfollows.

a. Fueltankevaporativeloss	5 to 10 %ofHC
b. Carburetorevaporativeloss	5 %ofHC
c. Crankcaseblowby	20 to 35 %ofHC
d. TailPipeexhaust	50to 60 % ofHCand almost all Co and NOx

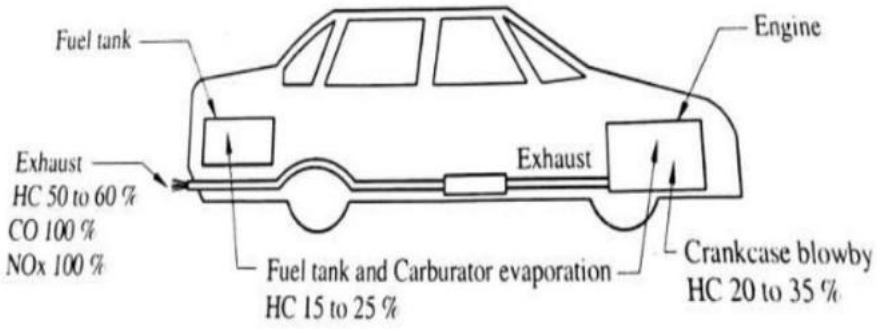


Fig.1Pollutant in Automobile

EmittanceasaPollutant:

An Emittance is said to be a pollutant when it has some harmful effect upon our surroundings.

The primary source of energy for our automotive vehicles is crude oil from underground which typically contains varying amounts of Sulphur. Much of the Sulphur is removed during refining of automotive fuels. Thus thefinal fuel is hydrocarbon with onlya smallamountofSulphur.IfweneglectSulphurandconsidercompletecombustion,onlywater and carbondioxide would appear in the exhaust.

Water is not generallyconsidered undesirable and therefore it is not considered as a pollutant.Likewise,carbondioxideisalsonotconsideredaspollutantinearlierdays.But due to increase in global warming due to CO_2which is a greenhouse gas, now a days $CO_2$is also considered as unwanted one.

ThenapartfromthiswegetSulphurdioxideapollutantwhichisaproductofcomplete combustion.Apartfromthisallthecompoundscurrentlyconsideredaspollutantsaretheresult of imperfect or incomplete combustion.

Pollutants	PollutantEffects
Unburned HydroCarbons (UBHC)	PhotochemicalSmog
NitricOxide	Toxic,PhotochemicalSmog
Carbonmonoxide	Toxic
Leadcompounds	Toxic

Smoke combines with fog and forms a dense invisible layer in the atmosphere which is knownas Smog. The effect of Smog is that it reduces visibility.

Effectof PollutantsonEnvironment:

a. UnburnedHydroCarbons(UBHC):

The major sources of UBHC in an automobile are the engine exhaust, evaporative losses from fuelsystem, blow by loss and scavengingin case of2-stroke petrol engines.

Unburned or partially burned hydrocarbons in gaseous form combine with oxides of nitrogen in the presence ofsunlight to formphotochemical smog.

UBHC+NOx Photochemicalsmog

Theproductsofphotochemicalsmogcausewateringandburningoftheeyesand affecttherespiratorysystem,especiallywhentherespiratorysystemismarginalforother reasons.

Some of the high molecular weight aromatic hydrocarbons have been shown to becarcinogenicinanimals.Someoftheunburnedhydrocarbonsalsoserveasparticulate matter in atmosphere.

b. Carbon monoxide:

Carbon monoxide is formed during combustion in engine only when there is insufficientsupply ofair. The main source is the engine exhaust.

The toxicity of carbon monoxide is well known. The hemoglobin the human bloodwhichcarriesoxygentovariouspartsofthebodyhasgreataffinitytowardscarbon monoxide than for oxygen. When a human is exposed to an atmosphere containing carbon monoxide, the oxygen carrying capacity of the blood is reduced and results in the formation of carboxy hemoglobin. Due to this the human is subjected to various ill effects and ultimately leads to death.

The toxic effects of carbon monoxide are dependent both on timeand concentration as shown in the diagram.

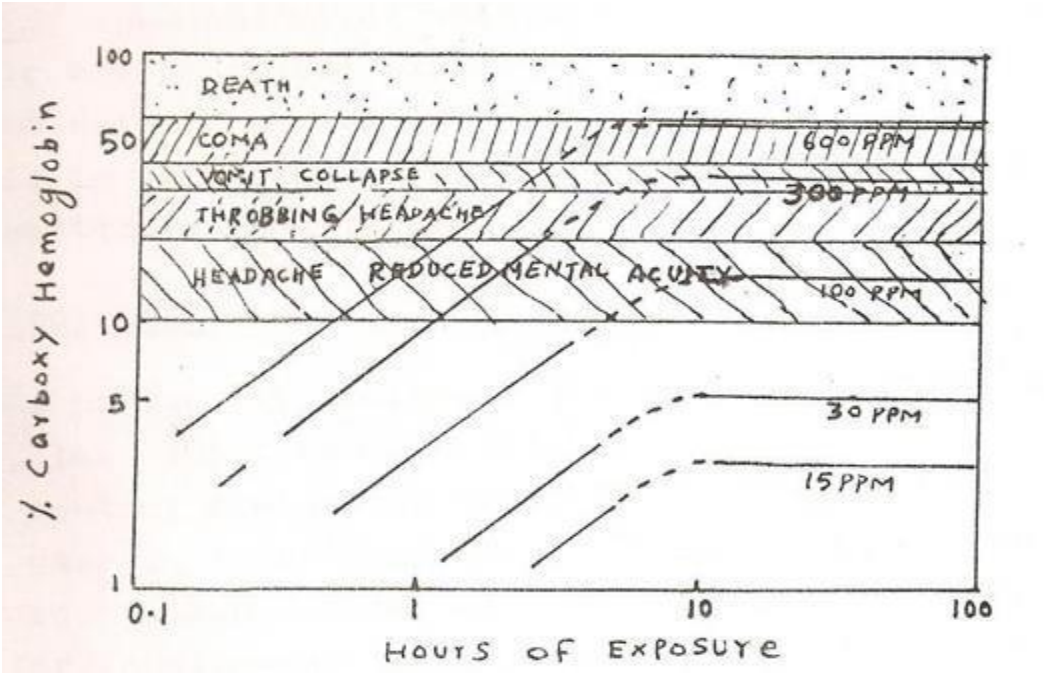


Fig.2Toxicityofcarbon monoxide

c. OxidesofNitrogen(NOx):

Oxides of nitrogen (NO, NO_2, N_2O_2etc) are formed at higher combustion temperature present inengines and the engine exhaust is the major source.

Like carbon monoxide, oxides of nitrogen also tend to settle on the hemoglobin in blood. Their most undesirable effect is their tendency to join with moisture in the lungstoformdilutenitricacid.Becausetheamountsformedareminuteanddilute,their effect is very small but over a long period of time cam be cumulatively undesirable, especially whenthe respiratoryproblems for other reasons are found.

Another effect is that, the oxides of nitrogen are also one of theessential components for the formation of photochemicalsmog.

d. Sulphurdioxide:

Sulphur dioxide from automotive vehicle is very less when compared to that emitted by burning coal. Sulphur dioxide combines with moisturein atmosphere and forms sulphuric acid at highertemperatures. This comes to the earthas acid rain.

Much of the Sulphur dioxide combines with other materials in the atmosphere and forms sulphates which ultimately formparticulate matter.

e. Particulates:

Particulatemattercomesfromhydrocarbons,leadadditivesandSulphurdioxide. If lead is used with the fuel to control combustion almost 70% of theleadis airborne withtheexhaustgasses.Inthat30%oftheparticulatesrapidlysettletothegroundwhile remaining remains inthe atmosphere. Lead is wellknown toxic compound

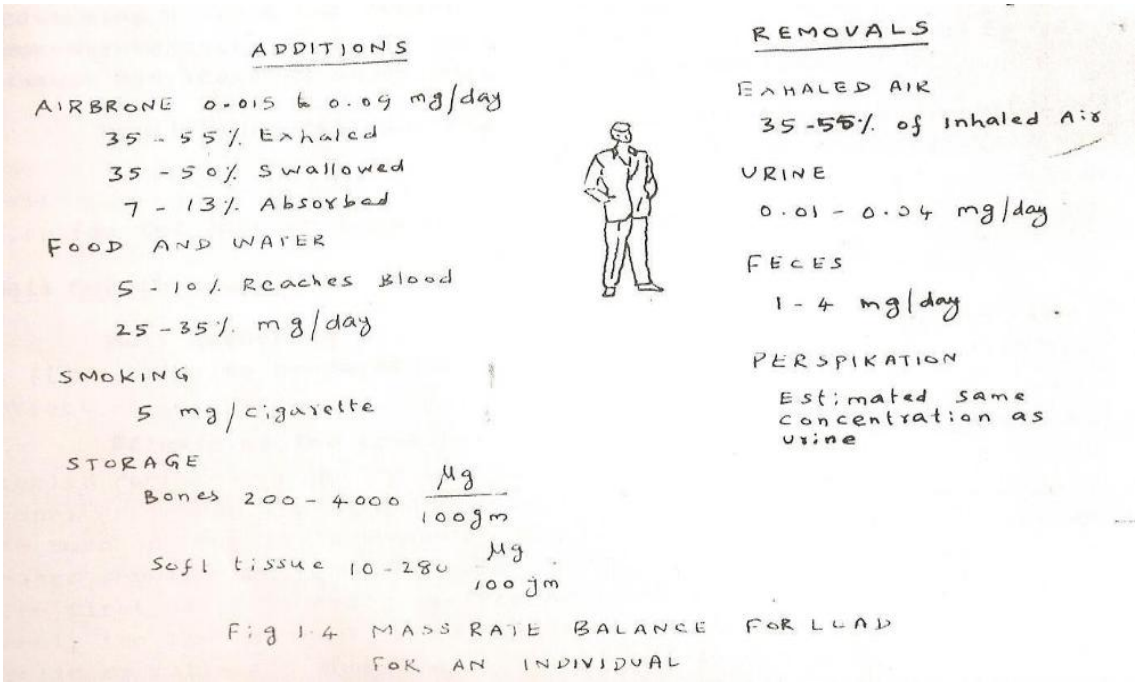


Fig 1.4 MASS RATE BALANCE FOR LEAD FOR AN INDIVIDUAL

Fig.3MassRateBalance forLoadforanIndividual

Particulateswheninhaledortakenalongwithfoodleadstorespiratoryproblemsand other infections. Particulateswhensettleonthegroundtheyspoilthenatureoftheobjectonwhich theyare settling. Lead, a particulate is a slowpoisonand ultimately leads to death.

Greenhouseeffect

Greenhouse effect, a warming of Earth's surface and troposphere (the lowest layer of theatmosphere)causedbythepresenceofwatervapour,carbondioxide,methane,andcertain othergasesintheair.Ofthosegases,knownasgreenhousegases,watervapourhasthelargest effect.

TheatmosphereallowsmostofthevisiblelightfromtheSuntopassthroughandreach Earth's surface. As Earth's surface is heated by sunlight, it radiates part of this energy back towardspaceasinfraredradiation.Thisradiation,unlikevisiblelight,tendstobeabsorbedby thegreenhousegasesintheatmosphere,raisingitstemperature.Theheatedatmosphereinturn radiates infrared radiation back toward Earth's surface. Without the heating caused by the greenhouseeffect,Earth'saveragesurfacetemperaturewouldbeonlyabout−18°C(0°F).On Venus the very high concentration of carbon dioxide in the atmosphere causes an extreme greenhouse effect resulting in surface temperatures as high as 450 °C (840 °F). Although the greenhouse effect is a naturally occurring phenomenon, it is possible that the effect could be intensified by the emission of greenhouse gases into the atmosphere as the result of human activity. From the beginning of the Industrial Revolution through the end of the 20th century, the amount of carbon dioxide in the atmosphere increased by roughly 30 percent and the amount of methane more than doubled. A number of scientists have predicted that human-related increases in atmospheric carbon dioxide and other greenhouse gases could lead by the endofthe21stcenturytoanincreaseintheglobalaveragetemperatureof3–4°C(5.4–7.2°F) relative to the 1986–2005 average. This global warming could alter Earth's climates and thereby produce new patterns and extremes of drought and rainfall and possibly disrupt food production in certain regions.

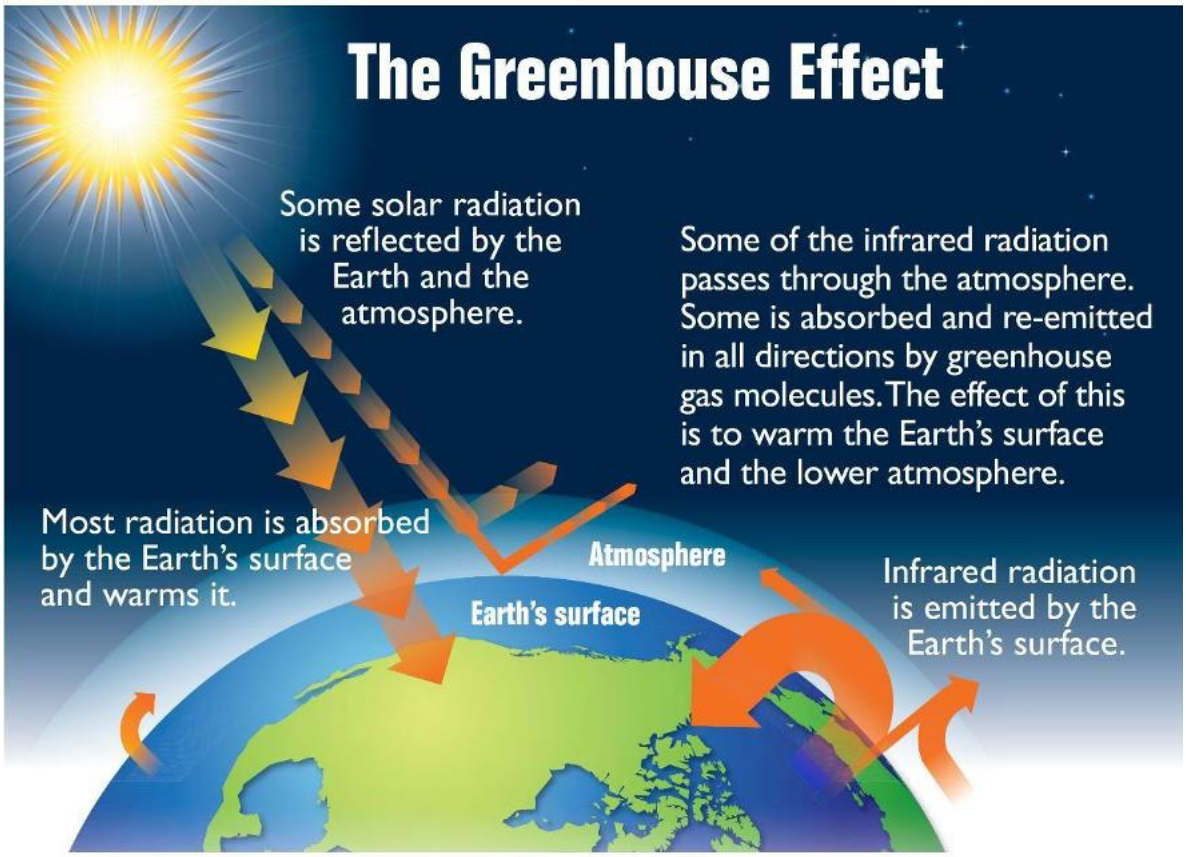


Fig.4GreenHouseEffect

GlobalWarming

A gradual increase in the overall temperature of the earth's atmosphere generally attributed to the green house effect caused by increased levels of carbon dioxide, CFCs and other pollutants.

CausesofGlobalWarming

Global Warming occurs when carbon di-oxide (CO_2) and other air pollutants andgreenhousegasescollectintheatmosphereandabsorbsunlightandsolarradiation that have bounced off the earth's surface.

1. Deforestation.
2. GreenhouseEffect
3. ProcessofrecoveringFossilFuels.

Effectsof GlobalWarming

1. IncreasedmeltingofIce caps.
2. Rise in sea levels.
3. Desertification.
4. Hurricaneand Cyclones.
5. SpreadofDiseases.
6. Agriculture.
7. HeatWaves.

8. Longer/Shorter Seasons.
9. Crops.
10. Ocean's
11. Animal Extinction.

EFFECTSOFAIRPOLLUTION

1. Acidification:

Chemical reactions involving air pollutants can create acidiccompounds which can cause harm to vegetation and buildings. Sometimes, when an air pollutant, such as sulfuric acid combines with the water droplets that make up clouds, the water droplets become acidic, formingacidrain.Whenacidrainfallsoveranarea,itcankilltreesandharmanimals,fish, and other wildlife.

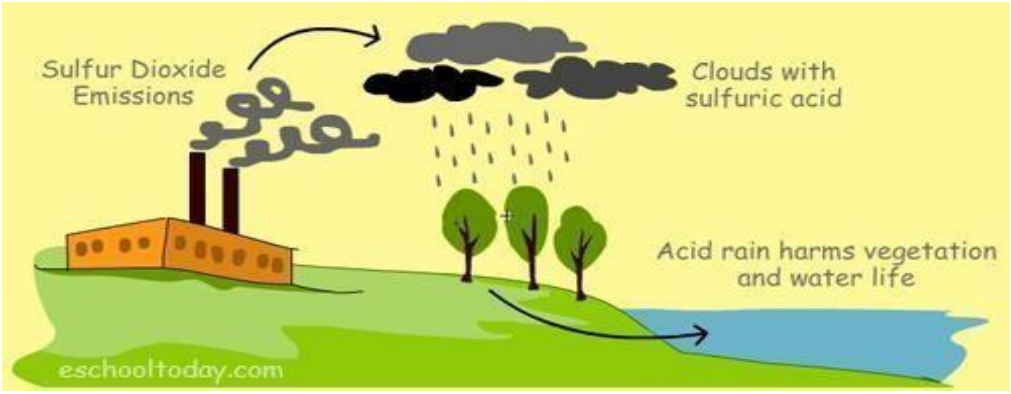


Fig.5 Acidification

Acidraindestroystheleavesofplants.Whenacidraininfiltratesintosoils,itchanges thechemistryofthesoilmakingitunfitformanylivingthingsthatdependonthesoil as a habitat or for nutrition. Acid rain also changes the chemistry of the lakes and streams that the rainwater flows into, harming fish and other aquatic life.

Eutrophication:

Rain can carry and deposit the Nitrogen in some pollutants on rivers and soils. This willadverselyaffectthenutrientsinthesoilandwaterbodies.Thiscanresult inalgae growth in lakesand water bodies, and make conditions for other living organism harmful.

Ground-levelozone:

Chemical reactions involving air pollutants create a poisonous gas ozone (O3). Gas Ozone canaffectpeople'shealthandcandamagevegetationtypesandsomeanimallife too.

Particulatematter:

Airpollutantscanbeintheformofparticulatematterwhichcanbeveryharmfulto

our health. The level of effect usually depends on the length of time of exposure, as well the kind and concentration of chemicals and particles exposed to. Short-term effects include irritation to the eyes, nose and throat, and upper respiratory infections such as bronchitis and pneumonia. Others include headaches, nausea, and allergic reactions.Short-termairpollutioncanaggravatethemedicalconditionsofindividuals withasthmaandemphysema.Long-termhealtheffectscanincludechronicrespiratory disease, lung cancer, heart disease, and even damage to the brain, nerves, liver, or kidneys.Continualexposuretoairpollutionaffectsthelungsofgrowingchildrenand may aggravate or complicate medical conditions in the elderly.

EffectsofAirPollution:onHumanHealth,AnimalsandAtmosphere!

Air pollution has now become a worldwide phenomenon and every individual in one way or the other is facing problems caused by it. Its impact can be seen locally, at regional level as well asat global level.

At local and regional levels its manifestations are in the form of alterations in (i) visibility, (ii) intensity of sunshine, (iii) precipitation amount, and (iv) acid rain. Its global effects are. (i) Change in natural climate by rise of temperature, melting of snow,(ii)increaseincarbondioxide,(iii)increaseinparticulates, (iv)holesinozone layer, etc. Several aspects of air pollution, such as effects on the ozone layer, greenhouse effect, smog and acid rain have already been discussed.

Theeffectsofair pollutioncanbegroupedunderthefollowingheads:

(i) Effectsonhumanhealth,

(ii) Effectsonanimalsandplants,

(iii) Effectsonatmosphere, and

(iv) Othereffects.

1. EffectsonHumanHealth:

Some environmental poisons can cause acute illness and even death. Others may be harmful,butthediseasemaytakeyearsorevendecadestoappear.Airpollutionmainly affects the respiratorysystem.

Bronchitis, emphysema, asthma and lung cancer are some of the chronic diseases caused due to exposure to polluted air. It is feared that lung cancer is caused mainly due to polluted air becausecarcinogens are found in it. Its mortality rate is higher in urban areas.

Figureshowsthevariouseffectsofairpollutiononthehumanbody.Sulfurdioxide isthemostseriousandwidespreadairpollutant.Itslowerconcentrationisacauseof

spasmsin the smoothmuscle of bronchioles andits higher concentration inducesincreased mucus production.

Sulfur dioxide is also considered to cause cough, shortness of breath, spasm of the larynx and acute irritation to the membranes of the eyes. It also acts as an allergenic agent. When it reacts with some compounds, sulfuric acid is formed which may damage lungs.

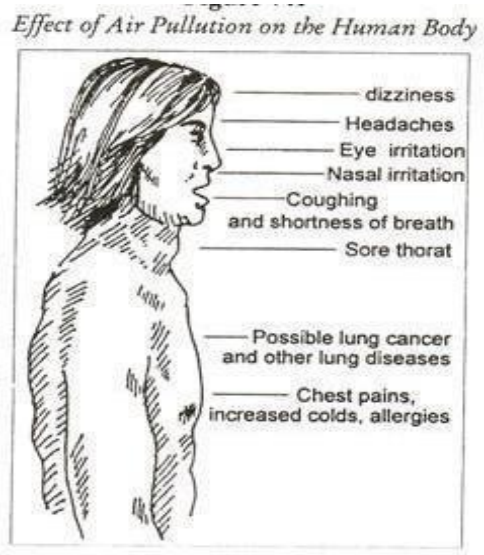


Fig.6EffectofAir PollutionontheHuman Body

Carbon monoxide often affects the oxygen carrying capacity of blood. Nitric oxide is reported tobe a pulmonary irritant and its excess concentration may cause pulmonary haemorrhage.

Hydrogensulfide isalso toxic. Leademitted fromautomobile exhausts isacumulative poisonand is dangerous particularly to children and may cause brain damage.

The particulate pollutants such as asbestos, silica, carbon, beryllium, lead, etc., are capableofexertinganoxious(fibrotic)localactionintheinterstitialareasofthelungs. Radioactiveelementsarealsoharmfultomanandotherlivingorganisms.Asdescribed earlier,smoghasakillereffect,whichisalsotheresultofairpollution.Thedeathtoll by smog varies from few persons to thousands.

In December 1952, about 4,000 persons died in London due to smog. Similar cases havebeenreportedfromLondonitselfin1956,1957and1962inwhichthedeathtoll wasbetween700and1,000persons.Inothercountriesalsosmogdeathshavebeen

reported.Infact,thegrowingairpollutionhas nowbecomeahealthhazard for man.

2. EffectsonAnimalsandPlants:

Theimpact ofairpollutiononanimalsis moreorlesssimilartothaton man.Chronic poisoning results from the ingestion of forage contaminated with atmospheric pollutants. Among the metallic contaminants, arsenic, lead and molybdenum are important. Fluoride isanother pollutant, which causes fluorosis among animals.

AnumberoflivestockhavebeenpoisonedbyfluoridesandarsenicinNorthAmerica. Bone lesions in animals due to excessive fluorides have also been reported.

Airpollutionhascausedwidespreaddamagetotrees,fruits,vegetables,flowersandin general, vegetation as a whole. The total annual cost of plantdamage caused by air pollution in USA alone has been estimated to be in the range of 1 to 2 billion dollars. The most dramatic early instances of plant damage were seen in the total destruction of vegetation by sulfur dioxide in theareas surrounding smelters.

When the absorption of sulfur dioxide exceeds a particular level, the cells become inactiveandarekilled,resultingintissuecollapseanddryingofleaves.Cotton,wheat, barley and apple are more sensitive to this pollutant.

Fluorides are responsible for various types of injuries to plants. The leaves of apple, apricot, fig, peach and prune are more susceptible to air borne fluorides. Fluorides seem to interfere with the photosynthesis and respiration of plants. Smogalso causes injurytoplants.Similarimpactofozonecanbeseeninthelesionstoplants.Chlorine, ammonia, hydrogen sulfide, etc., are also harmful to vegetation.

3. EffectsonAtmosphere:

Someoftheeffectsofairpollutiononatmosphericconditions,suchaseffectonozone layer,greenhouseeffect,etc.,havealreadybeendiscussed.Thereisanincreaseinthe carbon dioxide concentration in the air due to increased combustion of fossil fuels. Carbon dioxide absorbs heat strongly and the radiative cooling effect of the earth is thus decreased.

The rising of temperatures and ozone holes are some of the problems which have attracted the attention of the scientists all over the world. These problems are not relatedtoanyregionoracountrybutaretheglobalproblemsandtheirimpactonworld climate may be hazardous to the whole world.

The local weather conditions are highly susceptible to air pollution. Its impact on temperature,humidity,rainfallandcloudsisapparent.The_smogdom‘onlargeurban centres is the result of air pollution. Due to air pollution, visibility also reduces.

4. OtherEffects:

Air pollution can also cause damage to property and materials. The smoke, grit, dust and oxides of sulphur have harmful effects on structures.

In1972,whenanoilrefineryatMathurawasopened,itsimpactonTajMahalbecame a major issue. Sulfur dioxide is the most damaging of gaseous pollutants. Aluminum alloys, copper and copper alloys, iron and steel are corroded when exposed to contaminated air.

Hydrogen sulfide reacts with lead paints to form lead sulfide thereby producing a browntoblackdiscolouration.Thedamagecausedbyairpollutiontostructuresisnot serious but from an aesthetic point of view, it is not desirable.

OzoneHoles

Ozone depletion occurs when chlorofluorocarbons (CFCs)—formerly foundin aerosol spray cans and refrigerants—are released into the atmosphere. These gases, through several chemical reactions, cause the ozone molecules to break down, reducing ozone's ultraviolet (UV) radiation- absorbing capacity.

ozone

Ozoneissimplyamoleculeconsistingof3oxygenatoms,whichreactsstronglywith other molecules. Ozone is createdinthestratospherewhenhighenergyuv radiationcauseson O2 molecule to split. The free oxygen atoms collide and react with other O2 molecules to form O3.

Production is highest where the solar uv is the greatest eg near the tropics, but once created,theozoneisthencirculatedtowardsthepolesbytheatmosphere.Theamount ofozoneinthestratospherecanvarywithlocation,seasonandevendaytodayclimatic conditions.

The process of ozone creation is what makes the O3 in the atmosphere very effective at shieldingthe Earth from harmful uv radiation, which can cause many biological problems, such as skin cancer.However,due to its high reactivity,the uv foundin the troposphere at ground level can also be dangerous as a toxic pollutant which is harmful to plants and lung tissue, and is a major cause of smog.

The discovery of the annual depletion of ozone above the Antarctic was first announced in a paper by Joe Farman, Brian Gardiner and Jonathan Shanklin which appeared in Nature in May 1985. Later, NASA scientists re-analyzed their satellite data and found that the whole of the Antarctic was affected.

All living cells, whether microbes, plants or animals, contain a complex molecule called DNA which carries the genetic code. This is the set of instructions which describesthestructureandbiochemistryofanorganism.Unfortunately,DNAreadily

absorbs high-energy UV-B radiation and becomes damaged so that the instructions cannot be read properly. If the amount of UV-B entering the cell increases (as during the ozone hole), the risk of damage also increases and may result in malfunction or death of the organism. Some Antarctic organisms such as algae, lichens and mosses also contain a pigment called chlorophyll. This absorbs visible light as the energy source of photosynthesis for making organic compounds. Chlorophyll also absorbs UV-Blightso that the system becomes bleached and non-functional. Even enzymes and other proteins are damaged by this high-energy radiation. Living organisms therefore have to protect themselves from UV-B. Humans can cover their skin with artificial sunscreens, but natural protection systems have also evolved. Many microbes, plants and other animals synthesize protective pigments. Our skin cells synthesize brown melanin to protect againstsunburn (which is causedby UV-B radiation), and so do Antarctic lichens on rocks near the edge of the polar ice-cap. A variety of suncreen pigments are produced by Antarctic organisms on land, in freshwaterandinthesea.Thatiswhyexposed,snow-freerocksareoftencoveredwith bright orange and yellow lichens. Some lichens and microbes even live inside translucent rocks to shelter from high radiation levels and desiccating winds!

The Greenhouse Effect (producing global warming) and ozone depletion are two separate problems, however there are links between them. Warming at the earth's surface is caused by certain gases in the atmosphere which can trap energy from the sun. An increase in the amount ofthese gases produces an increase in the surface temperature. The largest increase is in carbon dioxide from burning coal, oil, gas and forests,butothergasessuchasmethane(fromcattleandricefields)playapart.Alink with ozone depletion is that CFCs are gases which also contribute to greenhouse warming.

A further link is that although the Greenhouse Effect warms the surface, it allows the higheratmosphere,whereozoneispresent,tocool.Thismeansthat morestratospheric clouds may form and so make the ozone hole worse.

Even if the problem of ozone depletion is solved, global warming will still remain. It will cause arise in sea-level and change the regions where crops can be grown. The issuewillbehardertotacklethanozonedepletion,butisonewhichconcernseveryone on our planet.

The only way to med the ozone hole is to stop releasing CFCs and other ozone depletinggasesintotheatmosphere.TherestrictionsoftheMontrealProtocolandits extensions are helping to do this.

GreenhouseEffect

The Sun powers Earth ‘s climate, radiating energy at very short wavelengths, predominately inthe visible or near-visible (e.g., ultraviolet) part of the spectrum. Roughly one-third of the solar Energythat reachesthetopofEarth ‘satmosphereis reflecteddirectly back tospace.Theremaining two-thirds is absorbed by the surface and, to a lesser extent, by the atmosphere. Tobalance the absorbed incoming energy, the Earth must, on average, radiate the same amount ofenergy back to space. BecausetheEarthismuchcolderthantheSun,itradiatesatmuchlongerwavelengths, primarily in the infrared part of the spectrum (see Figure 1). Much of this thermal radiation emitted by the land and ocean is absorbed by the atmosphere, including clouds, andreradiated back to Earth. This is called the greenhouse effect. The glass walls in a greenhousereduce airflow and increase thetemperatureofthe air inside. Analogously, but throughadifferent physical process, the Earth‘s greenhouse effect warms the surface of the planet.

WithoutthenaturalgreenhouseeffectAverageTemperatureatEarth‘ssurfacewould be belowthe freezing point of water. Thus,

Earth‘s natural greenhouse effect makes life as we know it possible. However, human activities,primarily the burning of fossil fuels and clearing of forests, have greatly intensified the natural greenhouse effect, causing global warming.The two most abundantgasesin theatmosphere,nitrogen (comprising 78% of the dry atmosphere) and oxygen (comprising 21%), exert almost no greenhouse effect. Instead, the greenhouse effect comes from molecules that are more complexand much less common.Watervapouristhemostimportantgreenhousegas,andcarbondioxide(CO2) is the second-most important one. Methane, nitrous oxide, ozone and several other gasespresent in the atmosphere in small amounts also contribute to the greenhouse effect.Inthehumidequatorial regions, where there is so much water vapour in the air that the greenhouse effect isvery large, adding a small additional amount of CO2 or water vapour has only a small directimpactondownwardinfraredradiation.However, in the cold, dry polar regions, the effect of asmall increase in CO2 or water vapour is much greater.

The same is true for the cold, dryupperatmosphere where a small increase in water vapour has a greater influence on the greenhouseeffectthanthesamechangeinwater vapourwouldhaveneartheSurface.Severalcomponentsofthe climate system,notably the oceans andliving things, affectatmospheric concentrations ofgreenhousegases. AprimeexampleofthisisplantstakingCO2outoftheatmosphereandconverting it (and water) into carbohydrates via photosynthesis. In the industrial era, human activities have added greenhouse gases to the atmosphere, primarily through the burning of fossilfuels and clearing of forests. Adding more of a greenhouse gas, such as CO2, to the atmosphere intensifies the greenhouse effect, thus warming Earth‘s climate. The amount of warming dependson various feedback mechanisms. For example, as the atmosphere warms due to rising levels of greenhouse gases, its concentration of water vapour increases, further intensifying thegreenhouse effect. Thisinturncausesmorewarming,whichcausesanadditionalincreaseinwatervapour, in a self-reinforcing cycle.

Thiswatervapourfeedbackmaybestrongenoughtoapproximatelydouble

theincreaseinthegreenhouseeffectduetotheaddedCO2alone.Additional important feedback mechanisms involve clouds. Clouds are effective at absorbinginfrared radiationandthereforeexertalargegreenhouseeffect,thuswarmingtheEarth.Clouds arealsoeffectiveatreflectingawayincomingsolarradiation,thuscoolingtheEarth.A change inalmost any aspect of clouds, such as their type, location, water content,cloud altitude, particlesize and shape, or lifetimes, affects the degree to which clouds warmorcoolthe Earth. Somechangesamplifywarmingwhileothersdiminishit.Much researchisinprogresstobetterunderstand how clouds change in response to climate warming,andhowthesechangesaffectclimatethroughvariousfeedbackmechanisms.

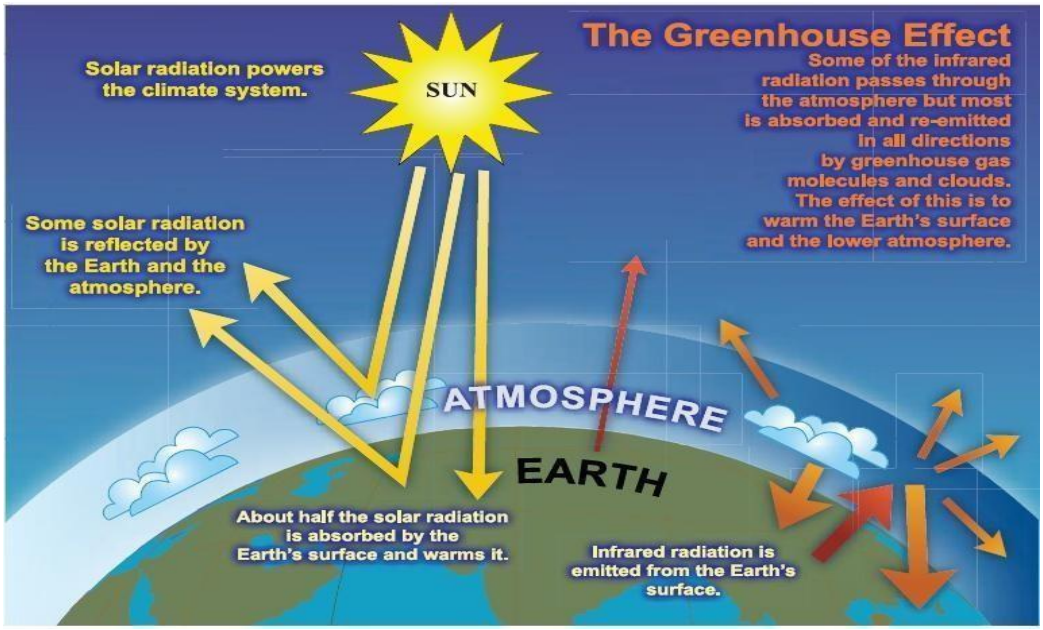


Fig.7Greenhouse Effect

ClimateChange

The climate of the Earth is always changing. In the past it has altered as a resultof natural causes. Nowadays, however, the term climate change is generally used when referring to changesin our climate which have been identified since the early part of the twentieth century. The changes we've seen over recent years and those which are predicted over the next 100 years are thought by many to be largely as a result of human behaviour rather than due to natural changes in the atmosphere.

Thegreenhouseeffectisveryimportantwhenwetalkaboutclimatechangeasitrelates tothegaseswhichkeeptheEarthwarm.Althoughthegreenhouseeffectisanaturally occurring phenomenon, it is believed that the effect could be intensified by human activityandtheemissionofgasesintotheatmosphere.Itistheextragreenhousegases which humans have released which are thought to pose the strongest threat.

TheGreenhouse Gases

Almost the Earth‘s entire atmosphere (99%) is made up of nitrogen (about 78%) and oxygen(about21%).Whilebothofthesegasesplayimportantrolesinthevastnumber ofprocessesthatsupportlifeonEarth,theyplayalmostnodirectroleinregulatingthe climate. This is carried out by some of the trace gases in the remaining 1% of the atmosphere which occur in relatively smallamounts:

Water vapour Carbon dioxide (produced by burning fossil fuel) Methane (a byproduct of agriculture)Nitrogen Oxides (from car exhausts)OzoneCFCs (chlorofluorocarbons from aerosol and refrigerators)

Althoughtheproportionofthetracegasesintheatmosphereappearsrelativelysmall, they can still have a big impact on climate change.

ExtremeWeather

- Increasing temperatures means the World is likely to see less frostydays and cold spells,but we are expected to experience an increase in heat waves and hot spells
- Greaterriskofdroughtincontinentalareas
- Increaseinextremeprecipitationevents
- Hurricanes likely to be more intense in some parts of the World due to more rainfall andmore intense winds
- AnintensificationoftheAsiansummermonsoonisexpected
- There will be regional variation in temperature changes; increases will be higheroverland and in the northern hemisphere
- HoweverthetemperatureincreaseovertheNorthAtlanticwillbesmall

Therefore, even if we stopped CO_2emission simmediately,the effectsof what we've already done would still influence our weather for years to come.

However,carbondioxide emissions are not going to stop and with that in mind,some change is certainly expected-the level of change depends on the amount of green house gases we continuetouse,which is turn is related to population growth,the use of new technologies and how much energy we use.

The European Commission has set a target adopted by all industrialised countries of cutting greenhouse gas emissions to an average of 30% below 1990 levels by 2020.

This is the magnitude of reduction which is required,the Commission believes,to have a 50/50 chance of limiting the global temperature increase to2°Cabovepre-industrial levels.

By reducing the number of greenhouse gases even marginally, the rate of change should be less and therefore there will be less impact on our planet and our lives. A gradualchangetoourclimateiseasiertoadaptaswell-weshouldhavemoretimeto prepare our houses and other buildings for changes to the weather, wildlife should have more time to migrate,and the changes to our agricultural practices should be less sudden.

Most commentators say it isn't too lateto address climatechange and that weneed to all work together to do our bit to reduce emissions and the damage we are currently doing to our local environment.We areal ready seeing change and will continue to do so,but if the scientific model sare on the right lines,our climate will be a very different place in the next ten to twenty years to what it is now.

Global Warming Scientists say the temperature of the earth could rise by 3°Cover the next 50 years.This may caused rought in some parts of the world,andfloods in others, as ice at the North and South Poles begins to melt and sea level rise.

It´s normal for temperatures to sometimes be cooler for many hundreds of years, and then sometimes to be warmer. But this time, humans have caused the increase, with carbon from cars and factories.

Global warming is caused by the greenhouse effect. Normally, heat from the sun warmstheearthandthen escapesbackintospace. Butcarbondioxideandothergases in the atmosphere trap the sun´s heat, and this is slowly making the earth warmer.

Theozonelayerisalayerofgashighabovethesurfaceoftheearththathelpstoprotect it from the sun´s ultraviolet radiation, which can damage our skins and cause cancer. Scientists have discovered holes in the ozone layer, caused by substances called chlorofluorocarbons. CFCs are used in refrigerators, aerosol cans and in the manufacture of some plastic products. Some companies now make aerosols that do not contain CFCs, and these are often marked —ozone-friendly‖.Tropicalrainforests arebeingburntandcutdownbecausepeopleneedmorelandforagriculture,morehard wood for furniture and firewood. Cutting down the rainforests is dangerous for many reasons.

Weneedtheoxygenthatcomesfromrainforests.Theforestsabsorbcarbondioxidein the process called photosynthesis. Without trees carbon dioxide levels will increase.

Rainforests are the homes of many insects, plants, and animals that we need for medicine and other reasons. Many plants and animals will become extinct.

Theycanhelpcatchwaterandgiveitbacktotheearthintheformofclouds,which

bring us water. The roots of trees and plants in the rainforest keep water and soil in place. Without the rainforest, there are many problems like floods and mudslides.

Doyoubelievethatsometypesofextremeweathermaybecausedbyglobalwarming?
Extreme weather (downpours/ heavy rains, monzoons, tornadoes, hurricanes, droughts)isapartofnaturebutIthink/don´tthinkit isconnectedwithenvironmental problems.

The green house effect is the temperaturer iseth at the earth experiences.This happens becauseof certain gases that get energy from the sun. Without the greenhouse effect, the earth would be too cold, not warm enough for people to live.The green house effect begins with the sun and the energy itradiatesto the earth.The earth and the atmosphere absorb some of this energy, but the restisradiated back into space.Naturally occurring gas esinthe atmosphere trap some of this energy and reflect it back,warmingtheearth. Scientist believes that extra gases we release into the air intensify the greenhouse effect. Evidence that scientist have is the result of some of the warmest years in recorded history.

Globalwarmingistheincreaseintheaveragetemperatureoftheearth‘ssurface.The increase in greenhouse gases, fossil fuel burning, and deforestation contributes to globalwarming.Theaveragetemperatureshaveclimbedabout1.4°aroundtheworld since 1880. The rate of the warming is decreasing. The IPPC (International Panel on Climate Control) reports that 11 of the past 12 years are among the dozen warmest since 1850.

GlobalWarming-Contributing Factors

Oneof thebiggest contributors to global warming is the methane from cow toots and feces. The methane from the cow comes from the methanotropic bacteria in its stomach. That bacteria helpsthe cows digest grass, their main diet. The methane is produced form carbon in the grass. Also, another contributor to global warming is combustion offossil fuelsincars, factories, and electricityproduction.The releaseof carbondioxideandothergasesintotheatmospherehas climbed.Methaneandcarbon dioxide have hit their highest levels in the last 400 years.

GlobalWarming: LocalEffects

Human activity causing changes in the environment is known as global warming. Scientist reports that 1998 was the warmest year in measured history, with 2005 coming in second place.

Readingstakingfromtheicewarsshowthatthegreenhousesgasescarbondioxideand methane have reached their highest levels in the past 420,000 years. Arctic sea ice is melting,andhasdeclinedinthelast30years.Inthelastcentury,theearth‘s

temperature has raised about 1.2-1.4 degrees Fahrenheit. . Researchers report that temperaturewillincrease10degreesFahrenheitbytheendofthecentury.Hurricanes will become more frequent because of the warm weather. Rising sea levels can flood coastal areas. Severe droughts can becomemore common in dry areas, and species unable to adapt to the changing areas, would have to face extinction.

PreventionStrategy

Tohelp, you can save energyaroundthe houseby unplugging appliances you are not using,andchangingregularbulbstofluorescentlightbulbs.Youcandrivefewerhours in your car each dayand instead walk to near places that you can. Also, believe it or not, taking a shower instead of a bath can help save more water! If you recycle cans, bottles, cardboard, and paper materials that will save a lot of room in landfills. If you carrywateraroundwithyou,refillitinametalcanteensothatwedon‘thastouseand makemoreplasticbottle.Whenyouusethetap,besurenotto leaveitrunning.When washing your clothes, itsbetter to hang them on an outside line todry. This will save more energy using a dryer. To keep from running to the store all the time, you can grow fruits and vegetables, and go to the store for produce and other groceries. Anotherthingthatcanhelpstopglobalwarmingthatweallloveisflyingtheairplane. If you and your family took local trips, that could save a lot of oil, a popularly used nonrenewablesource.Ifyouplanttreesthatcanmajorlyhelptheearth.Mosttreesnow are getting cut down for paper so if we plantmore if may come close to evening out.

OriginsofContaminants

Indoor contamination has different origins: the occupants themselves; inadequate materials or materials with technical defects used in the construction of the building; theworkperformedwithin;excessiveorimproperuseofnormalproducts(pesticides, disinfectants, products used forcleaning and polishing); combustion gases (from smoking,kitchens,cafeteriasandlaboratories);andcross-contaminationcomingfrom other poorly ventilated zones which then diffuses towards neighbouring areas and affectsthem.Itshouldbeborneinmindthatsubstancesemittedinindoorairhavemuch lessopportunityofbeingdilutedthanthoseemittedinoutdoorair,giventhedifference inthevolumesofairavailable.Asregardsbiologicalcontamination,itsoriginismost frequently due to the presence of stagnant water, materials impregnated with water, exhausts and so on, and to defective maintenance of humidifiers and refrigeration towers.

Finally, contamination coming from outside must also be considered. As regards human activity,three main sources may be mentioned: combustion in stationary sources (power stations); combustion in moving sources (vehicles); and industrial processes.Thefivemaincontaminantsemittedbythesesourcesarecarbonmonoxide, oxidesofsulphur,oxidesofnitrogen,volatileorganiccompounds(including

hydrocarbons), polycyclic aromatic hydrocarbons and particles. Internal combustion in vehiclesis the principal source of carbon monoxide and hydrocarbons and is an important source of oxides of nitrogen. Combustion in stationary sources is the main originofoxides ofsulphur. Industrialprocessesand stationarysourcesofcombustion generate

more than half of the particles emitted into the air by human activity,andindustrial processescanbeasourceofvolatileorganiccompounds.Therearealsocontaminants generatednaturallythatarepropelledthroughtheair,suchasparticlesofvolcanicdust, soil and sea salt, and spores and micro-organisms. The composition of outdoor air varies from place to place, depending both on the presence and the nature of the sources of contamination in thevicinity andon the direction of the prevailing wind. If there are no sources generating contaminants, the concentration of certain contaminants that will typically be found in ―clean‖ outdoor air are as follows: carbondioxide,320ppm;ozone,0.02ppm: carbonmonoxide,0.12ppm;nitricoxide, 0.003 ppm; and nitrogen dioxide, 0.001 ppm. However, urban air always contains much higher concentrations of these contaminants.

Apart from the presence of the contaminants originating from outside, it sometimes happens that contaminated air from the building itself is expelled to the exterior and then returns inside again through the intakes of the air-conditioning system. Another possible way by which contaminants may enter from the exterior is by infiltration through the foundations of the building (e.g., radon, fuel vapours, sewer effluvia, fertilizers, insecticides and disinfectants). It has been shown that when the concentrationofacontaminantintheoutdoorairincreases,itsconcentrationintheair insidethebuildingalsoincreases,althoughmoreslowly(acorrespondingrelationship obtains when the concentration decreases); it is therefore said that buildings exert a shielding effect against external contaminants. However, the indoor environment is not, of course, an exact reflection of the conditions outside.

Contaminantspresentinindoorairaredilutedintheoutdoorairthatentersthebuilding andtheyaccompanyitwhenitleaves.Whentheconcentrationofacontaminantisless in the outdoor air than the indoor air, the interchange of indoor and outdoor air will result in a reduction in the concentration of the contaminant in the air inside the building.Ifacontaminantoriginatesfromoutsideandnotinside,thisinterchangewill result in a rise in its indoor concentration, as mentioned above.

Models for the balance of amounts of contaminants in indoor air are based on the calculation of their accumulation, in units of mass versus time, from the difference between the quantity that enters plus what is generated indoors, and what leaves with the air plus what is eliminated by other means. If appropriate values are available for eachofthefactorsintheequation,theindoorconcentrationcanbeestimatedforawide rangeofconditions.Useofthistechniquemakes possiblethecomparison ofdifferent alternatives for controlling an indoorcontamination problem.

Buildings with low interchange rates with outdoor air are classified as sealed or energy-efficient. They are energy-efficient because less cold air enters in winter, reducing the energy required to heat the air to the ambient temperature, thus cutting thecostofheating.Whentheweatherishot, lessenergyisalsousedtocooltheair.If the building does not have this property, it is ventilated through open doors and windowsbyaprocessofnaturalventilation.Althoughtheymaybeclosed,differences of pressure, resulting both from the wind and from the thermal gradient existing betweentheinteriorandtheexterior,forcetheairtoenterthroughcrevicesandcracks, window and door joints, chimneys and other apertures, giving rise to what is called ventilationby infiltration.

Theventilation of a building is measured in renewals per hour. One renewal perhour means that a volume of air equal to the volume of the building enters from outside everyhour;in thesame way, an equal volumeof indoorairis expelled to theexterior everyhour.Ifthereisno forced ventilation(withaventilator)thisvalueisdifficultto determine, although it is considered to varybetween 0.2 and 2.0 renewals per hour. If theotherparametersareassumedtobeunchanged,the concentrationofcontaminants generated indoors will be less in buildings with high renewal values, although a high renewal value is not a complete guarantee of indoor air quality. Except inareas with marked atmospheric pollution, buildings that are more open will have a lower concentrationofcontaminantsintheindoorairthanthoseconstructedinamoreclosed manner.However,buildingsthataremoreopenarelessenergy-efficient.Theconflict between energy efficiency and air quality is of great importance.

Much action undertaken to reduce energy costs affects indoor air quality to a greater orlesser extent. In additiontoreducing thespeed withwhichthe aircirculateswithin the building, efforts to increase the insulation and waterproofing of the building involve the installation of materials that may be sources of indoor contamination. Other action, such as supplementing old and frequently inefficient central heating systems with secondary sources that heat or consume the indoor air can also raise contaminant levels in indoor air.

Contaminants whose presence in indoor air is most frequently mentioned, apart from those coming from outside, include metals, asbestos and other fibrous materials, formaldehyde,ozone,pesticidesandorganiccompoundsingeneral,radon,housedust and biologicalaerosols. Together with these, a wide variety of types of micro-organisms can be found, such as fungi, bacteria, viruses and protozoa. Of these, the saprophytic fungi and bacteria are relatively well known, probably because a technologyisavailableformeasuringtheminair.Thesameisnot trueofagentssuch as viruses, rickettsia, chlamydia's, protozoa and many pathogenic fungi and bacteria, for the demonstration and counting of which no methodology is as yetavailable. Among the infectious agents, special mention should be made of: Legionella pneumophila,Mycobacteriumavium,viruses,CoxiellaburnetiiandHistoplasma

capsulatum;andamong theallergens: Cladosporium,PenicilliumandCytophaga.

NATUREANDSOURCESOFINDOORCHEMICALCONTAMINANTS

CharacteristicChemicalPollutants

Chemical contaminants of the indoor air can occur as gases and vapours (inorganic andorganic)andparticulates.Theirpresenceintheindoorenvironmentistheresultof entry into the building from the outdoor environment or their generation within the building. The relative importance of these indoor and outdoor origins differs for different pollutants and may vary over time.

Themajorchemicalpollutantscommonlyfoundintheindoorair arethefollowing:

1. Carbon dioxide (CO2), which is a metabolic product and often used as an indicatorofthegenerallevelofairpollutionrelatedtothepresenceofhumansindoors

2. Carbon monoxide (CO), nitrogen oxides (NOx) and sulphur dioxide (SO2), which are inorganic combustion gases formed predominantly during the combustion of fuels and ozone (O3), which is a product of photochemical reactions in polluted atmospheres but may also be released by some indoor sources

3. Organiccompoundsthatoriginatefromavarietyofindoorsourcesandoutdoors.
Hundredsof organic chemicals occur in indoor air although most are present at very low concentrations.

Identifies four groups of organic compounds: (1) very volatile organic compounds (VVOC); (2) volatile (VOC); (3) semi-volatile (SVOC); and (4) organic compounds associated with particulate matter (POM). Particle-phase organics are dissolved in or adsorbedonparticulatematter.Theymayoccurinboththevapourandparticlephase depending on their volatility. For example, polyaromatic hydrocarbons (PAHs) consisting of two fusedbenzenerings (e.g., naphthalene) are found principally in the vapour phase and those consisting of five rings (e.g., benz(a)pyrene) are found predominantly in the particle phase.

Animportantcharacteristicofindooraircontaminantsisthattheirconcentrationsvary bothspatiallyandtemporallytoagreaterextentthaniscommonoutdoors.Thisisdue to the large variety of sources, the intermittent operation of some of the sources and thevarious sinks present.

Concentrations of contaminants that arise principally from combustion sources are subjectto very large temporal variation and are intermittent. Episodic releases of volatileorganiccompoundsduetohumanactivitiessuchaspaintingalsoleadtolarge variations in emission withtime. Other emissions, such as formaldehyde release from wood-basedproductsmayvarywithtemperatureandhumidityfluctuationsinthe

building,buttheemissioniscontinuous.Theemissionoforganicchemicalsfromother materials may be less dependent upon temperature andhumidity conditions but their concentrations in indoor air will be greatly influencedby ventilation conditions.

Spatial variations within a room tend to be less pronounced than temporal variations. Within a building there may be large differences in the case of localized sources, for example, photocopiers in a central office, gas cookers in the restaurant kitchen and tobacco smoking restricted to a designated area.

SourceswithintheBuilding

Elevated levels of pollutants generated by combustion, particularly nitrogen dioxide and carbon monoxide in indoor spaces, usually result from unvented, improperly vented orpoorly maintained combustion appliances and the smoking of tobacco products.Unventedkeroseneand gasspaceheatersemit significant quantities of CO, CO2, NOx, SO2, particulates and formaldehyde. Gas cooking stoves and ovens also releasetheseproductsdirectlyintotheindoorair.Undernormaloperatingconditions, vented gas-fired forced air heaters and water heaters should not release combustion productsintotheindoorair.Howeverfluegasspillageandbackdraftingcanoccurwith faulty appliances when the room is depressurized by competing exhaust systems and under certain meteorological conditions.

Environmentaltobaccosmoke

Indoor air contamination from tobacco smoke results from sidestream and exhaled mainstreamsmokeusuallyreferredtoasenvironmentaltobaccosmoke(ETS).Several thousand different constituents have been identified in tobacco smoke and the total quantities of individual components vary depending upon the type of cigarette andthe conditions of smoke generation. The main chemicals associated with ETS are nicotine, nitrosamines, PAHs, CO, CO_2, NOx, acrolein, formaldehyde and hydrogen cyanide.

Buildingmaterialsandfurnishings

Thematerialswhichhavereceivedgreatestattentionassourcesofindoorairpollution havebeenwood-basedboardscontainingureaformaldehyde(UF)resinandUFcavity wall insulation (UFFI). Emission of formaldehyde from these products results in elevated levelsof formaldehyde in buildings andthis has been associated with many complaints of poor indoor air quality in developed countries, particularly during the late 1970s and early 1980s. Table 44.2 gives examples of materials that release formaldehyde in buildings. These show that the highest emission rates may be associated with the wood-based products and UFFIwhichareproductsoftenusedextensivelyinbuildings.Particleboardis

manufacturedfromfine(about1mm)woodparticleswhicharemixedwithUFresins (6 to 8 weight%) and pressed into wood panels. It is widely used for flooring, wall panelling, shelving and components of cabinets and furniture. The plies of hardwood are bonded with UF resin and are commonly usedfor decorative wall panelling and components of furniture. Medium-density fibreboard (MDF) contains finer wood particlesthanthoseusedinparticleboardandthesearealsoboundwithUFresin.MDF is most often used for furniture. The primary source of formaldehyde in all these productsistheresidualformaldehydetrappedintheresinasaresultofitspresencein excess neededforthereactionwithureaduringthemanufactureoftheresin.Release is therefore highest when the product is new, and declines at a rate dependent upon product thickness, initial emission strength, and presence of other formaldehyde sources,localclimateandoccupantbehavior.Theinitialdeclinerateofemissionsmay be50%overthefirsteighttoninemonths,followedbyamuchslowerrateofdecline.

Secondary emission can occur due tohydrolysis of the UF resin and hence emission rates increase during periods of elevated temperature and humidity. Considerable efforts by manufacturers have led to the development of lower-emitting materials by useoflowerratios(i.e.closerto1:1)ofureatoformaldehydeforresinproductionand the use of formaldehyde scavengers. Regulation and consumer demand have resulted in widespread use of these products in some countries.