SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

UNIT – I – Prefabricated Structures – SCIA7017

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 may tend to be injurious to human beings or other living creatures or plants or property or enjoyment".

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 vapor in quantities or characteristics and of duration such as to be injurious to human, plant or animal life or to property or which unreasonably interferes with the comfortable enjoyment of life and property."

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.

Major Classification of Air Pollutants:

1] Primary – Secondary
2] Natural – Manmade
3] Criteria Air Pollutants
4] Physical - chemical - biological

Primary pollutants and secondary pollutants: Primary pollutants are substances that are directly emitted into the atmosphere from sources. Primary pollutants are those that are emitted directly from identifiable sources. Secondary air pollutants are those that are produced in the air by the interaction of two or more primary airpollutant.

Primary Air pollutants:-

(i) Fine (less than 100μ) and coarse (more than 100μ) suspended particulatematter

(ii) Oxides ofsulfur

(iii) Oxides ofnitrogen

(iv) Carbonmonoxide

(v) Halogens

(vi) Organiccompounds

(vii) Radioactivecompounds

Secondary Air pollutants:-

(i) Ozone

(ii) PAN (peroxiaceylnitrate)

(iii) Photochemicalsmog

(iv) Acidmists

Air pollutants arise from both manmade and natural processes. The ambient air quality may be defined by the concentration of a set of pollutants which may be present in the 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 into the atmosphere from plants etc. The air transported pollen grains range mainly between 10 and 50 microns. Manmade refers to any pollutant produced to influence or action ofhumans.

Aerosols: Aerosols refer to the dispersion of solid or liquid particles of microscopic size in the 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 by addition with other particles (agglomeration) it is no longer an air pollutant. The diameter of the aerosol may range from 0.01 (or less) micron to 100 micron.

The various aerosols are as follows:-

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

(ii) **Smoke:** Smoke is made up of finely divided particles produced by incomplete combustion. 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 visibility to less than 500 m. In natural fog the size of particles range from 1.0 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.Gases:

Following are the **main air pollutant gases**

(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 of nitrogen:** Oxides of nitrogen are produced either in the production of nitric acid or in the automobile exhausts and as the effluent of power plants. Out of the seven oxides of 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 asNO_X.

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

(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 compounds are methyl mercaptan (CH_3SH) and dimethyl sulphide (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 is respiratory 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 of photochemical reactions. Formaldehydes are irritating to theeyes.

Classification according to chemical composition: (Organic – inorganic)

1. Sulfur-containingcompounds.
2. Nitrogen-containingcompounds.
3. Carbon-containingcompounds.
4. Halogen-containingcompounds.
5. Toxic substances (any ofabout).
6. Radiativecompounds.

Classification according to physical state:

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,O_3.
2. Carbon monoxide,CO.
3. Sulfur dioxide, SO_2.
4. Nitrogen oxides,NO_x.
5. Lead,Pb.
6. Particulates,PM_{10}.

Pollutant	Description	Sources	Health Effects	Welfare Effects
Carbon Monoxide (CO)	Colorless, odorless gas	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 that dissolves in water vapor to form acid, and interact with other gases and particles in 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)	Reddish brown, 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 the formation of smog, acid rain, water quality deterioration, global warming, and visibility impairment.
Ozone (O3)	Gaseous pollutant when it is formed in the troposphere.	Vehicle exhaust and certain other fumes. Formed from other air pollutants in the presence of sunlight.	Eye and throat irritation, coughing, respiratory tract problems, asthma, lung damage.	Plant and ecosystem damage.
Lead (Pb)	Metallic element	Metal refineries, lead smelters, battery manufacturers, iron and steel producers.	Anemia, high blood pressure, brain and kidney damage, neurological disorders, cancer, lowered IQ.	Affects animals and plants, affects aquatic ecosystems.

Particulate Matter (PM)	Very small particles of soot, dust, or other matter, including tiny droplets of 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.

Emission Sources

Major Classification of Air Pollution Sources:

1] Based on Origin: Natural and Manmade

While man-made air pollution does present health hazards, natural sources of air pollution can be equally dangerous at times. These sources include dust picked up by wind erosion, the emission of 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. These can produce clouds of abrasive volcanic ash and other harmful substances such as chlorine and sulfur.

2] Based on Position: Stationary and Mobile

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

3] Based on Aix of Release: Horizontal axis (Roadways traffic)

Vertical Axis release (Industrial Stacks)

4] Based on Intensity/frequency of release: Continuous release (Industrial Stacks)

Instantaneous release (Roadways traffic)

Stationary Sources

The stationary industrial sources are usually classified by process type or sub-type. Thus an oil 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 theplant.

(i) Point source (power plantstacks)

(ii) Area source (forest fires, openburning)

(iii) Line Source (highway vehicleexhausts)

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.
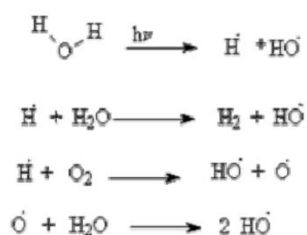
Chemical Reactions in the Atmosphere

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 compounds with successively larger carbon to hydrogen ratios and finally to products with a form of pure carbon. However, atmospheric chemical reactions have the opposite effect on substances, causing an atom to 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.

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

Chemical reactions in the atmosphere can occur as gas phase collisions between molecules, on the surfaces of solid particles or in aqueous solution (in water droplets); predominantly acid-base reactions. Particles spend short residence time in the atmosphere. Due to this, reactions that 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 is formed by several reactions. However, the primary process is one where an O-H bond of the water molecule is broken to form a hydrogen atom (H·) and a hydroxyl radical (HO·). The hydrogen atom can then react with another water molecule to form hydrogen and 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 to form two new hydroxylradicals.

$$\underset{H}{\overset{H}{\diagdown}} O^- H \xrightarrow{h\nu} \dot{H} + H\dot{O}$$

$$\dot{H} + H_2O \longrightarrow H_2 + H\dot{O}$$

$$\dot{H} + O_2 \longrightarrow H\dot{O} + \dot{O}$$

$$\dot{O} + H_2O \longrightarrow 2\, H\dot{O}$$

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(*).

$$\cdot NO_2(g) \xrightarrow{h\nu} \cdot NO_2^*$$
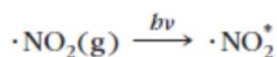
The excited molecule may quickly re-emit a photon of light, or the energy may break an N-O bond to form a nitrogen monoxide (NO) molecule and an oxygen atom (O). Both NO and O are free radicals, because they have one or more unpaired electrons each denoted by adot.

$$\cdot NO_2^*(g) \xrightarrow{b\nu} \cdot NO(g) + \cdot O \cdot (g)$$
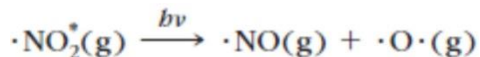
Photodissociation is another mechanism of formation of radicals, in which a molecule absorbs an ultraviolet photon and produces two free radicals as products. Molecular oxygen can photodissociate to form two oxygen atoms.

$$O_2(g) \xrightarrow{b\nu} \cdot O \cdot (g) + \cdot O \cdot (g)$$
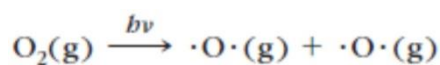
Some free radicals, such as an oxygen atom, react with another atom or molecule almost immediately. Others, such as an NO2 molecule, are not quite so reactive and are stable enough to exist for a somewhat longer time. Most radicals are highly reactive and short-lived.

Fate of air pollutants in the atmosphere

1] NO_x, Hydrocarbons, Ozone, Mist: - Formation of photochemical smog

2] SO_2, NO_x: - Formation of Acid Mist / Rain

3] SO_2, CO, Mist: - Formation of coal induced smog

4] [O], NOx, OH^- - Formation of Ozone

PHOTO CHEMICAL SMOG

Photochemical smog was first described in the 1950s. It is the chemical reaction of sunlight, nitrogen oxides and volatile organic compounds in the atmosphere, which leaves airborne

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 usually highly 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, dry climates and a large number of motor vehicles. Because it travels with the wind, it can affect sparsely populated areas as well.

$$VOCs + NOx + sunlight \rightarrow photochemical\ smog$$
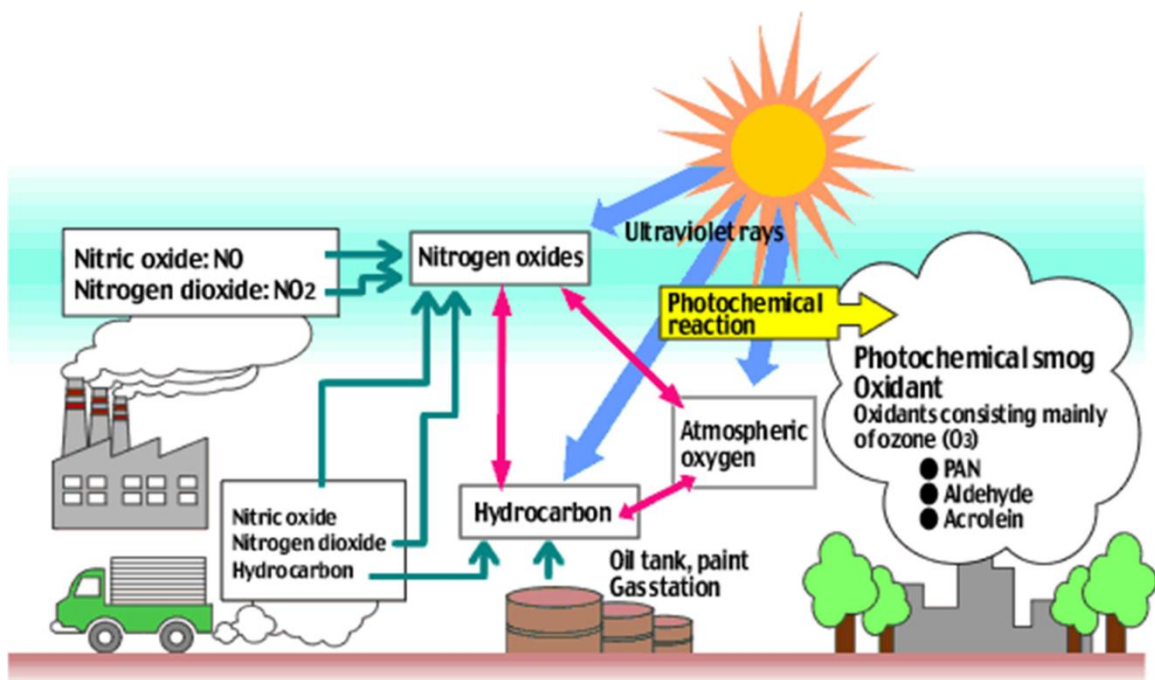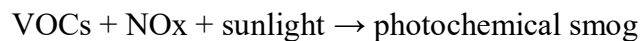
To begin the chemical process of photochemical smog development the following conditions must occur:

- Sunlight.

- The production of oxides of nitrogen(NOx).

- The production of volatile organic compounds(VOCs).

- Temperatures greater than 18 degreesCelsius.

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 can break down nitrogen dioxide back into nitrogen oxide.

$$NO2 + sunlight »»» NO + O$$

The atomic oxygen formed in the above reaction then reacts with one of the abundant oxygen molecules producing ozone.

$$O + O2 »»» O3$$
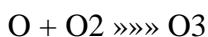
Nitrogen dioxide can also react with radicals produced from volatile organic compounds in a series of reactions to form toxic products such as peroxyaceyl nitrates.

$$NO2 + R »»» products such as PAN$$

Note the symbol R represents a hydrocarbon (a molecule composed of carbon, hydrogen and other atoms) which is primarily created from volatile organic compounds.

Steps

1) Nitrogen oxides generate oxygenatoms

2) Oxygen atoms form hydroxylradicals

3) Hydroxyl radicals generate hydrocarbonradicals

4) Hydrocarbon radicals form hydrocarbonperoxides

5) Hydrocarbon peroxides formaldehydes

6) Aldehydes form aldehydeperoxides

7) Aldehyde peroxides formperoxy-acyl-nitrates

Health effects

It can cause eye and nose irritation and it dries out the protective membranes of the nose and throat and interferes with the body's ability to fight infection, increasing susceptibility toillness.

COAL INDUCED SMOG

Introduction to Smog

Smog is a recent compound word from "smoke" and "fog", and was coined by Harold Antoine des Voeux, a doctor, in 1905. Smog refers to locally high concentrations of acids, dry acid- forming compounds, particulates, or other pollutants in stagnant, stable air. Smog's form when emissions are prevented from dispersing by stable or sinking air masses. They were 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.

$$HSO_{2\ 4(g)} + H_2O_2 \ \square \ HSO_{2\ 4(aq)}$$

$$SO_{2(g)} + HO_{2\ (l)} \ \square \ H_2SO_{3(aq)}$$
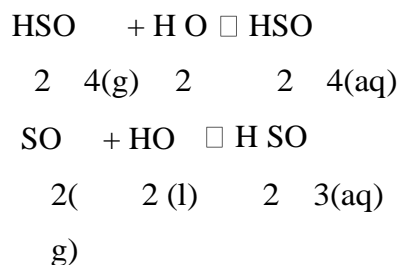
Chemistry

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 street by 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 in the following week. Bronchitis and emphysema were the two conditions that stood out in the coroner's records as showing the greatest increase. Cardiovascular disease accounted for 22 per cent of the increased number of deaths in the first week and 16 per cent in the week ending 20 December. The disaster ultimately led to the introduction of the Clean AirActs.

ACID MIST/ RAIN

Definition

Normal Rain water p^H is slightly acidic due to certain concentration of CO_2dissolved as rainwater trickles downatmosphere,

$$CO_2 + H_2O \rightarrow HCO^{3-} + H^+$$
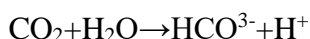
Acid rain is defined as any type of precipitation with a p^H that is unusually low or lower than 5.7. Acid rain was first found in Manchester, England. In 1852, Robert Angus Smith found the relationship between acid rain and atmospheric pollution. Though acid rain was discovered in 1852, it wasn't until 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 principal cause of acid rain is sulfuric and nitrogen compounds from human sources, 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, but this 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 seventy percent of acid rain while nitrogen oxides provide the remaining thirty percent. The sources of sulfur in the atmosphere include coal combustion, smelting, organic decay, and ocean spray. Approximately ninety percent of atmospheric sulfur results from human activities.

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

$$gas: SO_2 + H_2O + 1/2O_2 \rightarrow H_2SO_4$$
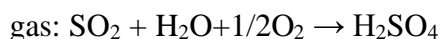
Next, hydrogen sulfite reacts with oxygen to form sulfuric acid, a major component of acid

$$rain: H_2SO_3 + 1/2O_2 \rightarrow H_2SO_4$$
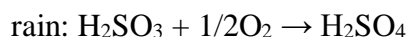
The sources of nitrogen oxides include the combustion of oil, coal and natural gas, forest fires, bacterial action in soil, volcanic gases, and lighting-induced atmospheric reactions.

In the atmosphere, nitrogen monoxide reacts with oxygen gas to form nitrogen dioxide

$$gas: NO + 1/2O_2 \rightarrow NO_2$$
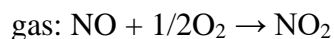
Then, nitrogen dioxide reacts with water vapor in the atmosphere to form hydrogen nitrite and hydrogen nitrate:

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$
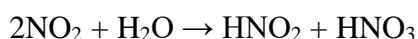
Henceforth, acid rain is a mixture of HNO_3, H_2SO_4 + HCl. however conditions needed to favor formation of these are sunlight, temperature, humidity, hydrocarbons, NO_X, SO_2.

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 hatch and lower p^H can kill adult 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 usually a direct result of acid rain; often it weakens trees and makes them more susceptible to other threats. Some scientists have suggested direct links to human health, 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 deaths such as cancer and other deadlydiseases

Toxic metals released into the environment by acid rain may enter water supplies or accumulate in 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 can also cause damage to certain building 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 rate of oxidation foriron.

Control

> Design more efficient automobile engines in order to reduce nitrogen oxideemissions.

> Increase efficiency of power plants that burn coal in order to reduce waste that contains sulfur dioxide and nitrogenoxide.

> Increase penalties on industries that do not meet air pollutionguidelines.

> Increase tax incentives to industries that do meetguidelines.

> Use alternative energy sources, Increase funding for alternative energy sources; for example, give tax incentives to buyers of hybridcars.

> Provide tax incentives to companies that use alternative energysources.

> Add $CaCO_3$ (calcium carbonate) to lakes suffering from acid deposition; calcium carbonate acts as a buffer, resisting a change in p^H and lessening the negative effects of acid rain.

OZONE DEPLETION

Definition

Ozone layer is an umbrella 24 km [15 miles] from earth surface, an essential component of the stratosphere that absorbs short wavelength ultraviolet radiation from the sun, heating the gases of the stratosphere in the process. World ozone day is celebrated on Sept, 16 of 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 200 DU, it's considered as Ozone hole. It is thinnest around equator and thickest nearpoles.

Stratospheric ozone depletion is the term applied to the loss of stratospheric ozone molecules (O_3) and the disruption of Oxygen-Ozone concentration equilibrium in stratosphere [i.e., when chlorine atoms upset the natural O_2/O_3 equilibrium 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).
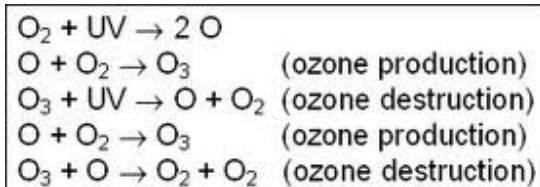
Causes

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. The discussion below focuses on CFCs, but is relevant to all ODS [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 process that can take as long as 2 to 5 years. When CFCs reach the stratosphere, the ultraviolet radiation from the sun causes them to break apart and release chlorine atoms which react with ozone, starting chemical cycles of ozone destruction that deplete the ozone layer. One chlorine atom can break apart more than 100,000 ozonemolecules.

Other chemicals that damage the ozone layer include methyl bromide (used as a pesticide), 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, which are 40 times more destructive to ozone molecules than chlorineatoms.

Chapman's Reaction

$$O_2 + UV \rightarrow 2\,O$$
$$O + O_2 \rightarrow O_3 \qquad \text{(ozone production)}$$
$$O_3 + UV \rightarrow O + O_2 \quad \text{(ozone destruction)}$$
$$O + O_2 \rightarrow O_3 \qquad \text{(ozone production)}$$
$$O_3 + O \rightarrow O_2 + O_2 \quad \text{(ozone destruction)}$$

All above reactions occur in the presence of UV rays, while the 2nd set of reactions governs the oxygen-ozone equilibrium due to its spontaneity.

Effects

Effect of ozone 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 factor to 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 of cornea (outer coating of eyeball). The most common forms of skin 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% of the cases diagnosed. In India there is no standard for Ozone. However WHO standard is 100 ppm for 8 hrs. – avg.

Control Measures

The Montreal Protocol, an international agreement signed by 139 nations, banning the 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 production could result in additional damage and prolong the ozone layer's recovery. Control mechanism stresses on replacement of the banned chemical by ammonia, steam, heliumetc.

SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

# UNIT – II – Prefabricated Structures – SCIA7017

Air Pollution and Meteorology

The science of meteorology has great bearing on air pollution. An air pollution problem involves 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 patterns on scales of a 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, rural open land, irregular topography and urban development, effect of radiant heat from deserts and cities, effect of lakes, etc. The movement of air 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 ofpollutants.

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 according to 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 from which the wind was blowing, the length of various segments of the spokes show the percent of time the wind was of the designated speed. Thus from the diagram, most often (12% of time) the wind was from SE; the strongest wind (9-11 m/s) was from NW andNNW.
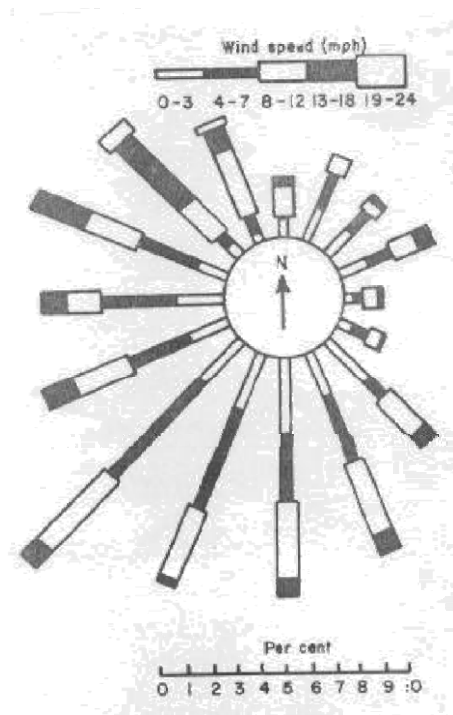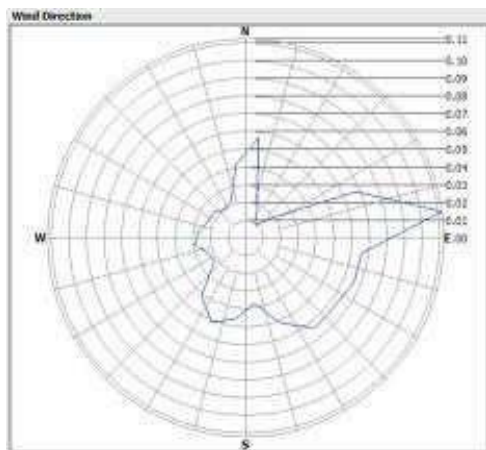
Importance of wind rose in air pollution studies

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 city planning and siting ofindustries.

An anemometer is a device for measuring wind speed, and is a common weather station instrument. Anemometers can be divided into two classes: those that measure the wind's speed, 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 of four horizontal arms, which in turn were mounted at equal angles to each other on a vertical shaft. The air flow past the cups in any horizontal direction turned the cups in a manner that was proportional to the wind speed. Therefore, counting the turns of the cups over a set time period produced the average wind speed for a wide range of speeds. On an anemometer with four cups it is easy to see that since the cups are 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 thecross.
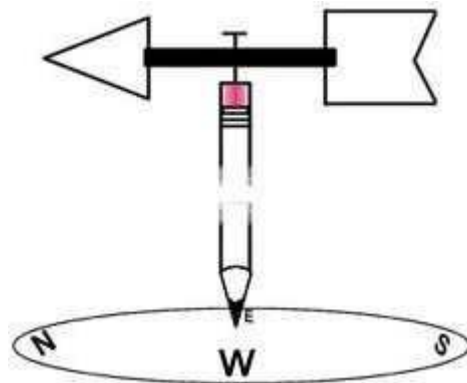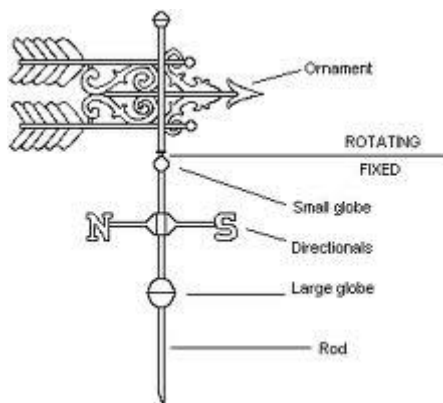
A weather vane (or weathercock) is an instrument for showing the direction of the wind . They are typically used as an architectural ornament to the highest point of a building. Although partly functional, weather vanes are generally decorative, often featuring the traditional cockerel design with letters indicating the points of the compass. Other common motifs include ships, arrows andhorses.

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 unequally divided, so that the pointer can move freely on its axis. The side with the larger surface area is blown away from the 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 mean wind speed variation with altitude is the planetary boundary layer can be represented by a simple empirical power.

$$\frac{U}{U1} = \left[\frac{Z}{Z1}\right]\alpha \ -\ -\ -\ -\ -\ -\ -(2.11)$$
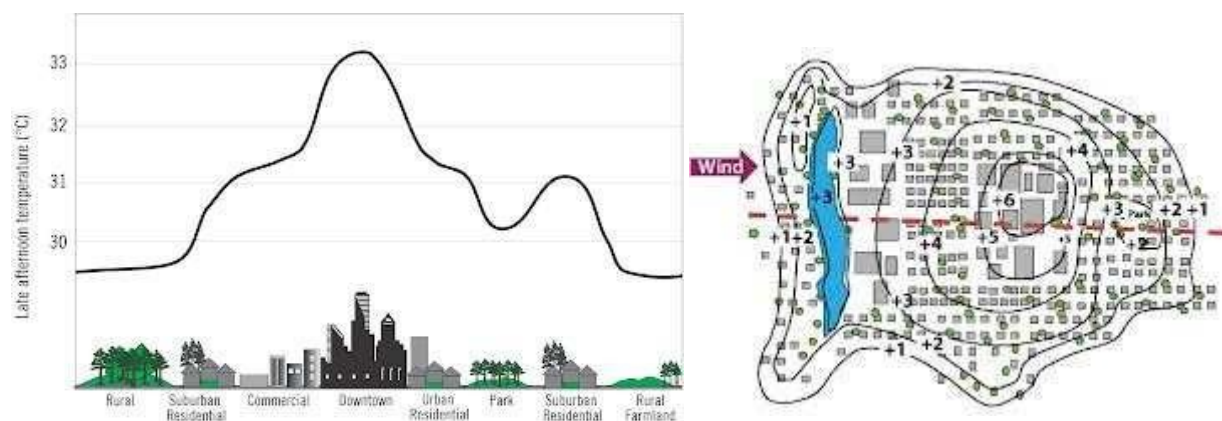
Where: U is the wind at altitude Z

U₁ 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

Urban Heat Islands

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 of all these 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 away from cities. In fact, UHIs have been indirectly related 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 builtsurfaces, 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 that contributes 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.

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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 generated by 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 form urban canyons that inhibit the escape of the reflected radiation from most of the three-dimensional urban surface to space. This radiation is ultimately absorbed by the building walls (i.e. reduced sky view factor), thus enhancing the urban heat release. Additional factors such as the scattered and emitted radiation from atmospheric pollutants to the urban area, the production of waste heat from air 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 been recognized 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 with poor thermal isolation. This increases the overall energy consumption for cooling (i.e. refrigeration and air-conditioning), hence increasing the energy production by power 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 energy demand means more costs to citizens and goverments, which in large metropolitan areas may induce significant economic impacts. On the other hand, UHIs promote high air temperatures that contribute to formation of ozone precursors, which combined 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 and respiratory systems. Heatstroke, heat exhaustion, heat syncope,and heat cramps, are some of the main stress events, while a wide number of diseases may become worse, particularly in the elderly and children. In a similar way, respiratory and 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 reducing heat gain to the building. Cool pavements have mainly based on the use of whitened asphalt roads, a very warmmaterial.

Urban Dust Domes

Urban dust domes are a meteorological phenomenon in which soot, dust, and chemical emissions 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 descendslowlyontheperipheryofthedevelopedcore.Thiscycleisoftenacauseofsmog

through photochemical reactions that occur when strong concentrations of the 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.

Atmospheric Stability

The ability of the atmosphere to disperse the pollutants emitted in to it depends to a large extent on the degree of stability. A comparison of the adiabatic lapse rate with the environmental lapse rate gives an idea of stability of the atmosphere. When the environmental lapse rate and the dry adiabatic lapse rate are exactly the same, a raising parcel of air will have the same pressure and temperature and the density of the surroundings and would experience no buoyant force. Such atmosphere is said to be neutrally stable where a displaced mass of air neither tends to return to its original position nor tends to continue its displacement

Lapse rate

As a parcel of air rises in the earth's atmosphere it experiences lower and lower pressure from the 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.*

If the parcel moves down it warms up at the same rate. For a particular place at a particular 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,* or the *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 by drop of less than 1ºC/100 m. A special case of weak lapse rate is the inversion, a condition which has warmer layer above colderair.
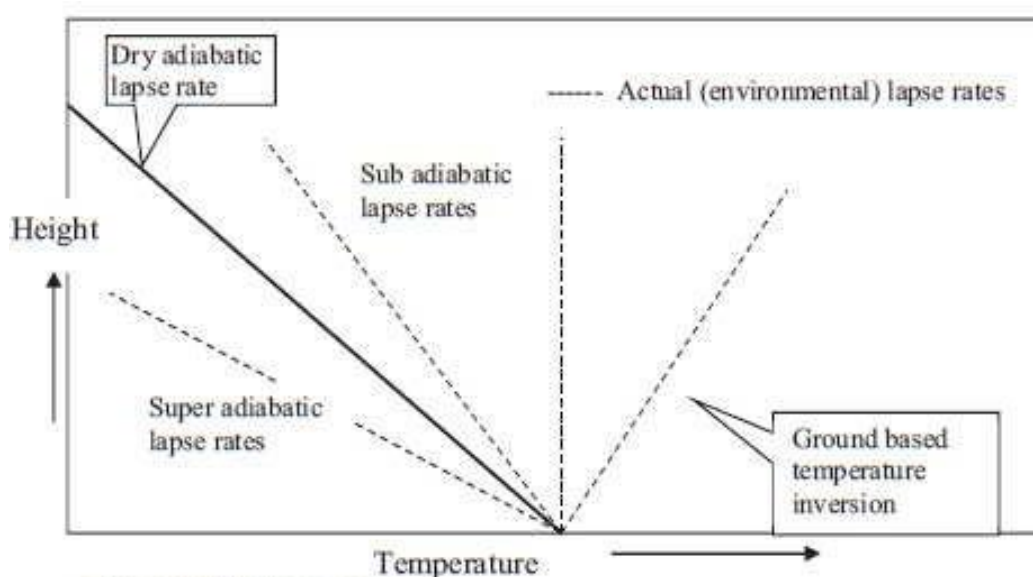

During super-adiabatic lapse rate the atmospheric conditions are unstable. If a parcel of air at 500m elevation, at 20ºC is pushed upward to 1000m, its temperature will come down to 15ºC (according to adiabatic lapse rate). The prevailing temperature is however 10ºC at 1000m. The parcel of air will be 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 20°C. If the parcel is displaced to 1000 m it will cool by 5°C to 15°C. 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.
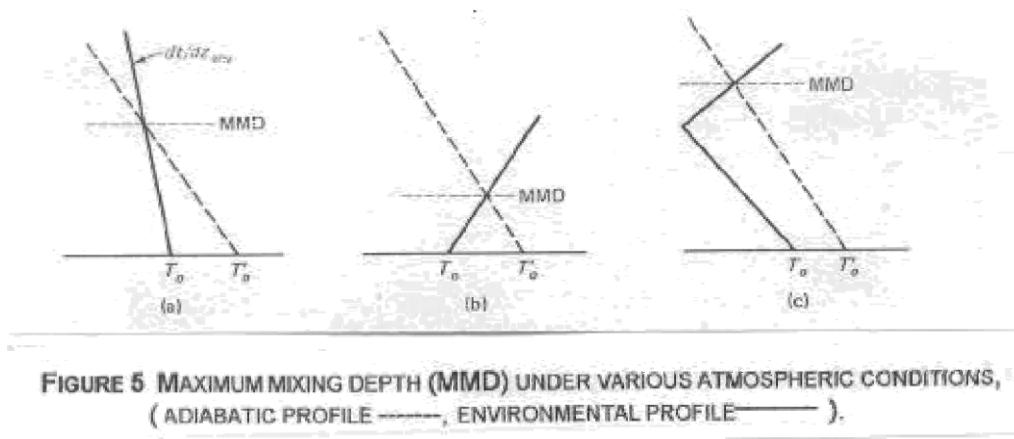
Inversion

An inversion is an extreme sub-adiabatic condition, and thus the vertical air movement within the 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 results in a temperature profile in the lower atmosphere, which is represented by a negative temperature gradient. On a clear night, the ground surface radiates heat and quickly cools. The air layer adjacent to the earth surface are cooled to a temperature below that of the layers of air at higher elevations. This type of the inversion is strongest just before daylight when it may extend to 500 m. It breaks up as the morning sun heats theground.

FIGURE 4 ILLUSTRATIONS OF SUBSIDENCE AND RADIATION INVERSIONS.
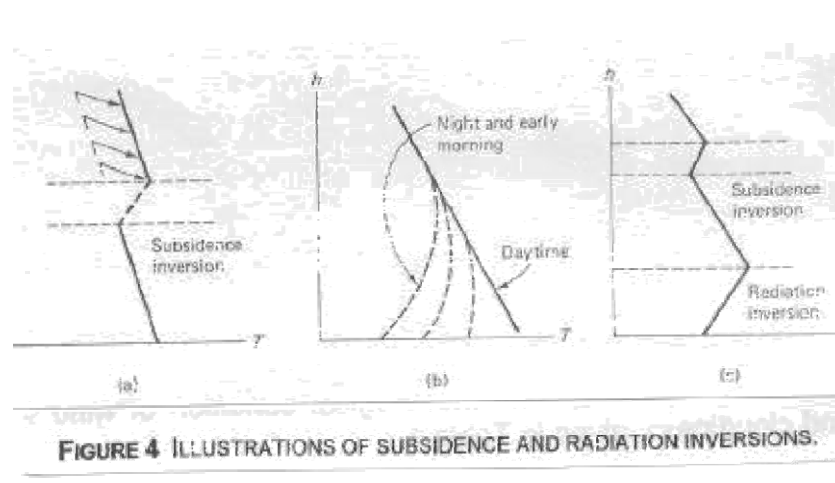
Maximum mixing depth

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 also affected 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 rateprofiles.

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 ground level 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————).

Plume Dispersion

Gases that are emitted from stacks are often pushed out by fans. As the turbulent exhaust gases exit the stack they mix with ambient air. This mixing of ambient air into the plume 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 stream to 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.
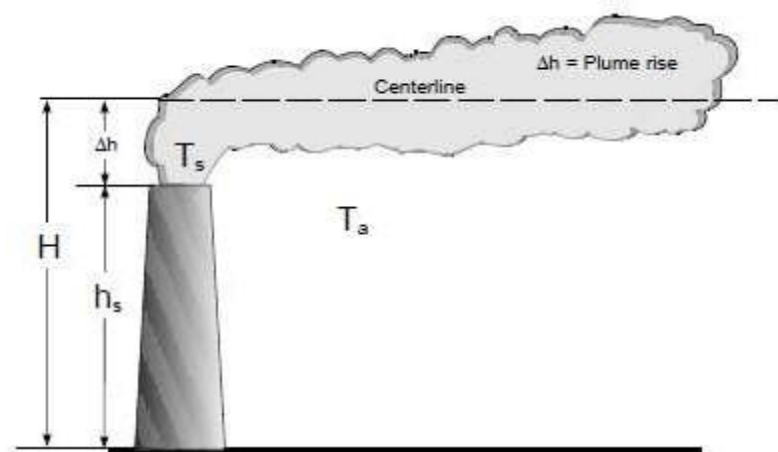
The final height of the plume, referred to as the effective stack height (H), is the sum of the physical stack height (hs) and the plume rise (Δh). Plume rise is actually calculated as the distance to the imaginary centerline of the plume rather than to the upper or lower edge of the plume (Figure 6-1). 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.

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The Gaussian plume model

The present tendency is to interpret dispersion data in terms of the Gaussian model. The standard deviations are related to the eddy diffusivities.

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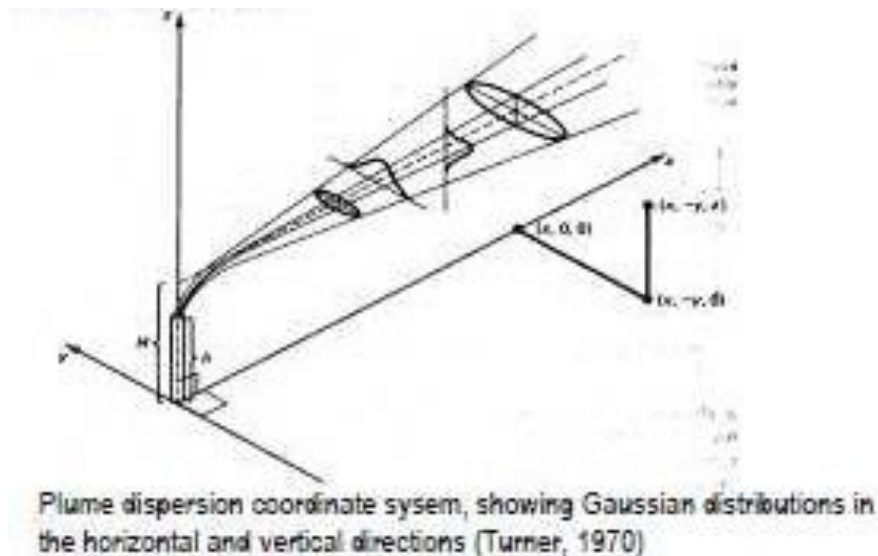
Ground level concentration

In this case Z=0

$$[\rho 4](x,y,0,H) = \frac{Q}{\pi \delta y\, \delta z u} \exp\left(\frac{-1}{2}\left[\frac{y}{\delta y}\right]^2\right) \cdot \exp\left[\frac{-1}{2}\left(\frac{H}{\delta z}\right)\right]$$

Dispersion characteristics of stack plumes

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 reachingground.

Looping

Under super-adiabatic condition, both upward and downward movement of the 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 in the presence of a negative lapse rate when vertical dispersion 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 unstable layers.
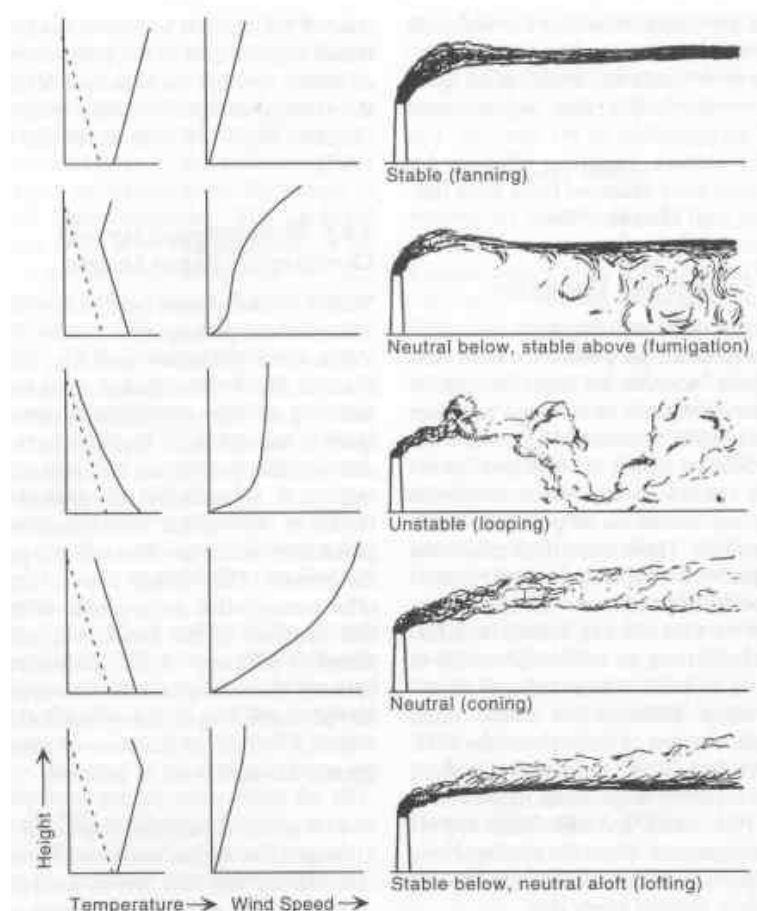
SCHOOL OF BUILDING AND ENVIRONMENT

DEPARTMENT OF CIVIL ENGINEERING

UNIT – III – Prefabricated Structures – SCIA7017

AIR POLLUTION CONTROL

CONTROL DEVICES FOR PARTICULATE EMISSIONS

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 filters and penetrate deeply into the lungs, which could cause harm to human health. 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.

VENTURI SCRUBBERS

Venturi scrubbers use a liquid stream to remove solid particles. A venturi scrubber accelerates the waste gas stream to 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 is sprayed into the gas stream before the gas encounters the venturi throat, or in the throat, or upwards against the gas flow in the throat. The scrubbing liquid is then atomized into small droplets by the turbulence in the 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.
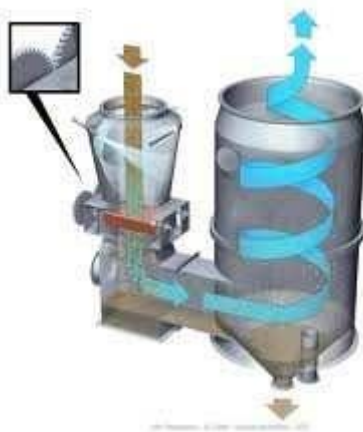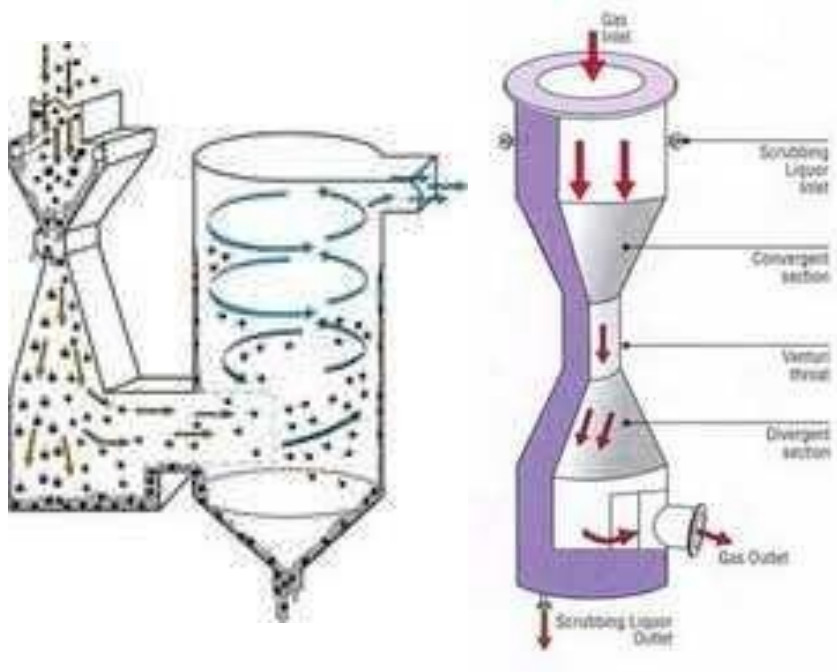
Advantages of Venturi Scrubbers

• Capable of handling flammable and explosivedusts

• Can handle mists in processexhausts

• Relatively lowmaintenance

• Simple in design and easy toinstall

• Collection efficiency can bevaried

• Provides cooling for hotgases

• Neutralizes corrosive gases and dusts

Disadvantages of Scrubbers

• Effluent liquid can create water pollutionproblems

• Waste product collectedwet

• High potential for corrosionproblems

• Requires protection againstfreezing

• Final exhaust gas requires reheating to avoid visibleplume

• Collected PM may be contaminated, and notrecyclable

• Disposal of waste sludge may be veryexpensive

ELECTROSTATIC PRECIPITATORS.

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 where gaseous ions flow. Electrodes in the center of the 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 of the ESP that run through the axis of each tube. Rigid electrodes are generally supported by both an upper and lower frame. The power supplies for the ESP convert the industrial AC voltage to pulsating DC voltage in the range of 20,000 to 100,000 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 electrode to the collecting pipe. Therefore, each electrode-pipe combination establishes a charging zone through which the particles mustpass.

As larger particles (>10µm diameter) absorb many times more ions than small particles (>1µm diameter), the electrical forces are much stronger on the large particles. When the collection plates 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 collection efficiency of an ESP is quite reliably about 99 percent for particles less than 10 micrometers. ESPs, in general, are very expensive to operate and are not very well suited for use in industrial processes because they are too sensitive to fluctuations in the gas stream. The Electrostatic Precipitator (ESP) separates particles from the gas stream by electrically charging theparticles.
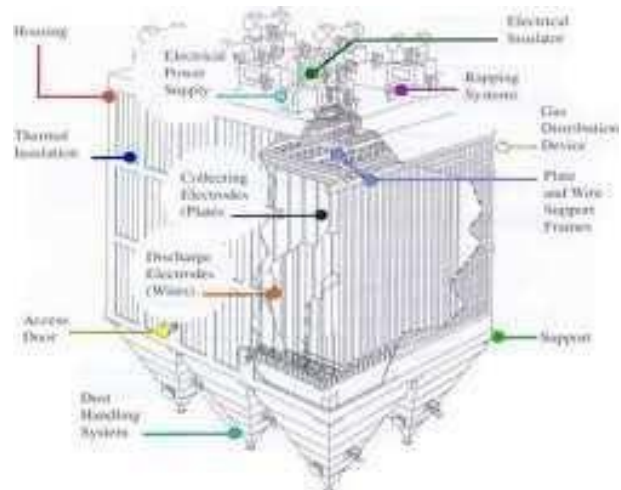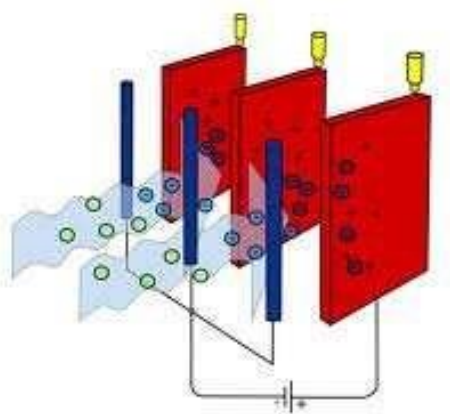
FABRIC FILTER

In a fabric filter, flue gas is passed through a tightly woven or felted fabric, causing PM in the 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) are useful only at relatively low temperatures of 95° to 150ºC (200° to 300ºF). For high temperature flue gas streams, more thermally stable fabrics such as fiberglass, Teflon, or Nomex must beused.

The practical application of fabric filters requires the use of a large fabric area in order to avoid an 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 to cloth area. The selection of air-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 avoid forming too heavy a dustcake.

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 greater

fraction of particulate. In order to accomplish this, some fabrics are coated with a membrane of very fine openings for enhanced removal of submicron particulate. 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 lower the removal efficiency of the fabric filter. On the other hand, if removal is too infrequentor
too ineffective, then the baghouse pressure drop will become too high.

Mechanical shaking of the bags has been a 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 been used extensively and improved over the years. It is a gentler but sometimes less effective cleaning mechanism than mechanical shaking. Most reverse-air fabric filters operate in a 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 of the 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 in direction of the gas flow causes the bag to flex and crack the filter cake. In internal cake collection, the bags are allowed to collapse to some extent during reverse-air cleaning. The bags are usually prevented from collapsing entirely by some kind of support, such as rings that 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-airsystems.

Fabric filters in general provide high collection efficiencies on both coarse and fine (submicron) particulates. Typical new equipment design efficiencies are between 99% and 99.9%.
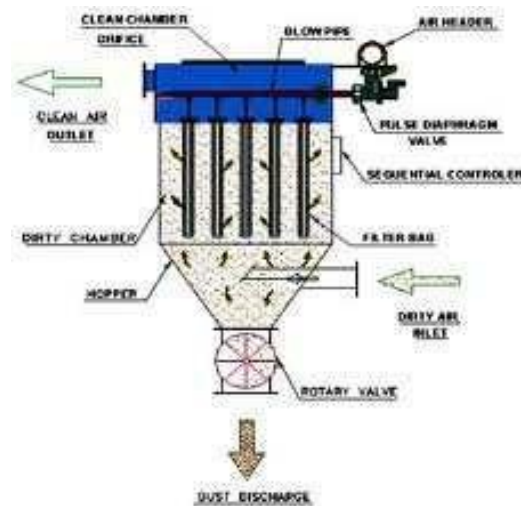
SETTLING CHAMBERS

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, expansion chambers, and outfall chambers. This is because settling chambers are quite effective 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 Chamber

Clean Gas Out

Dirty Gas In

Dust Hoppers
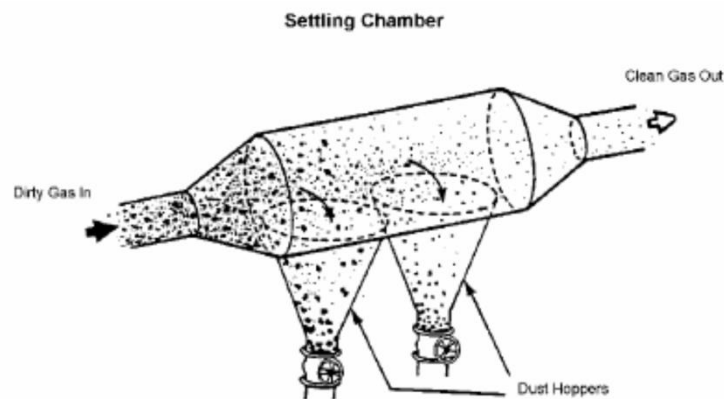
Settling chambers, which rely on gravitational settling as a collection mechanism are the simplest and oldest mechanical collectors. Settling chambers are generally built in the form of long, horizontal, rectangular chambers with an inlet at one end and an exit at the side or top of the opposite end. 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 the gas 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 they are 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 of settling 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-tray settling chambers may experience plugging of the individual gas passages. Such failures can be prevented or minimized by use of hopper level indicators or by continuous monitoring of the dust discharge. Scheduled internal inspection can determine areas of air leakage and condensation, both of which 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

Advantages of Settling Chambers

• Low capitalcost

• Very low energycost

• No movingparts

• Few maintenancerequirements

• Low operatingcosts

• Excellentreliability

• Low pressure drop throughdevice

• Device not subject to abrasion due to low gasvelocity

• Provide incidental cooling of gasstream

• Dry collection anddisposal

Disadvantages of Settling Chambers

• Relatively low PM collectionefficiencies

• Unable to handle sticky or tackymaterials

• Large physicalsize

• Trays in multiple-tray settling chamber maywarp

Control of gaseous pollutants from stationary 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 from the gas either enter the inside of the 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 usually weak 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. In carbon adsorption, the gas is attracted and adheres to the porous surface of the activated carbon. Removal efficiencies of 95 percent to 99 percent 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 cleaningprocess.

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, another bed

is 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 pollutant in the gas stream is relatively high. Non-regenerative systems have thinner beds of activated carbon. In a non-regenerative adsorber, the spent carbon is disposed of when 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.
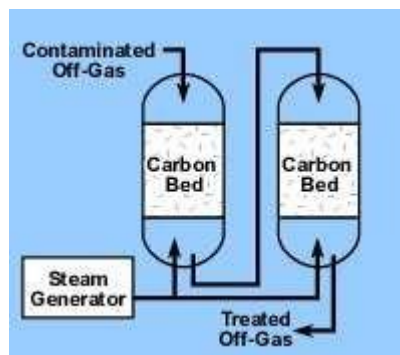
Regenerative CarbonAdsorptionSystem
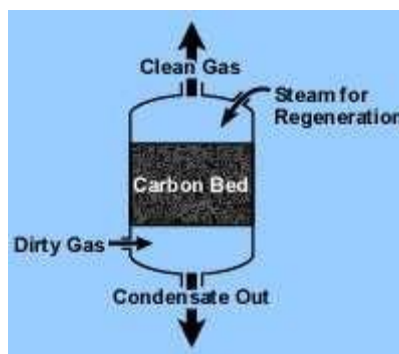
Non-RegenerativeCarbon AdsorptionSystem

Control of gaseous pollutants from stationary sources – Absorption

The removal of one or more selected components from a gas mixture by absorption is probably the most important operation in the control of gaseous pollutant

emissions. Absorption is a process 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 commonly used 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 of absorption equipment. The principal types of gas absorption equipment include spray towers, packed columns, spray chambers, and venture
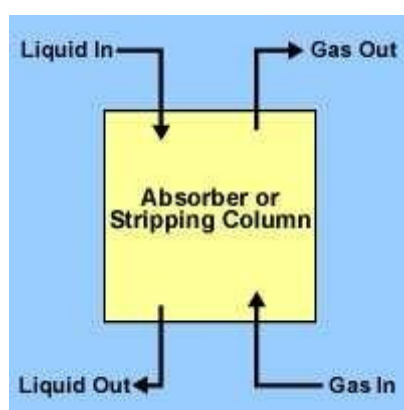
Typical packed column diagram

scrubbers. The packed column is by far the most commonly 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 capability of the column. In addition, the introduction of the gas and liquid at opposite ends of the column causes mixing to be more efficient because of the counter-current flow through 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 – IV – Prefabricated Structures – SCIA7017

AIR QUALITY MANAGEMENT

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. The sources of air pollutants include vehicles, industries, domestic and natural sources. The presence of air pollutants in the 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 AirQuality 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 operationand

maintenance. 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 alsohavemajor 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-

engine motor vehicles. These include carbon monoxide (CO), oxides of nitrogen (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 containmicroscopic

1solids 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 from the original emission site. The report presents results of ambient air quality monitoring carried out during the year 2008 at various monitoring stations under NAMP. Four criteria pollutants namely sulphur dioxide, nitrogen dioxide,respirable suspended particulate matter and suspended particulate matter have been monitored regularly at 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 carbonmonoxide monitored in Delhi and ammonia in six 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 Pollutants

a) Sulphur dioxide(SO2)

SO2, is formed when fuel containing sulfur is burned. Sulfur is prevalent in raw materials such as crude oil, coal, and ore that contain common metals like aluminum, copper, zinc, lead etc. SO2 reacts with other gases in the atmosphere to formsulphates that can cause harm to human health. Effects of SO2 include respiratory illness, visibility impairment, acid rain and aesthetic damage. Sulfur oxides are emitted in significant quantities from thermal power plants, smelting process of sulfide ores to produce copper, lead and zinc and also from petroleum refining processes. The diesel driven vehicles are specific source of sulfur dioxide generated during combustion process. Sulfate particles, can be transported over long distances and deposited far from the sources. SO2 can result in respiratory illness, particularly in children andthe

elderly, and it can also aggravate existing heart and lung diseases.

b) Oxides of Nitrogen (NOx)

Oxides of nitrogen are a generic term for a group of highly reactive gases that contain nitrogen and oxygen in varying amounts. Nitrogen dioxide (NO2) along with particulates is seen as a reddish brown layer over urban areas. Nitrogen oxides are formed when fuel is burned at high temperature. Sources of nitrogen oxides includes vehicles, industrial processes that burn fuel. Oxides of nitrogen react with Volatile Organic Compounds (VOCs) to form ground level ozone. They also react to formnitrates, acid aerosols. They also contribute to nutrient overload that deteriorates water quality. Nitrogen dioxide irritates the nose and throat, and it appears to increases usceptibility to respiratory infections.

c) Particulate Matter (RSPM10 &PM2.5)

Particulate matter is a mixture of many subclasses of pollutants that contain many different chemical species. The particle size is often described by aerodynamic diameter. Aerodynamic diameter depends on particle density and is defined as the diameter of a particle with the same settling velocity as spherical particle with unit density i.e. 1 g/cm3 (USEPA, 1996). PM10 are the particles with upper size limited bya 50% cut at 10 μm aerodynamic diameter (USEPA, 1996). PM10 can be formed by physical processes of crushing, grinding and abrasion of surfaces. Mining and agricultural activities are some of the sources of large size particles.PM2.5 are the particles with upper size limited by a 50% cut at 2.5 μm aerodynamic diameter(USEPA, 1996). Particulate matter is called primary if it is in the same form chemical form in which it is emitted into the atmosphere. The primary particulate matter includes wind blown dust such as road dust, fly ash, soot etc. Particulate matter is called secondary it is formed by chemical reactions in the atmosphere. Secondary particulate matter include sulphates, nitratesetc.

The size of particles is directly linked to their potential for causing health problems. Small particles less than 2.5 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your blood stream. Numerous scientific studies have linked particle pollution exposure to a variety of problems, including increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease (USEPA, 2008). People with heart or lung diseases, children and older adults are the most likely to be affected by particle pollution exposure (USEPA, 2008). Environmental effects of particulate matter include visibility reduction, aesthetic damage etc.

Composition of Particulate Matter

Atmospheric particles include combustion-generated particles, such as diesel soot or fly ash; photochemically produced particles, such as those found in urban haze; and soil-like particles from resuspended dust. The major constituents of RSPM are organic and elemental carbon, metals/elements like silicon, magnesium, iron, ions like sulphates, nitrates, ammonium etc. Understanding composition of particulate matter is most important to gain insight into the health effects caused and sources to be controlled. Composition of particulate matter varies from place to place and season depending upon sources present.

(i) ElementalCarbon

Elemental carbon (EC), also called __black carbon'' or __graphitic carbon'', has a chemical structure similar to impure graphite. Atmospheric elemental carbon is from primary anthropogenic sources and is not formed by reactions involving gaseous hydrocarbon precursors in the atmosphere. EC plays an important role in atmospheric chemistry because of its adsorptive and catalytic properties, which can capture other pollutants to react on its surface.

(ii) Organic Carbon

Organic carbon (OC), a mixture of hydrocarbons and oxygenates, is formed by a variety of processes, including combustion and secondary organic aerosol (SOA) formation. Organic carbon may be emitted as primary particles directly from sources, but secondary organics can also be formed in the atmosphere from the low vapor pressure products of atmospheric chemical reactions. OC is a complex mixture of different organic compounds, containing polycyclic aromatic hydrocarbons and othercomponents.

(iii) Elements/Metals

Calcium, aluminum, silicon, magnesium, and iron are some of the crustal material found predominately in the coarse particles. Most of the elements are emitted from coal, oil combustion, vehicles, and industrial processes. Other sources include crustral material from road dust, tyre wear, construction activities etc.

(iv) Ions

The common ions found in particulate matter are sodium, sulphates, nitrates, calcium, chloride, potassium. Potassium and nitrate may be found in both the small size and coarse particles. Potassium comes from soil in coarse particles and in small size particles it comes from wood burning. Nitrate in formed by reaction of gas phase nitric acid with gas-phase ammonia forming particulate ammonium nitrate.

d) Carbon Monoxide(CO)

Carbon monoxide is a colorless, odorless and poisonous gas. It is formed by incomplete combustion of carbon containing fuels. Major source of CO are vehicles. Incomplete combustion is most likely to occur at low air-to-fuel ratios in the engine. These conditions are common during vehicle starting when air supply is restricted and are not tuned properly, and at altitude, where thin air effectively reduces the amount of oxygen available for combustion. CO enters the bloodstream through lungs and forms carboxyhemoglobin which inhibits blood's oxygen carrying capacity to organs and tissues. Persons with heart disease are especially sensitive to carbon monoxide poisoning and may experience chest pain if they breathe the gas while exercising. Infants, elderly persons, and individuals with respiratory diseases are also particularlysensitive.

e) Ozone

Ozone is a secondary pollutants formed in the atmosphere by reaction between oxides of nitrogen and volatile organic compounds (VOCs) in the presence of sunlight. Vehicles, industrial emissions, gasoline vapours, chemical solvents emitoxidesof nitrogen and VOCs that form ozone. Peak O3 levels occur typically during the warmer times of theyear.

f) Ammonia

Ammonia is found in small quantities in the atmosphere, and is produced from the putrefaction of nitrogenous animal and vegetable matter. Ammonia occurs naturally and is produced by human activity. Ammonia and ammonium salts are also found in small quantities in rainwater. It is an important source of nitrogen which is needed by plants and animals. Ammonia gas can be dissolved in water and is called liquid ammonia or aqueous ammonia. Once exposed to open air, liquid ammonia quickly turns into a gas. Exposure to ammonia may occur by breathing or consuming food or water containing ammonia. No health effects have been found in humans

exposed to typical environmental concentrations of ammonia. Exposure to high levels of ammonia in air may be irritating to skin, eyes, throat, and lungs and cause coughing and burns. Lung damage and death may occur after exposure to very high concentrations ofammonia.

g) Hazardous AirPollutants

Hazardous air pollutants are also known as toxic air pollutants which may cause health effects such as reproductive effects, cancer etc. Toxic air pollutants include benzene, perchlorethlyene, methylene chloride, dioxin, asbestos, toluene, and metals such as cadmium, mercury, chromium, and lead compounds. Sources of benzene are gasoline and perchlorethlyene, is emitted from some dry cleaning facilities. Methylene chlorideis used as a solvent and paint stripper by a number of industries. As per USEPA, 2007 (Source:http://www.epa.gov/ttn/atw/allabout.html) people exposed to toxic air pollutants at sufficient concentrations and durations may have an increased chance of experiencing serious health effects and these health effects can include damage to the immune system, as well as neurological, reproductive (e.g., reduced fertility), developmental, respiratory, cancer and other health problems. Also as per USEPA, 2007, in addition to exposure from breathing air toxics, some toxic air pollutants such as mercury can deposit onto soils or surface waters, where they are taken up by plants and ingested by animals and are eventually magnified up through the foodchain.

Air (Prevention and Control of Pollution) Act1981

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 airpollution.

• To plan and cause to be executed a nation-wide programme for the prevention, control and abatement of air pollution.• To provide technical assistance and guidance to the State Pollution ControlBoard.

• To carry out and sponsor investigations and research related to prevention, control and abatement of airpollution.

• To collect, compile and publish technical and statistical data related to air pollution;and

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

• To plan a comprehensive programme for prevention, control and abatement of air pollution and to secure the executionthereof.

• To advise the State Government on any matter concerning prevention, control and abatement of airpollution.

• To collect and disseminate information related to airpollution.

• To collaborate with Central Pollution Control Board in programme related top revention, control and abatement of air pollution;and

• To inspect air pollution control areas, assess quality of air and to take steps for prevention, control and abatement of air pollution in such areas.

National Ambient Air Quality Standards(NAAQS)

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

• To indicate the levels of air quality necessary with an adequate margin of safety to Protect the public health, vegetation andproperty;

• To assist in establishing priorities for abatement and control of pollutantlevel;

• To provide uniform yardstick for assessing air quality at national level;and

• To indicate the need and extent of monitor ring programme.

Air Quality Monitoring and AQI Considerations

The air quality monitoring network in India can be classified as (i) online and (ii) manual. The pollutant parameters, frequency of measurement and monitoring methodologies for twonetworks are very different. The AQI system for these networks could be at variance, especially for reporting and completeness in terms of parameters. (i) Online Monitoring network: These are automated air quality monitoring stations which record continuous hourly, monthly or annually averaged data. In India, ~ 40 automatic monitoring stations are operated (e.g. Figure 3.2: continuous stations in Delhi), where parameters like PM10, PM2.5, NO2 , SO2 , CO, O3 , etc. are monitored continuously. Data from these stations are available almost in real-time. Thus such networks are most suitable for computation of AQI sub-indices, as information on AQI can be

generated in real time. For AQI to be more useful and effective, there is a need to set up more online monitoring stations for continuous and easy availability of air quality data for computation of AQI for more Indiancities.

Manual:

The manual stations involve mostly intermittent air quality data collection, thus such stations are not suitable for AQI calculation particularly for its quick dissemination. In India, air quality is being monitored manually at 573 locations under National Air Monitoring Programme (NAMP). In most of these manually operated stations, only three criteria pollutants viz. PM10, sulphur dioxide (SO2) and nitrogen dioxide (NO2) are measured, at some stations PM2.5 and Pb are also measured. The monitoring frequency is twice a week. Such manual networks are not suitable for computing AQI, as availability of monitored data could have a lag of 1-3 days and sometimes not available at all. However, some efforts are required to use the information in some productive manner. Historical AQIs on weekly basis can be calculated and used for data interpretation and ranking of cities or towns for further prioritization of actions on air pollution control.

Computation and Basis of Sub-index Breakpoints Segmented linear functions are used for relating actual air pollution concentration (Xi) (of each pollutant) to a normalized number referred to as sub-index (Ii). While AQI system is not complex in understanding, to arrive at breakpoints which will relate to AQI description is of paramount significance. Consequences of inappropriate adoption of breakpoints could be far reaching; it may lead to incorrect information to general public (on health effects) and decisions taken for pollution control may be incorrect. The basis for linear functions (for this study) to relate air quality levels to AQI requires careful consideration. Services of practicing doctors and experts in this field (see Appendix 1) have proved very useful. In this study, in addition to dose response relationship, the breakpoints adopted by other countries/agencies (USEPA 2014; U.K. 2013; Malaysia 2013; GVAQI 2013; Ontario 2013) have been examined for using these in INDAQI. It is important that an AQI system should build on AQS and pollutant dose-response relationships to describe air quality in simple terms which clearly relates to health impacts. The first step for arriving at breakpoints for each pollutant is to consider attainment of INAQS (Table 3.1). The index category is classified as ‗good‘ for concentration range up to half of INAQS (for example, for SO2 AQI=0-50 for

concentration range of 0-40 μg/m3) and as ‗satisfactory' up to attainment of INAQS (i.e. SO2 range 41-80μg/m3 linearly maps to AQI=51-100). To arrive at breakpoints for other categories (for each pollutant), we require a thorough research/review of dose response relationships, which is described here. 3.3.1 Carbon Mono-oxide (CO) Carbon monoxide (CO) is an important criteria pollutant which is ubiquitous in urban environment. CO production mostly occurs from sources having incomplete combustion. Due to its toxicity and appreciable mass in atmosphere, it should be considered as an important pollutant in AQI scheme. CO rapidly diffuses across alveolar, capillary and placental membranes. Approximately 80-90% of absorbed CO binds with Hb to from Carboxyhaemoglobin (COHb), which is a specific biomarker of exposure in blood. The affinity of Hb for CO is 200-250 times than that of oxygen. In patients with hemolytic anemia, the CO production rate was 2–8 times higher and blood COHb concentration was 2–3 times higher than in normal person (WHO 2000). The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered and maylead

to Coma or death if high exposures continue. A US study estimated that 6 per cent of the congestive heart failures and hospitalizations in the cities were related to an increase in CO concentration in ambient atmosphere (WHO 2000). Reduction in the ability of blood to transport oxygen leads to tissue hypoxia. The body compensates for this stress by increasing cardiac output and the blood flow to specific areas, such as the heart and brain. As the level of COHb in the blood increases, the person suffers from effects which become progressively more serious. CO has both 1 hr and 8 hrs standard. Figure 3.3 shows air pollution level and percent of COHb. The symptoms associated with various percent blood saturation levels of COHb

Nitrogen Dioxide (NO2)
 The major source of NO2 is combustion processes. An appreciable quantity of NO2 is present in rural and urban environments. Further, NO2 is showing alarmingly high increasing trend in Indian cities due to increase in number of vehicles. On inhalation, 70–90% of NO2 can be absorbed in the respiratory tract of humans, and physical exercise increases the total percentage absorbed (Miller et al., 1982). NO2 exposure can cause decrement in lung function (i.e. increased airway resistance), increased airway responsiveness to broncho-constrictions in healthy subjects at concentration exceeding 1 ppm (WHO 2000). Below 1 ppm level, there are evidences of change in lung volume, flow volume, characteristics of lung or airway resistance in healthy

persons. It has been established that continuous exposure with as little as 0.1 ppm NO2 over a period of one to three years, increases incidence of bronchitis, emphysema and have adverse effect on lung performance (WHO 2000). Exposure to excessive NO2 , affects the defence mechanism leaving the host susceptible to respiratory illness. Chronic exposure of NO2 may lead to chronic lung disease and variety of structural/morphological changes in lung epithelium conducting airways and air -gas exchange region. Exposure to high levels (>1.0 ppm) of NO2 causes Eustachian of bronchiolar and alveolar epithelium, inflammation of epithelium and definite emphysema (WHO 2000). Normal healthy people exposed at rest or with light exercise for less than 2 hours to concentrations of more than 4700μg/m3 (2.5ppm) experience pronounced decrements in pulmonary function; generally, such people are not affected at less than 1880μg/m3 (1ppm). One study showed that the lung function of people with chronic obstructive pulmonary disease is slightly affected by a 3.75-hour exposure to 560μg/ m3 (0.3ppm). A wide range of findings in asthmatics has been reported; one study observed no effects from a 75-minute exposure to 7520μg/m3 (4ppm), whereas others showed decreases in FEV1 (forced expiration volume in one second) after 10 minutes of exercise during exposure to 560μg/m3 (0.3ppm). The lowest concentration causing effects on pulmonary function was reported from two laboratories that exposed mild asthmatics for 30–110 minutes to 560μg/m3 (0.3ppm) during intermittent exercise (WHO 2000). WHO (2003) has reported some but not all studies show increased responsiveness to bronchoconstrictors at nitrogen dioxide levels as low as 376–560 μg/m3 (0.2–0.3 ppm); in other studies, higher levels had no such effect. Studies of asthmatics exposed to 380–560 μg/m3 indicate a change of about 5% in pulmonary function and an increase in airway responsiveness to bronchoconstrictors. Asthmatics are more susceptible to the acute effects of nitrogen dioxide as they have higher baseline airway responsiveness. For acute exposures, only very high concentrations (1990 μg/m3 ;> 1000 ppb) affect healthy people. Asthmatics and patients with chronic obstructive pulmonary disease are clearly more susceptible to acute changes in lung function, airway responsiveness and respiratory symptoms. Given the small changes in lung function (< 5% drop in FEV1 between air and nitrogen dioxide exposure) and changes in airway responsiveness reported in several studies, 375–565 μg/m3 (0.20 to0.30 ppm) is a clear lowest-observed effect level. A 50% margin of safety is proposed because of the reported statistically significant increase in response to a bronchoconstrictor (increased airway responsiveness) with exposure to 190 μg/m3 and a met a analysis suggesting changes in airway responsiveness below 365 μg/m3 (WHO 2000) After giving due consideration to INAQS for

NO2 , two categories good (Sub-Index: 0-50) and satisfactory (51-100), the breakpoint concentration are fixed as 40µg/m3 and 80µg/m3 . Various studies reported that the small change in lung function (< 5% drop in FEV1 between air and nitrogen dioxide exposure) and changes in airway responsiveness gives 375–565µg/m3 (0.20 to 0.30 ppm), as the lowest-observed-effect level. Therefore, breakpoints of 280µg/m3 for poor, 400 µg/m3 for very poor and 400+ µg/m3 for severe category are adopted. For moderately-polluted category an intermediate value of 180 µg/m3 (between 80 and 280 µg/m3) has been adopted. It may be noted that minor tweaking has been done with breakpoints so that these also corroborate with international breakpoints adopted by other countries. The details of proposed break points for IND-AQI and breakpoints of USEPA, China and EU

Particulate Matter (PM):

PM10 and PM2.5 PM levels in Indian cities are about 4-5 times higher than in the US cities (WRI, 1996). These high PM levels may have severe impact on public health. The sixteen-year long survey by Dockery et al. (1994) has revealed that there is a strong correlation between ambient PM concentrations and increase in mortality and hospitalizations due to respiratory diseases. Several epidemiological studies (Pope, 1989; Schwartz, 1996) have linked PM10 (aerodynamic diameter ≤ 10 µm)and PM2.5 with significant health problems, including: premature mortality, chronic respiratory disease, emergency visits and hospital admissions, aggravated asthma, acute respiratory symptoms, and decrease in lung function. PM2.5 is of specific concern because it contains a high proportion of various toxic metals and acids, and aerodynamically it can penetrate deeper into the respiratory tract. A HEI study, (Wichmannetal., 2000) reported that the concentration of both ultrafine.

Clean Air Implementation Plans

Air quality management aims at the preservation of environmental quality by prescribing the tolerated degree of pollution, leaving it to the local authorities and polluters to devise and implement actions to ensure that this degree of pollution will not be exceeded. An example of legislation within this approach is the adoption of ambient air quality standards based, very often, on air quality guidelines (WHO 1987) for different pollutants; these are accepted maximum levels of pollutants (or indicators) in the target area (e.g., at ground level at a specified point in a

community) and can be either primary or secondary standards. Primary standards (WHO 1980) are the maximum levels consistent with an adequate safety margin and with the preservation of public health, and must be complied with within a specific time limit; secondary standards are those judged to be necessary for protection against known or anticipated adverse effects other thanhealthhazards(mainlyonvegetation)andmustbecomplied‒withina reasonabletime‖.Air quality standards are short-, medium- or long-term values valid for 24 hours per day, 7 days per week, and for monthly, seasonal or annual exposure of all living subjects (including sensitive subgroups such as children, the elderly and the sick) as well as non-living objects; this is in contrast to maximum permissible levels for occupational exposure, which are for a partial weekly exposure (e.g., 8 hours per day, 5 days per week) of adult and supposedly healthy workers.

Typical measures in air quality management are control measures at the source, for example, enforcement of the use of catalytic converters in vehicles or of emission standards inincinerators, land-use planning and shut-down of factories or reduction of traffic during un favourable weather conditions. The best air quality management stresses that the air pollutant emissions should be kept to a minimum; this is basically defined through emission standards for single sources of air pollution and could be achieved for industrial sources, for example, through closed systems and high-efficiency collectors. An emission standard is a limit on the amount or concentration of a pollutant emitted from a source. This type of legislation requires a decision, for each industry, on the best means of controlling its emissions (i.e., fixing emissionstandards).

The basic aim of air pollution management is to derive a clean air implementation plan (or airpollution abatement plan) (Schwela and Köth-Jahr 1994) which consists of the following elements:

- description of area with respect to topography, meteorology and socioeconomy

- Emissionsinventory

- Comparison with emissionstandards

- Air pollutant concentrationsinventory

- Simulated air pollutantconcentrations

- Comparison with air qualitystandards

- Inventory of effects on public health and theenvironment

- Causalanalysis

- controlmeasures

- cost of controlmeasures

- cost of public health and environmentaleffects

- Cost-benefit analysis (costs of control vs. costs ofefforts)

- Transportation and land-useplanning

- Enforcement plan; resourcecommitment

- Projections for the future on population, traffic, industries and fuelconsumption

- Strategies for follow-up.

Some of these issues will be described below.

Emissions Inventory; Comparison with Emission Standards

The emissions inventory is a most complete listing of sources in a given area and of their individual emissions, estimated as accurately as possible from all emitting point, line and area (diffuse) sources. When these emissions are compared with emission standards set for a particular source, first hints on possible control measures are given if emission standards are not complied with. The emissions inventory also serves to assess a priority list of important sources according to the amount of pollutants emitted, and indicates the relative influence of different sources—for example, traffic as compared to industrial or residential sources. The emissions inventory also allows an estimate of air pollutant concentrations for those pollutants for which ambient concentration measurements are difficult or too expensive toperform.

Air Pollutant Concentrations Inventory; Comparison with Air Quality Standards

The air pollutant concentrations inventory summarizes the results of the monitoring of ambient air pollutants in terms of annual means, percentiles and trends of these quantities. Compounds measured for such an inventory include the following:

- ✓ Sulphurdioxide

- ✓ Nitrogenoxides

- ✓ suspended particulatematter

- ✓ Carbonmonoxide

- ✓ Ozone

- ✓ Heavy metals (Pb, Cd, Ni, Cu, Fe, As,Be)

- ✓ polycyclic aromatic hydrocarbons: benzo(a)pyrene, benzo(e)pyrene, benzo(a)anthracene, dibenzo(a,h)anthracene, benzoghi)perylene,coronen

- ✓ volatile organic compounds:n-hexane, benzene, 3-methyl-hexane,n-heptane, toluene, octane, ethyl-benzene xylene (*o*-,*m*-,*p*-), *n*-nonane, isopropylbenzene, propylbenezene,*n*-2-/3-
- ✓ /4-ethyltoluene, 1,2,4-/1,3,5-trimethylbenzene, trichloromethane, 1,1,1 trichloroethane, tetrachloromethane, tri-/tetrachloroethene.

Comparison of air pollutant concentrations with air quality standards or guidelines, if they exist, indicates problem areas for which a causal analysis has to be performed in order to find out which sources are responsible for the non-compliance. Dispersion modelling has to be used in performing thiscausal analysis (see ‒Air pollution: Modelling of air pollutant dispersion‖).

Devices and procedures used in today's ambient air pollution monitoring are described in ‒Air quality monitoring‖.

Simulated Air Pollutant Concentrations; Comparison with Air Quality Standards

Starting from the emissions inventory, with its thousands of compounds which cannot all be monitored in the ambient air for economy reasons, use of dispersion modelling can help to estimate the concentrations of more ‒exotic‖ compounds. Using appropriate meteorology

parameters in a suitable dispersion model, annual averages and percentiles can be estimated and compared to air quality standards or guidelines, if they exist.

Inventory of Effects on Public Health and the Environment; Causal Analysis

Another important source of information is the effects inventory (Ministerium fürUmwelt 1993), which consists of results of epidemiological studies in the given area and of effects of air pollution observed in biological and material receptors such as, for example, plants, animals and construction metals and building stones. Observed effects attributed to air pollution have to be causally analysed with respect to the component responsible for a particular effect—for example, increased prevalence of chronic bronchitis in a polluted area. If the compound or compounds have been fixed in a causal analysis (compound-causal analysis), a second analysis has to be performed to find out the responsible sources (source-causalanalysis).

Control Measures; Cost of Control Measures

Control measures for industrial facilities include adequate, well-designed, well-installed, efficiently operated and maintained air cleaning devices, also called separators or collectors. A separator orcollector can be defined as an ‑apparatus for separating any one or more of the following from a gaseous medium in which they are suspended or mixed: solid particles (filter and dust separators), liquid particles (filter and droplet separator) and gases (gas purifier)‖. The basictypesofairpollutioncontrolequipment(discussedfurtherin‑Airpollutioncontrol‖)are the following:

· For particulate matter: inertial separators (e.g., cyclones); fabric filters (baghouses); electrostatic precipitators; wet collectors(scrubbers)

· For gaseous pollutants: wet collectors (scrubbers); adsorption units (e.g., adsorption beds); afterburners, which can be direct-fired (thermal incineration) or catalytic (catalyticcombustion).

Wet collectors (scrubbers) can be used to collect, at the same time, gaseous pollutants and particulate matter. Also, certain types of combustion devices can burn combustible gases and

vapours as well as certain combustible aerosols. Depending on the type of effluent, one or a combination of more than one collector can be used.

The control of odours that are chemically identifiable relies on the control of the chemical agent(s) from which they emanate (e.g., by absorption, by incineration). However, when an odouris not defined chemically or the producing agent is found at extremely low levels, other techniques may be used, such as masking (by a stronger, more agreeable and harmless agent) or counteraction (by an additive which counteracts or partially neutralizes the offensive odour).

It should be kept in mind that adequate operation and maintenance are indispensable to ensure the expected efficiency from a collector. This should be ensured at the planning stage, both from the know-how and financial points of view. Energy requirements must not be overlooked. Whenever selecting an air cleaning device, not only the initial cost but also operational and maintenance costs should be considered. Whenever dealing with high-toxicity pollutants, high efficiency should be ensured, as well as special procedures for maintenance and disposal of waste materials.

The fundamental control measures in industrial facilities are the following:

Substitution of materials. Examples: substitution of less toxic solvents for highly toxic ones used in certain industrial processes; use of fuels with lower sulphur content (e.g., washed coal), therefore giving rise to less sulphur compounds and so on.

Modification or change of the industrial process or equipment. Examples: in the steel industry, a change from raw ore to pelleted sintered ore (to reduce the dust released during ore handling); use of closed systems instead of open ones; change of fuel heating systems to steam, hot water or electrical systems; use of catalysers at the exhaust air outlets (combustion processes) and so on.

Modifications in processes, as well as in plant layout, may also facilitate and/or improve the conditions for dispersion and collection of pollutants. For example, a different plant layout may facilitate the installation of a local exhaust system; the performance of a process at a lower rate

may allow the use of a certain collector (with volume limitations but otherwise adequate). Process modifications that concentrate different effluent sources are closely related to the volume of effluent handled, and the efficiency of some air-cleaning equipment increases with the concentration of pollutants in the effluent. Both the substitution of materials and the modification of processes may have technical and/or economic limitations, and these should beconsidered.

Adequate housekeeping and storage. Examples: strict sanitation in food and animal product processing; avoidance of open storage of chemicals (e.g., sulphur piles) or dusty materials (e.g., sand), or, failing this, spraying of the piles of loose particulate with water (if possible) or application of surface coatings (e.g., wetting agents, plastic) to piles of materials likely to give offpollutants.

Adequate disposal of wastes. Examples: avoidance of simply piling up chemical wastes (such as scraps from polymerization reactors), as well as of dumping pollutant materials (solid or liquid) in water streams. The latter practice not only causes water pollution but can also create a secondary source of air pollution, as in the case of liquid wastes from sulphite process pulp mills, which release offensive odorous gaseouspollutants.

Maintenance. Example: well maintained and well-tuned internal combustion engines produce less carbon monoxide and hydrocarbons.

Work practices. Example: taking into account meteorological conditions, particularly winds, when spraying pesticides.

By analogy with adequate practices at the workplace, good practices at the community level can contribute to air pollution control - for example, changes in the use of motor vehicles (more collective transportation, small cars and so on) and control of heating facilities (better insulation of buildings in order to require less heating, better fuels and so on).

Control measures in vehicle emissions are adequate and efficient mandatory inspection and maintenance programmes which are enforced for the existing car fleet, programmes of enforcement of the use of catalytic converters in new cars, aggressive substitution of solar/battery-powered cars for fuel-powered ones, regulation of road traffic, and transportation and land use planning concepts.

Motor vehicle emissions are controlled by controlling emissions per vehicle mile travelled (VMT) and by controlling VMT itself (Walsh 1992). Emissions per VMT can be reduced by controlling vehicle performance - hardware, maintenance - for both new and in-use cars. Fuel composition of leaded gasoline may be controlled by reducing lead or sulphur content, which also has a beneficial effect on decreasing HC emissions from vehicles. Lowering the levels of sulphurin diesel fuel as a means to lower diesel particulate emission has the additional beneficial effect of increasing the potential for catalytic control of diesel particulate and organic HC emissions.

Another important management tool for reducing vehicle evaporative and refuelling emissions is the control of gasoline volatility. Control of fuel volatility can greatly lower vehicle evaporative HC emissions. Use of oxygenated additives in gasoline lowers HC and CO exhaust as long as fuel volatility is notincreased.

Reduction of VMT is an additional means of controlling vehicle emissions by control strategies such as

✓ use of more efficient transportationmodes

✓ increasing the average number of passengers percar

✓ spreading congested peak trafficloads

✓ reducing traveldemand.

While such approaches promote fuel conservation, they are not yet accepted by the general population, and governments have not seriously tried to implement them.

All these technological and political solutions to the motor vehicle problem except substitution of electrical cars are increasingly offset by growth in the vehicle population. The vehicle problem can be solved only if the growth problem is addressed in an appropriateway.

Cost of Public Health and Environmental Effects; Cost-Benefit Analysis

The estimation of the costs of public health and environmental effects is the most difficult part of a clean air implementation plan, as it is very difficult to estimate the value of lifetime reduction of disabling illnesses, hospital admission rates and hours of work lost. However, this estimation and a comparison with the cost of control measures is absolutely necessary in order to balance the costs of control measures versus the costs of no such measure undertaken, in terms of public health and environmentaleffects.

Transportation and Land-Use Planning

The pollution problem is intimately connected to land-use and transportation, including issues such as community planning, road design, traffic control and mass transportation; to concerns of demography, topography and economy; and to social concerns (Venzia 1977). In general, the rapidly growing urban aggregations have severe pollution problems due to poor land-use and transportation practices. Transportation planning for air pollution control includes transportation controls, transportation policies, mass transit and highway congestion costs. Transportation controls have an important impact on the general public in terms of equity, repressiveness and social and economic disruption - in particular, direct transportation controls such as motor vehicle constraints, gasoline limitations and motor vehicle emission reductions. Emission reductions due to direct controls can be reliably estimated and verified. Indirect transportation controls such as reduction of vehicle miles travelled by improvement of mass transit systems, traffic flow improvement regulations, regulations on parking lots, road and gasoline taxes, car-use permissions and incentives for voluntary approaches are mostly based on past trial-and-error experience, and include many uncertainties when trying to develop a viable transportationplan.

National action plans incurring indirect transportation controls can affect transportation and land-use planning with regard to highways, parking lots and shopping centres. Long-term planning for the transportation system and the area influenced by it will prevent significant deterioration of air quality and provide for compliance with air quality standards. Mass transit is consistently considered as a potential solution for urban air pollution problems. Selection of a mass transit system to serve an area and different modal splits between highway use and bus or rail service will ultimately alter land-use patterns. There is an optimum split that will minimize air pollution; however, this may not be acceptable when non-environmental factors are considered.

The automobile has been called the greatest generator of economic externalities ever known. Some of these, such as jobs and mobility, are positive, but the negative ones, such as air pollution, accidents resulting in death and injury, property damage, noise, loss of time, and aggravation, lead to the conclusion that transportation is not a decreasing cost industry in urbanized areas. Highway congestion costs are another externality; lost time and congestion costs, however, are difficult to determine. A true evaluation of competing transportation modes, such as mass transportation, cannot be obtained if travel costs for work trips do not include congestioncosts.

Land-use planning for air pollution control includes zoning codes and performance standards, land-use controls, housing and land development, and land-use planning policies. Land-use zoning was the initial attempt to accomplish protection of the people, their property and their economic opportunity. However, the ubiquitous nature of air pollutants required more than physical separation of industries and residential areas to protect the individual. For this reason, performance standards based initially on aesthetics or qualitative decisions were introduced into some zoning codes in an attempt to quantify criteria for identifying potential problems.

The limitations of the assimilative capacity of the environment must be identified for long-term land-use planning. Then, land-use controls can be developed that will prorate the capacity equitably among desired local activities. Land-use controls include permit systems for review of new stationary sources, zoning regulation between industrial and residential areas, restriction by easement or purchase of land, receptor location control, emission-density zoning and emission allocation regulations.

Housing policies aimed at making home ownership available to many who could otherwise not afford it (such as tax incentives and mortgage policies) stimulate urban sprawl and indirectly discourage higher-density residential development. These policies have now proven to be environmentally disastrous, as no consideration was given to the simultaneous development of efficient transportation systems to serve the needs of the multitude of new communities being developed. The lesson learnt from this development is that programmes impacting on the environment should be coordinated, and comprehensive planning undertaken at the level where the problem occurs and on a scale large enough to include the entire system.

Land-use planning must be examined at national, provincial or state, regional and local levels to adequately ensure long-term protection of the environment. Governmental programmes usually start with power plant siting, mineral extraction sites, coastal zoning and desert, mountain or other recreational development. As the multiplicity of local governments in a given region cannot adequately deal with regional environmental problems, regional governments or agencies should coordinate land development and density patterns by supervising the spatial arrangement and location of new construction and use, and transportation facilities. Land-use and transportation planning must be interrelated with enforcement of regulations to maintain the desired air quality. Ideally, air pollution control should be planned for by the same regional agency that does land-use planning because of the overlapping externalities associated with both issues.

Enforcement Plan, Resource Commitment

The clean air implementation plan should always contain an enforcement plan which indicates how the control measures can be enforced. This implies also a resource commitment which, according to a polluter pays principle, will state what the polluter has to implement and how the government will help the polluter in fulfilling the commitment.

Projections for the Future

In the sense of a precautionary plan, the clean air implementation plan should also include estimates of the trends in population, traffic, industries and fuel consumption in order to assess responses to future problems. This will avoid future stresses by enforcing measures well in advance of imagined problems.

Strategies for Follow-up

A strategy for follow-up of air quality management consists of plans and policies on how to implement future clean air implementation plans.

Role of Environmental Impact Assessment

Environmental impact assessment (EIA) is the process of providing a detailed statement by the responsible agency on the environmental impact of a proposed action significantly affecting the quality of the human environment (Lee 1993). EIA is an instrument of prevention aiming at consideration of the human environment at an early stage of the development of a programme or project.

EIA is particularly important for countries which develop projects in the framework of economic reorientation and restructuring. EIA has become legislation in many developed countries and is now increasingly applied in developing countries and economies in transition.

EIA is integrative in the sense of comprehensive environmental planning and management considering the interactions between different environmental media. On the other hand, EIA integrates the estimation of environmental consequences into the planning process and thereby becomes an instrument of sustainable development. EIA also combines technical and participative properties as it collects, analyses and applies scientific and technical data with consideration of quality control and quality assurance, and stresses the importance of consultations prior to licensing procedures between environmental agencies and the public which could be affected by particular projects. A clean air implementation plan can be considered as a part of the EIA procedure with reference to the air.

AIR QUALITY MONITORING

Air quality monitoring means the systematic measurement of ambient air pollutants in order to beable to assess the exposure of vulnerable receptors (e.g., people, animals, plants and art works) on the basis of standards and guidelines derived from observed effects, and/or toestablish the source of the air pollution (causalanalysis).

Ambient air pollutant concentrations are influenced by the spatial or time variance of emissions of hazardous substances and the dynamics of their dispersion in the air. As a consequence, marked daily and annual variations of concentrations occur. It is practically impossible to determine in a unified way all these different variations of air quality (in statistical language, the population of air quality states). Thus, ambient air pollutant concentrations measurements always have the character of random spatial or time samples.

Measurement Planning

The first step in measurement planning is to formulate the purpose of the measurement as precisely as possible. Important questions and fields of operation for air quality monitoring include:

Area measurement:

- representative determination of exposure in one area (general airmonitoring)

- representative measurement of pre-existing pollution in the area of a planned facility (permit, TA Luft (Technical instruction,air))

- smog warning (winter smog, high ozoneconcentrations)

- measurements in hot spots of air pollution to estimate maximum exposure of receptors (EU- NO_2 guideline, measurements in street canyons, in accordance with the German Federal Immission ControlAct)

- checking the results of pollution abatement measures and trends overtime

- screeningmeasurements

- scientific investigations - for example, the transport of air pollution, chemical conversions, calibrating dispersioncalculations.

Facility measurement:

- ✓ measurements in response tocomplaints

- ✓ ascertaining sources of emissions, causalanalysis

- ✓ measurements in cases of fires and accidentalreleases

- ✓ checking success of reductionmeasures

- ✓ monitoring factory fugitiveemissions.

The goal of measurement planning is to use adequate measurement and assessment procedures to answer specific questions with sufficient certainty and at minimum possible expense.

An example of the parameters that should be used for measurement planning is presented in table in relation to an assessment of air pollution in the area of a planned industrial facility. Recognizing that formal requirements vary by jurisdiction, it should be noted that specific reference here is made to German licensing procedures for industrial facilities.

Parameters for measurement planning in measuring ambient air pollution concentrations (with example of application)

Parameter	Example of application: Licensing procedure for industrial facilities inGermany
Statement of the question	Measurement of prior pollution in the licensing procedure; representative random probe measurement
Area of measurement	Circle around location with radius 30 times actual chimney height (simplified)
Assessment standards (place and time dependent): characteristic values to be obtained from measurementdata	Threshold limits IW1 (arithmetic mean) and IW2 (98th percentile) of TA Luft (Technical instruction, air); calculation of I1 (arithmetic mean) and I2 (98th percentile) from

	measurements taken for 1 km^2(assessment surface) to be compared with IW1 andIW2
Ordering, choice and density of measurementsites	Regular scan of1km^2, resulting in ‒random‖ choice of measurement sites
Measurement time period	1 year, at least 6 months
Measurement height	1.5 to 4 metres above ground
Measurement frequency	52 (104) measurements per assessment area for gaseous pollutants, depending on the height of the pollution
Duration of each measurement	1/2 hour for gaseous pollutants, 24 hours for suspended dust, 1 month for dustprecipitation
Measurement time	Random choice
Measured object	Air pollution emitted from the plannedfacility
Measurement procedure	National standard measurement procedure (VDI guidelines)
Necessary certainty of measurement results	High
Quality requirements, quality control, calibration, maintenance	VDI guidelines
Recording of measurement data, validation, archiving, assessment	Calculation of quantity of data I1V and I2V for every assessment area
Costs	Depend on measurement area and objectives

The example in shows the case of a measurement network that is supposed to monitor the air quality in a specific area as representatively as possible, to compare with designated air quality limits. The idea behind this approach is that a random choice of measurement sites is made in order to cover equally locations in an area with varying air quality (e.g., living areas, streets, industrial zones, parks, city centres, suburbs). This approach may be very costly in large areas due to the number of measurement sitesnecessary.

Another conception for a measurement network therefore starts with measurement sites that are representatively selected. If measurements of differing air quality are conducted in the most important locations, and the length of time that the protected objects remain in these ‒microenvironments‖isknown, then the exposure can be determined. This approachcan be extended to other microenvironments (e.g., interior rooms, cars) in order to estimate the total exposure. Diffusion modelling or screening measurements can help in choosing the right measurementsites.

A third approach is to measure at the points of presumed highest exposure (e.g., for NO_2 and benzene in street canyons). If assessment standards are met at this site, there is sufficient probability that this will also be the case for all other sites. This approach, by focusing on critical points, requires relatively few measurement sites, but these must be chosen with particular care. This particular method risks overestimating real exposure.

The parameters of measurement time period, assessment of the measurement data and measurement frequency are essentially given in the definition of the assessment standards (limits) and the desired level of certainty of the results. Threshold limits and the peripheral conditions to be considered in measurement planning are related. By using continuous measurement procedures, a resolution that is temporally almost seamless can be achieved. But this is necessary only in monitoring peak values and/or for smog warnings; for monitoring annual mean values, for example, discontinuous measurements areadequate.

The following section is dedicated to describing the capabilities of measurement procedures and quality control as a further parameter important to measurement planning.

Quality Assurance

Measurements of ambient air pollutant concentrations can be costly to conduct, and results can affect significant decisions with serious economic or ecological implications. Therefore, quality assurance measures are an integral part of the measurement process. Two areas should be distinguished here.

Procedure-oriented measures

Every complete measurement procedure consists of several steps: sampling, sample preparation and clean-up; separation, detection (final analytical step); and data collection and assessment. In some cases, especially with continuous measurement of inorganic gases, some steps of the procedure can be left out (e.g., separation). Comprehensive adherence to procedures should be strived for in conducting measurements. Procedures that are standardized and thus comprehensively documented should be followed, in the form of DIN/ISO standards, CEN standards or VDI guidelines.

User-oriented measures

Using standardized and proven equipment and procedures for ambient air pollutant concentration measurement cannot alone ensure acceptable quality if the user does not employ adequate methods of quality control. The standards series DIN/EN/ISO 9000 (Quality Management and Quality Assurance Standards), EN 45000 (which defines the requirements for testing laboratories) and ISO Guide 25 (General Requirements for the Competence of Calibration and Testing Laboratories) are important for user-oriented measures to ensure quality.

Important aspects of user quality control measures include:

- ✓ acceptance and practice of the content of the measures in the sense of good laboratory practice (GLP)

- ✓ correct maintenance of measurement equipment, qualified measures to eliminate disruptions and ensurerepairs

- ✓ carrying out calibrations and regular checking to ensure properfunctioning

- ✓ carrying out interlaboratory testing.

Measurement Procedures

Measurement procedures for inorganic gases

A wealth of measurement procedures exists for the broad range of inorganic gases. We will differentiate between manual and automatic methods.

Manual procedures

In the case of manual measurement procedures for inorganic gases, the substance to be measured is normally adsorbed during the sampling in a solution or solid material. In most cases a photometric determination is made after an appropriate colour reaction. Several manual measurement procedures have special significance as reference procedures. Because of the relatively high personnel cost, these manual procedures are conducted only rarely for field

Material	Procedure	Execution	Comments
SO_2	TCM procedure	Absorption in tetrachloromercurate solution (wash bottle); reaction with formaldehyde and pararosaniline to red-violet sulphonic acid; photometric determination	EU-reference measurement procedure; DL =0.2 µg SO_2; s = 0.03 mg/m^3 at 0.5 mg/m^3
SO_2	Silica gel procedure	Removal of interfering substances by concentrated H_3PO_4; adsorption on silica gel; thermal desorption in H_2-stream and reduction to H_2S; reaction to molybdenum-blue; photometric determination	DL = 0.3 µg SO_2; s = 0.03 mg/m^3 at 0.5 mg/m^3
NO_2	Saltzman procedure	Absorption in reaction solution while forming a red azo dye (wash bottle); photometric determination	Calibration with sodium nitrite; DL = 3 µg/m^3
O_3	Potassium iodide procedure	Formation of iodine from aqueous potassium iodide solution (wash bottle); photometric determination	DL = 20 µg/m^3; rel. s = ± 3.5% at390µg/m^3
F-	Silver bead procedure; variant 1	Sampling with dust preseparator; enrichment of F- on sodium carbonate-coated silver beads; elution and measurement with ion-sensitive lanthanum fluoride-electrodechain	Inclusion of an undetermined portion of particulate fluorideimmissions

F-	Silver bead procedure; variant 2	Sampling with heated membrane filter; enrichment of F- on sodium carbonate-coated silver beads; determination by electrochemical (variant 1) or photometric (alizarin-complexone)procedure	Danger of lower findings due to partial sorption of gaseous fluoride immissions on membrane filter; DL =0.5 $\mu g/m^3$
Cl-	Mercury rhodanide procedure	Absorption in 0.1 N sodium hydroxide solution (wash bottle); reaction with mercury rhodanide and Fe(III) ions to iron thiocyanato complex; photometric determination	DL = 9 $\mu g/m^3$
Cl$_2$	Methyl-orange procedure	Bleaching reaction with methyl-orange solution (wash bottle); photometric determination	DL = 0.015 mg/m^3
NH$_3$	Indophenol procedure	Absorption in dilute H_2SO_4 (Impinger/wash bottle); conversion with phenol and hypochlorite to indophenol dye; photometricdetermination	DL = 3 $\mu g/m^3$ (impinger); partial inclusion of compounds and amines
NH$_3$	Nessler procedure	Absorption in dilute H_2SO_4 (Impinger/wash bottle); distillation and reaction with Nessler's reagent, photometric determination	DL = 2.5 $\mu g/m^3$ (impinger); partial inclusion of NH_4^+- compounds andamines

H_2S	Molybdenum-blue procedure	Absorption as silver sulphide on glass beads treated with silver sulphate and potassium hydrogen sulphate (sorption tube); released as hydrogen sulphide and conversion to molybdenum blue; photometric determination	DL = 0.4 µg/m³
H_2S	Methylene blue procedure	Absorption in cadmium hydroxide suspension while forming CdS; conversion to methylene blue; photometric determination	DL = 0.3 µg/m³

Table 55.3 Manual measurement procedures for inorganic gases

DL = detection limit; s = standard deviation; rel. s = relative s.

A special sampling variant, used primarily in connection with manual measurement procedures, is the diffusion separation tube (denuder). The denuder technique is aimed at separating the gas and particle phases by using their different diffusion rates. Thus, it is often used on difficult separation problems (e.g., ammonia and ammonium compounds; nitrogen oxides, nitric acid and nitrates; sulphur oxides, sulphuric acid and sulphates or hydrogen halides/halides). In the classic denuder technique, the test air is sucked through a glass tube with a special coating, depending on the material(s) to be collected. The denuder technique has been further developed in many variations and also partially automated. It has greatly expanded the possibilities of differentiated sampling, but, depending on the variant, it can be very laborious, and proper utilization requires a great deal ofexperience.

Automated procedures

There are numerous different continuous measuring monitors on the market for sulphur dioxide, nitrogen oxides, carbon monoxide and ozone. For the most part they are used particularly in measurement networks. The most important features of the individual methods are collected

Table 55.4 Automated measurement procedures for inorganic gases

Material	Measuring principle	Comments
SO_2	Conductometry reaction of SO_2 with H_2O_2 in dilute H_2SO_4; measurement of increased conductivity	Exclusion of interferences with selective filter($KHSO_4$/$AgNO_3$)
SO_2	UV fluorescence; excitation of SO_2 molecules with UV radiation (190–230 nm); measurement of fluorescence radiation	Interferences, e.g., by hydrocarbons, must be eliminated with appropriate filtersystems
NO/NO_2	Chemiluminescence; reaction of NO with O_3 to NO_2; detection of chemiluminescence radiation with photomultiplier	NO_2 only indirectly measurable; use of converters for reduction of NO_2 to NO; measurement of NO and NO_x (=NO+NO_2) in separate channels
CO	Non-dispersive infrared absorption; measurement of IR absorption with specific detector against referencecell	Reference: (a) cell withN_2; (b) ambient airafterremoval of CO; (c) optical removal of CO absorption (gas filtercorrelation)
O_3	UV absorption; low-pressure Hg lamp as radiation source (253.7 nm); registration of UV absorption in accordance with Lambert-Beer's law; detector: vacuum photodiode, photosensitive valve	Reference: ambient air after removal of ozone (e.g.,Cu/MnO_2)

O₃	Chemiluminescence; reaction of O₃ with ethene to formaldehyde; detection of chemiluminescence radiation with photomultiplier	Good selectivity; ethylene necessary as reagent gas

It should be emphasized here that all automatic measurement procedures based on chemical-physical principles must be calibrated using (manual) reference procedures. Since automatic equipment in measurement networks often runs for extended periods of time (e.g., several weeks) without direct human supervision, it is indispensable that their correct functioning is regularly and automatically checked. This generally is done using zero and test gases that can be produced by several methods (preparation of ambient air; pressurized gas cylinders; permeation; diffusion; static and dynamic dilution).

Measurement procedures for dust-forming air pollutants and its composition

Among particulate air pollutants, dustfall and suspended particulate matter (SPM) are differentiated. Dustfall consists of larger particles, which sink to the ground because of their size and thickness. SPM includes the particle fraction that is dispersed in the atmosphere in a quasi-stable and quasi-homogenous manner and therefore remains suspended for a certain time.

Measurement of suspended particulate matter and metallic compounds in SPM

As is the case with measurements of gaseous air pollutants, continuous and discontinuous measurement procedures for SPM can be differentiated. As a rule, SPM is first separated on glassfibre or membrane filters. It follows a gravimetric or radiometric determination. Depending on the sampling, a distinction can be made between a procedure to measure the total SPM without fractionation according to the size of the particles and a fractionation procedure to measure the finedust.

The advantages and disadvantages of fractionated suspended dust measurements are disputed internationally. In Germany, for example, all threshold limits and assessment standards are based on total suspended particulates. This means that, for the most part, only total SPM measurements

are performed. In the United States, on the contrary, the so-called PM-10 procedure (particulate matter ≤ 10mm) is very common. In this procedure, only particles with an aerodynamic diameter up to 10 mm are included (50 per cent inclusion portion), which are inhalable and can enter the lungs. The plan is to introduce the PM-10 procedure into the European Union as a reference procedure. The cost for fractionated SPM measurements is considerably higher than for measuring total suspended dust, because the measuring devices must be fitted with special, expensively constructed sampling heads that require costly maintenance. Table contains details on the most important SPM measurement procedures.

Table Measurement procedures for suspended particulate matter (SPM)

Procedure	Measuring principle	Comments
Small filter device	Non-fractionated sampling; air flow rate 2.7–2.8 m^3/h; filter diameter 50 mm;gravimetric analysis	Easy handling; control clock; device operable with PM-10preseparator
LIB device	Non-fractionated sampling; air flow rate 15-16 m^3/h; filter diameter 120 mm;gravimetric analysis	Separation of large dust quantities; advantageous for analysis of dust components; controlclock
High-Volume-Sampler	Inclusion of particles up to approx. 30 μm diameter; air flow rate approx. 100 m^3/h; filter diameter 257 mm; gravimetricanalysis	Separation of large dust quantities, advantageous for analysis of dust components; relatively high noiselevel

FH 62 I	Continuous, radiometric dust measuring device; non-fractionating sampling; airflow rate 1 or 3 m^3/h; registration of dust mass separated on a filter band by measuring attenuation of β- radiation (krypton 85) in passage through exposed filter (ionizationchamber)	Gravimetric calibration by dusting of single filters; device also operable with PM-10 preseparator
BETA dust meter F 703	Continuous, radiometric dust measuring device; non-fractionated sampling; air flow rate 3 m^3/h; registration of dust mass separated on a filter band by measuring attenuation of β-radiation (carbon 14) in passage through exposed filter (Geiger Müller countertube)	Gravimetric calibration by dusting of single filters; device also operable with PM-10 preseparator
TEOM 1400	Continuous dust measuring device; non-fractionated sampling; air flow rate 1 m^3/h; dust collected on a filter, which is part of a self-resonating, vibrating system, in side stream (3 l/min); registration of the frequency lowering by increased dust load on thefilter	Relationship between frequency lowering and dust mass must be established throughcalibration

Recently, automatic filter changers have also been developed that hold a larger number of filters and supply them to the sampler, one after another, at timed intervals. The exposed filters are stored in a magazine. The detection limits for filter procedures lie between 5 and 10 µg/m^3 of dust, as a rule.

Finally, the black smoke procedure for SPM measurements has to be mentioned. Coming from Britain, it has been incorporated into EU guidelines for SO_2 and suspended dust. In this procedure, the blackening of the coated filter is measured with a reflex photometer after the sampling. The black smoke values that are thus photometrically obtained are converted into gravimetric units (µg/m^3) with the help of a calibration curve. Since this calibration function depends to a high degree on the composition of the dust, especially its soot content, the conversion into gravimetric units is problematic.

Today, metal compounds are often routinely determined in suspended dust immission samples. In general, the collection of the suspended dust on filters is followed by a chemical dissolution of the separated dusts, since the most common final analytical steps presuppose converting the metallic and metalloid compounds in an aqueous solution. In practice, the most important methods by far are atom absorption spectroscopy (AAS) and spectroscopy with plasma excitation (ICP-OES). Other procedures for determining metallic compounds in suspended dust are x-ray fluorescence analysis, polarography and neutron activation analysis. Although metallic compounds have been measured for more than a decade now as a component of SPM in outside air at certain measurement sites, important unanswered questions remain. Thus the conventional sampling by separating the suspended dust on filters assumes that the separation of the heavy metal compounds on the filter is complete. However, earlier indications have been found in the literature questioning this. The results are veryheterogeneous.

A further problem lies in the fact that different compound forms, or single compounds of the respective elements, cannot be distinguished in the analysis of metallic compounds in suspended dust using the conventional measurement procedures. While in many cases adequate total determinations can be made, a more thorough differentiation would be desirable with certain especially carcinogenic metals (As, Cd, Cr, Ni, Co, Be). There are often big differences in the carcinogenic effects of elements and their individual compounds (e.g., chromium compounds in oxidation levels III and VI - only those in level VI are carcinogenic). In such cases a specific

measurement of the individual compounds (species analysis) would be desirable. Despite the significance of this problem, only first attempts at species analysis are being made in measurement technique.

Measurement of dustfall and metallic compounds in dustfall

Two fundamentally different methods are used to collect dustfall:

❖ sampling in collecting vessels

❖ sampling on adhesive 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 and day (g/m^2d). The relative detection limit is 0.035 g/m^2d.

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

All measurement results for dust fall 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.

Measuring special materials in dust form

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 ≤ 3mm and a length of L ≥ 5mm, where L:D ≥ 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 energy dispersive 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 reliableresults.

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 composition and because of the fact that various constituents are also emitted from other sources, there is no measurement procedure specific to diesel soot. Nevertheless, in order to say something concrete about the concentrations in ambient air, soot is conventionally defined as elemental carbon, as a part of total carbon. It is measured after sampling and an extraction step and/or thermal desorption. Determination of the carbon content 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.

Measuring Wet 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 special problems) from the measurement of total deposition (bulk deposition, see section ‒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 through a funnel (open area 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. The conductivity, pH value and important anions (NO_3^-, SO_4^{2-}, Cl^-) and cations (Ca^{2+}, K^+, Mg^{2+}, Na^+, NH_4^+ and so on) are routinely measured. Unstable trace compounds and intermediate states like H_2O_2 or HSO_3 – are also measured for research purposes.

For analysis, procedures are used that are generally available for aqueous solutions such as conductometry for conductivity, electrodes for pH values, atom adsorption spectroscopy for cations (see section ‒Measuring special materials in dust form‖, above) and, increasingly, ion exchange chromatography with conductivity detection foranions.

Organic compounds are extracted from rain water with, for example, dichloromethane, or blown out 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 approximately 90 stations. There are also extensive measurement networks in North America.

SCHOOL OF BUILDING AND ENVIRONMENT
DEPARTMENT OF CIVIL ENGINEERING

UNIT – V – Prefabricated Structures – SCIA7017

NOISE POLLUTION AND ITS CONTROL

What is noise?

In simple terms, noise is unwanted sound. Sound is a form of energy which is emitted by a vibrating body and on reaching the ear causes the sensation of hearing through nerves. Sounds produced by all vibrating bodies are not audible. The frequency limits of audibility are from 20 HZ to 20,000 HZ.

A noise problem generally consists of three inter-related elements- the source, the receiver and the transmission path. This transmission path is usually the atmosphere through which the sound is propagated, but can include the structural materials of any building containing the receiver (See Fig.1)

Source   Path   Receiver

Barrier

Source   Path   Receiver
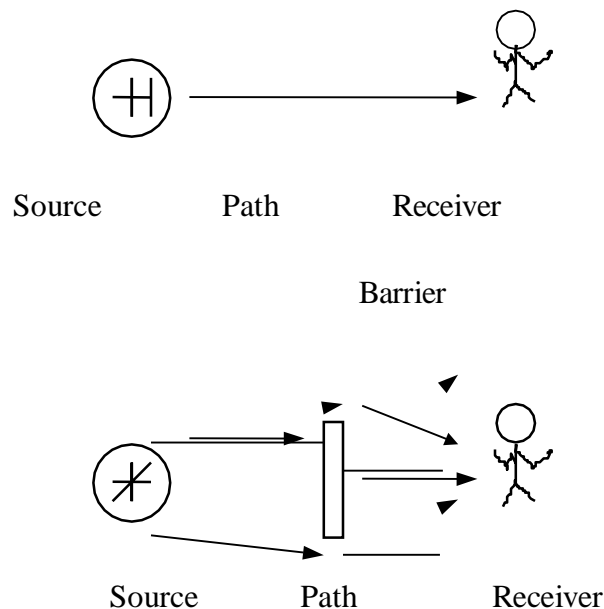
Fig. 1 Inter-relationship between the elements of noise

Noise may be continuous or intermittent. Noise may be of high frequency or of lowfrequency which is undesired for a normal hearing. For example, the typical cry of a child produces sound, which is mostly unfavorable to normal hearing. Since it is unwanted sound, we call it noise.

The discrimination and differentiation between sound and noise also depends upon the habit and interest of the person/species receiving it, the ambient conditions and impact of the sound generated during that particular duration of time. There could be instances that, excellently rendered musical concert for example, may be felt as noise and exceptional music as well during the course of the concert!

Sounds offrequencieslessthan20HZarecalledinfrasonicsandgreaterthan20,0000HZ are called ultrasonics. Since noise is also a sound, the terms noise and sound are synonymously used and are followed in thismodule.

Causes, effects and control of noise and thermal pollution.

Noise pollution

Noise is perhaps one of the most undesirable by products of modern mechanized lifestyle. It may not seem as insidious or harmful as the contamination of drinking water supplies from hazardous chemicals, but it is a problem that affects human health and well-being and that can also contribute to the general deterioration of environmental quality. It can affect people at home, in their community, or at their place ofwork.

Sound waves cause eardrums to vibrate, activating middle and inner organs and sending bioelectrical signals to the brain. The human ear can detect sounds in the frequency range of about 20 to 20,000 Hz, but for most people hearing is best in the range of 200 to 10,000 Hz. A sound of 50 Hz frequency, for example, is perceived to be very low-pitched, and a 15,000 - Hz sound is very high pitched.

Simply defined, noise is undesirable and unwanted sound. It takes energy to produce sound, so, in a manner of speaking, noise is a form of waste energy. It is not a substance that can accumulate in the environment, like most other pollutants, but it can be diluted with distance from a source. All sounds come from a sound source, whether it be a radio, a machine, a human voice, an airplane, or a musical instrument. Not all sound is noise. What may be considered music to one person may be nothing but noise to another. To a extent, noise pollution is a matter of opinion. Noise is measured in terms of Decibel units.

Sources of noise

Based on the type of noise include

     a) IndustrialNoise

     b) TransportNoise

     C) NeighbourhoodNoise

Industrial Noise

It is caused by machines used for the technological advancement. There exist a long list of sources of noise pollution including different machines of numerous factories, industries and mills.

Transport Noise:

Main source is transport. In addition to adversely impacting urban air quality, heavy automobile traffic creates seemingly unbearable noise pollution. Ever since industrial revolution doubling of noise for every 10 years

Pointed nose that angles downward during takeoff, the Anglo-French Concorde flies at more than twice the speed of sound. Supersonic plane is very noisy, and some believe its sonic booms
harm the environment.

Animals such as whales use water to communicate with one another over great distances. Human-generated noises in the ocean, such as engine noises by boats, may interfere with animalcommunication.

Measurement of noise

The noise is usually measured either by i) Sound Pressure or ii) Sound Intensity. The Sound intensity is measured in Decibel (dB), which is tenth part of the longest unit "Bel" named after Alexander Graham Bell. Decibel (dB) is a ratio expressed as the logarithmic scale relative to a reference sound pressure level. The db is thus expressed as

$$\text{Sound Intensity Level} = 10 \log \frac{\text{Intensity Measured (I)}}{\text{Reference intensity } (I_0)}$$

or $dB = 10 \log I / I_0$

Intensity of Noise sources

Sources	Intensity(dB)
Breathing	10
Trickling clock	20-30
Normal conversation	35-60
Office noise	60 - 80
Traffic	50-90
Motor cycle	105
Jet fly	100 - 110

Effects of Noise Pollution Auditory

effects

- Auditory fatigue -- Whistling & buzzing in ears(noise level -90dB)
- Deafness   -- Permanent hearing loss (noise level-100dB)

Tinnitus

- Persistent sound in one or bothears.
- Tinnitus is often experienced as a high-pitched hiss, ring, buzz, orroar.
- It is usually continuous, but it may pulsate, and the beats may coincide with theheartbeat.

Non auditory effects

- Interference with speech communication -50dB
- Annoyance, ill temper,bickering
- loss in working efficiency - tiredness, deterioration or complete loss of ability towork

Physiological disorders

Neurosis, anxiety, hypertension, increased sweating, giddiness, nausea, fatigue, visual disturbance, reduces depth and quality of sleep , peptic ulcers, Increases cholesterol level resulting in constriction of blood vessel , Low weight children to mothers

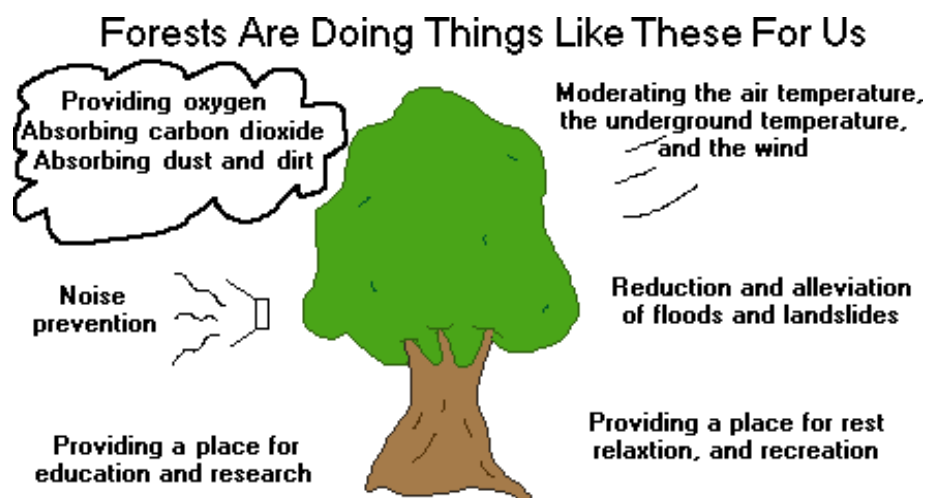| Noise intensity	Health hazards
80	Annoyance
90	Hearing damage
95	Very annoying
110	Stimulation of reception in skin
120	Pain threshold
130	Nausea,vomiting
140	Pain in ear
150	Burning of skin
160	Rupture of tymphonic membrane
180	Permanent damage

Even the nonliving things such as buildings undergo physical damage by cracks, breakage of windows, doors, and glasses etc. by sudden and explosive sounds.

Control of Noise Pollution

Noise definitely affects the quality of life. It is therefore important to ensure the mitigation or control of noise pollution**.** Noise pollution can be controlled

- At source level – Can be done by i) Designing and fabricating silencing devices in air craft engines, automobiles industrial machines and home appliances, ii) By segregating the noisy machines

- During Transmission – can be achieved by adding insulation and sound-proofing to doors, around industrial machinery. Zoning urban areas to maintain a separation between residential areas and zones of excessive noise.Sound
    a) Acoustillite : made up of Compressed wood pulp, wood fibers and is available in the form oftiles
    b) Acoustical blanket : Prepared from mineral wool or glassfibres
    c) Hair Felt: Consists of wool fibres, Coarse CottonFibres.
    d) Fibre Glass
    e) Cork Carpet: Prepared out of pieces of corks treated with linseed oil and is used for coveringfloors.
    f) Acoustic Plaster: Mainly consists of gypsum in the form ofplaster.
- Protecting the exposedperson
- By creating vegetation cover – Plants absorb and dissipate sound energy and thus act as Buffer Zone. Trees should be planted along highways, schools and otherplaces.

Planting vegetation to absorb and screen out noise pollution – Trees can act as a noise barrier

Forests Are Doing Things Like These For Us

Providing oxygen
Absorbing carbon dioxide
Absorbing dust and dirt

Moderating the air temperature, the underground temperature, and the wind

Noise prevention

Reduction and alleviation of floods and landslides

Providing a place for education and research

Providing a place for rest relaxtion, and recreation

- Through law
  a) Silence Zones must be created near Schools,hospitals
  b) Indiscriminate use of loudspeakers at public places should be banned/restricted bylaws
  c) Restriction on unnecessary us e of horns and vehicles plying without silencers
  d) Restrictions on aircraft flight at midnight

  e) Permissible Ambient Noise Level in Differentareas

Area	Code category	Noise level (dB)	
		Day Time (6 to 9 Am)	Night Time (9 to 6PM)
A	Industrial Area	75	70
B	Commercial Area	65	55
C	Residential Area	55	45
D	Silence Zone	50	40

  a) The Air (prevention and control of pollution) Act,1981
  b) The Motor VehiclesAct,1988
  c) Indian Penal Code – Sections 268 &290
- Through education - We Indians are Noisy people. Every occasion, it may be religious or family functions or elections; we used to celebrate with noise. Educating the people that noise is a pollutant, not a part of our routinelife.

Thermal Pollution

The term thermal pollution has traditionally been used more often to refer to the heating of lakes, river, streams, and other water bodies usually by electric power generating plants or by factories

- The combustion of fossil fuels always produces heat, sometimes as a primary desired product, and sometimes as a secondary, less desired by-product i.e.noise
- Heat is also produced when fossil fuels are burned to generate electricity. In this case, heat is a by-product, not the main reason that fuels areburned.
- Electricity is also generated in nuclear power plants, when no combustionoccurs.
- The decay of organic matter in landfills also releases heat to theatmosphere.

It is clear, therefore, that a vast array of human activities result in the release of heat to the environment. As those activities increase in number and extent, so does the amount of heat released. In many cases, heat added to the environment begins to cause problems for plants, humans, or other animals. This effect is then known as *thermal pollution.*

Sources of Thermal pollution

- Coal fired power planteffluents
- Domesticsewage
- Hydroelectric powereffluent
- Industrialeffluents
- Nuclear powerplants

Effects of thermal Pollution

A one megawatt nuclear power plant may require 1.3 billion gallons (five million m^3) of cooling water each day. The water used in such a plant has its temperature increased by about 63^oF (17^oC) during the cooling process. For this reason, such plants are usually built very close to an abundant water supply such as a lake, a large river, or the ocean.

When thermal pollution drives water temperatures up, most aquatic and marine wildlife cannot survive. Immobile organisms, such as plants and shellfish, simply die. One inevitable result of thermal pollution is a reduction in the amount dissolved oxygen in water. The amount of any gas that can be dissolved in water varies inversely with the temperature. As water is warmed, therefore, it is capable of dissolving less and less oxygen. Organisms that need oxygen to survive will, in such cases, cant be able to survive.

When heated water is released from a plant or factory, it does not readily mix with the cooler water around it. Instead, it forms a stream- like mass known as a thermal plume that spreads out from the outflow pipes. It is in this thermal plume that the most severe effects of thermal pollution are likely to occur. Only over an extended period of time does the plume gradually mix with surrounding water, producing a mass of homogenous temperature

Invasion of Destructive Organism

Water temperatures can have other, less expected effects also. As an example, trout can swim less rapidly in water above 66^oF (19^oC) making them less efficient predators. Organisms may become more subject to disease in warmer water too. The bacterium *Chondrococcuscolumnaris*is harmless to fish at temperatures of less than 50^oF (10^oC). Between temperatures of 50° - 70^oF (10° - 21^oC), however, it is able to invade through wounds in a fish's body and at temperatures above 70^oF (21^oC) it can even attack healthy tissue.

Urban Heat dome

Another example of thermal pollution is the development of urban heat islands. An urban heat island consists of a dome of warm air over an urban area caused by the release of heat in the region. Since more human activity occurs in an urban area than in the surrounding rural areas, the atmosphere over the urban area becomes warmer than it is over the rural areas.

It is not uncommon for urban heat islands to produce measurable climate changes. For example, the levels of pollutants trapped in an urban heat island can reach 5 to 25 percent greater than the levels over rural areas. Fog and clouds may reach twice the level of comparable rural areas, wind speeds may be produced by up to 30 per cent, and temperatures may be 32.9º - 35.6ºF (0.5º - 2ºC) higher than in surrounding rural areas. Such differences may cause both personal discomfort and, in some cases, actual health problems for those living within an urban heat island.

Thermal Air Pollution

Undesirable changes in Algal population: Excess Nutrients from the washout water from farm lands combined with thermal pollution cause an excessive algal growth with consequent changes. High Temperature promotes blue green algal blooms which disrupts the aquatic food chain.

Control of Thermal pollution

The water heated by thermal pollution also has a number of potential useful applications. For example, it may be possible to establish aquatic farms where commercially desirable fish and shellfish can be raised. The Japanese have been especially successful in pursuing this option. Some experts have also suggested using this water to heat buildings, to remove snow, to fill swimming pools, to use for irrigation, to de-ice canals, and to operate industrial processes that have modest heat requirements. Hot water is pumped into one end of the pond and cooler water is removed from the other end. The heat gets dissipated from the pond into the atmosphere. The main disadvantage is large amounts of water are lost due toevaporation

Here at Westport, Kentucky the Ohio River provides the large amount of water required by this coal-fired power plant. Thermal pollution is abated by the use of the large cooling tower which emits only steam into the atmosphere. The emission of the smokestack is largely steam but still containspollutants.

Lecture 11 Causes, effects and control of noise and thermal pollution.

1.	Human Ear can detect sounds in the frequency range of about -------------------	
	a) 20 Hz	**b) 20-20,000Hz**
	c) 40,000Hz	d) 24,000 Hz
2.	Unit of measuring noise is --------------------------	
	a)Dopson	b)Decimel
	c) Decibel	d) Dobson
3.	The permitted noise level in a silant zone during day time is -------------------	
	a)65	b)55
	c)50	d)70
4.	Human generated noise in the ocean may interfere with marine organisms	
	a) Communication	b) mobility
	c) food finds ability	d) migration
5.	When a person exposed to a voice level of 160 decibels for long time causes	
	a)Annoyance	b)Restlessness
	c)Tiredness	**d)Rupture of tymphonic membrane**
6.	For one megawatt energy generation, nuclear power plant requires colling water each day ------------------------------- Cooling water each day.	
	a) 1:3 million m^3	b) 0.3 million m^3
	c) 1 million m^3	**d) 5 million m^3**
7.	Thermal pollution in a river -------------------	
	a) reduces the O$_2$Disssolution	b) increases O$_2$ solubility
	c) stabilizes O$_2$ level	d) none of the above
8.	urban heat island is nothing but --------------------	
	a) a dome of cool air over the urban area	**b) a dome of warm air over the urban area**
	c) a dome of noise pollution over the urban	d) reduced wind speed over the urban area

	area	
9.	*Chondrococcuscolumnaris*is harmless to fish at 10°C but causes diseases when the temperature of water is	
	a) more than 12°C	**b) more than 21°C**
	c) less than 10°C	d) at 10°C
10.	The thermal pollution of water in a industrial process can be	
	a) used for cogeneration	b) used to heat building to remove snow
	c) used to deice canals	**d) all the above**
11.	Tinnitus is due to	
	a)Water pollution	**b) Noise Pollution**
	c)Soil pollution	d)Xenobiotics
12.	The major effect of discharging heated water from power plants to aquatic ecosystems	
	a)Reduction in DO concentration	B0)Reduction in Biodiversity of the Ecosystem
	c)Increase in metabolic rate of organism	**d) All the above**
13	The noise level during normal conversation is	
	a)30 db	**b)35-60 db**
	c)20 db	d)90 db
14	Persistent sound in one or both ears, often experienced as a high pitch ringing sound is	
	a)annoyance	b)all the above
	c)deafness	**d)tinnitus**
15	The amount of any gas that can be dissolved in water is	
	a)inverse with temperature	b)direct with temperature
	c)no relation with temperature	d)none of the above

How it is computed?

The intensity of sound is measured in sound pressure levels (SPL) and common unit of measurement is decibel, dB. The community (ambient) noise levels are measured in the A - weighted SPL, abbreviated dB(A). This scale resembles the audible response of human ear. Sounds of frequencies from 800 to 3000 HZ are covered by the A - weighted scale. If the sound pressure level, L_1 in dB is measured at r_1 meters, then the sound pressure level, L_2 in dB at r_2 meters is given by,

$$L_2 = L_1 - 20\log_{10}(r_2/r_1).......(1)$$

If the sound levels are measured in terms of pressure, then, sound pressure level, L_P is given by,

$$L_P = 20 \, \text{Log}_{10}(P/P_o) \, dB(A).......(2)$$

The L_p is measured against a standard reference pressure, $P_o = 2 \times 10^{-5} \text{N/m}^2$ which is equivalent to zero decibels. The sound pressure is the pressure exerted at a point due to a sound producing source (see. Fig. 2)

o)))))*)SPL

Fig. 2 Definition of sound pressure

Day-night equivalent noise levels (Ldn): The day night equivalent noise levels of a community can be expressed as -

$$\text{Ldn , dB(A)} = 10 \times \log_{10} [15/24 \, (10^{Ld/10}) + 9/24 \, (10^{(Ln+10)/10})]..............(3)$$

where, Ld = day-equivalent noise levels (from 6AM - 9 PM), dB (A)
         Ln = night equivalent noise levels (from 9 PM - 6 AM), dB (A)

The day hours in respect to assessment of noise levels, is fixed from 6 AM - 9 PM (i.e., 15 hrs) and night hours from 9 PM - 6 AM (i.e., 9 hrs). A sound level of 10 dB is added to Ln due to the low ambient sound levels during night for assessing the Ldn values.

Addition of sound levels: The effective sound levels form two or more sources cannot be simply added algebraically. For example, the effective sound level from two air conditioners 60dB(A) each, say is not 60+60=120dB(A) but 60+3=63dB(A). (See table 1). Similarly, the effective sound level of 57 dB, 63 dB, 63 dB, 66 dB and 69 dB is

72 dB. The computation is illustrated below.

```
57 ──────────────────────────────┐
                                  │
63 ──────┐                        │
         │                        │
    66 ──┐                        │
63 ──────┘   │                    │    72
             │
         69
66
                      72
69
```
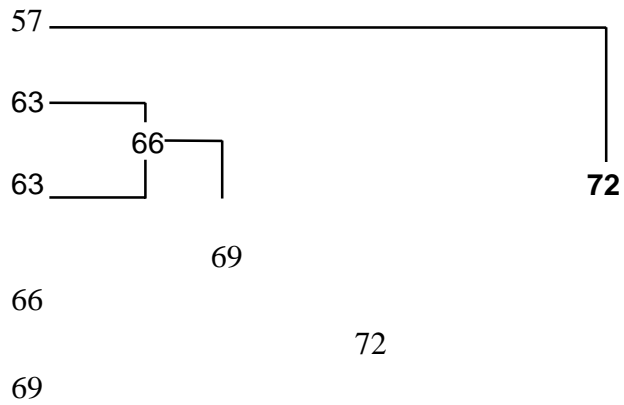
Table 1 Addition of sound levels, L_1 and L_2 ($L_1 > L_2$)

$L_1 - L_2$, dB	Add to L_1
0 or 1	3 dB
2 or 3	2 dB
4 - 8	1 dB
9 or more	0 dB

Source : Ref. (9)

13

Frequency analysis

The frequency analysis allow to separate the main components of the signals by dividingthe frequency range of interest into smaller frequency bands using a set of filters. We may distinguish between noises that consist of regularly repeated or periodic sounds and those that consist of aperiodic sounds. The simplest periodic sound is a pure tone i.e., a pressure disturbance that fluctuates sinusoidally at a particular frequency. The lower the frequency, the longer is the wave length (wavelength = velocity ofsound/frequency).

The noise produced by most sources of community noise, such as automobiles or aircraft engines, are examples of aperiodic sounds. Such sounds cannot be subdivided into sets of harmonically related pure tones but can be described in terms of components extending over finite frequency bands. Such frequency analysis are often done in bands of octaves or 1/3octaves.

An octave band is a frequency band with upper and lower cutoff frequencies having a ratio of 2. The cut off frequencies of 707 HZ and 1414 HZ define an octave band, whose band centrefrequency is 1000 HZ and would be referred to as the 1000 HZ octave band.

Frequency analyserscan be divided into two groups viz. constant band width analyserand constant percentage bandwidth analyser. In the constant bandwidth analyserthe filter bandwidth is kept constant throughout the frequency range while in the constant percentage bandwidth analyser, the bandwidth is proportional to the centre frequencies. The constant percentage bandwidth analyseris widely used. The nine preferred centre frequencies for noise level measurement are 31.5, 63, 125, 250, 500, 1000, 2000, 4000 and 8000 HZ.[3]

As already mentioned, dB(A) values give emphasis to sounds in the range of about 800 to 3000 HZ. Since the sound generating frequencies are not fully covered under dB(A), for detailed evaluation and engineering design, the multiple-number descriptions provided by frequency analysis are often required.

Noise measurement instruments

Noise measurement is an important diagnostic tool in noise control technology. The objective of noise measurement is to make accurate measurement which give us a purposeful act of comparing noises under different conditions for assessment of adverse impacts of noise and adopting suitable control techniques for noise reduction. The various

equipment used for noise level measurement are summarized at Table 2. The principle and the components of noise measuring instruments is summarized below.

A sound level meter consists basically of a microphone and an electronic circuit including an attenuator, amplifier, weighting networks or filters and a display unit. The microphone converts the sound signal to an equivalent electrical signal. The signal is passed through a weighting network which provides a conversion and gives the sound pressure level in dB. The instructions laid down by the noise level meter manufacturers shall be followed whileusing the instruments.

The time constants used for the sound level meter standards are
S (Slow) = 1 second
F (Fast) = 125 milli seconds

Relatively steady sounds are easily measured using the "fast" response and unsteady sounds using "slow" response. When measuring long-term noise exposure, the noise level is not always steady and may vary considerably, in an irregular way over the measurement period. This uncertainty can be solved by measuring the continuous equivalent level,which is defined as, the constant sound pressure level which would have produced the same total energy as the actuall evelover the giventime. It is denoted as **Leq**. The display of Leqfacility is also available in certain models of sound level meters. This is the desired parameter for assessment of ambient noiselevels.

Table2   Equipment used in the measurement of noiselevels

S.No.	Equipment	Specification/Area of usage
1.	Sound level meter	Type-0 : Laboratory reference standard
		Type-1: Lab use and field use in specified controlled environment
		Type-2: General field use (Commonly used)
		Type-3: Noise survey
2.	Impulse meters	For measurement of impulse noise levels e.g. hammer blows, punch press strokes etc.
3.	Frequency analysers	For detailed design and engineering purpose using a set of filters.
4.	Graphic recorders	Attached to sound level meter. Plots the SPL as a function of time on a moving paper chart.
5.	Noise dosimeters	Used to find out the noise levels in a working environment. Attached to the worker
6.	Calibrators	For checking the accuracy of sound level meters.

Noise Sampling

Bureau of Indian Standards (BIS) has published several code books for sampling and analysis of noise pollution and guidelines for control of noise pollution from domestic and industrial sources. The reader is advised to refer to the BIS code books (table 3) for a better understanding of methods of noise sampling. For sampling of noise levels from industrial sources, noise levels in the different octave bands are measured by a sound level meter in conjunction with octave - band filters at the workers ear level or at about a distance of one meter from the source ofnoise.

Table 3 Selected BIS code books on noise pollution

BIS Code	Description
IS-4954-1968	Noise abatement in town planning recommendations
IS-3098-1980	Noise emitted by moving road vehicles, measurement
IS-10399-1982	Noise emitted by stationary road vehicles, methods of measurement of
IS-6098-1971	Air borne noise emitted by rotating electrical machinery, method of measurement of
IS-4758-1968	Noise emitted by machines, methods of measurements of
IS-3483-1965	Noise reduction in industrial buildings, code of practice for
IS-1950-1962	Sound insulation of non-industrial buildings, code of practice for
IS-9167-1979	Ear protectors

Sources of noise

Where does it generate from? The sources of noise may vary according to daily activities. They sources may be domestic (movement of utensils, cutting and peeling of fruits/vegetables etc.) natural (shores, birds/animal shouts, wind movement, sea tide movement, water falls etc.), commercial (vendor shouts, automobiles, aeroplanes, marriages, laboratory, machinery etc.) industrial (generator sets, boilers, plant operations, trolley movement, transport vehicles, pumps, motors etc.). The noise levels of some of the sources are summarisedat table 4.

Typical surveys pertaining to causes of noise pollution, reveal the various sources of noise pollution and frequency variation of their occurrences. The results of a survey conducted in Central London, way back in 1961-62 reveals the presence of noise pollution even in the early '60s (Table 5). Road traffic is identified as the major source of noise pollution while at home or outdoors or at work.

Table 4 Typical noise levels of some point sources

Source	Noise level dB(A)	Source	Noise level, dB(A)
Air compressors	95-104	Quiet garden	30
110 KVA diesel generator	95	Ticking clock	30
Lathe Machine	87	Computer rooms	55-60
Milling machine	112	Type institute	60
Oxy-acetylene cutting	96	Printing press	80
Pulveriser	92	Sports car	80-95
Riveting	95	Trains	96
Power operated portable saw	108	Trucks	90-100
Steam turbine (12,500 kW)	91	Car horns	90-105
Pneumatic Chiseling	118	Jet takeoff	120

Table5   Noisethatdisturbpeople-1961-62CentralLondonSurvey

S.No.	Description of noise	No. of people disturbed per 100 questioned		
		When at home	When outdoors	When at work
1	Road traffic	36	20	7
2	Aircraft	9	4	1
3	Trains	5	1	0
4	Industry / Construction work	7	3	10
5	Domestic appliances	4	0	4
6	Neighbors impact	6	0	0
7	Children	9	3	0
8	Adult voices	10	2	2
9	Radio/TV	7	1	1
10	Bells/alarms	3	1	1

The variations in the emission of noise levels in a particular environment can be assessed from the statistical distribution of noise levels in that environment (See Fig 3). To draw a statistical distribution curve, terms like L_{10}, L_{50} and L_{90} play an important role.

The Sound levels exceeding 10%, 50% and 90% of the total time intervals during a

particular period are designated as L_{10}, L_{50} and L_{90} respectively.

From figure, it can be seen that, 90% of the sound levels are about 64 dB(A). Local disturbances increased the sound levels (L_{10}) to 76 dB(A), i.e., during 10% of the total time. L_{90} represents the background noiselevels.
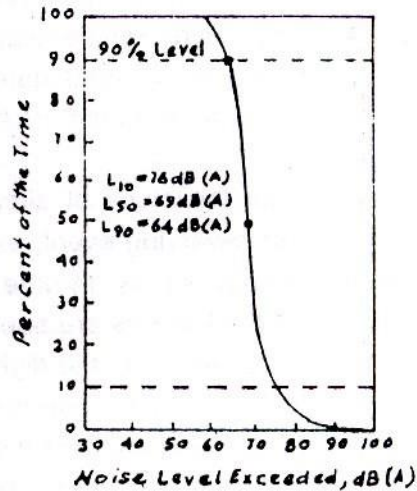

Fig. 3 Statistical distribution of noise levels

The equivalent noise levels, Leq can also be calculated as [5]
Leq = L_{50} + (L_{10} - L_{90})^2/ 60

Noise Climate (NC): It is the range over which the sound levels are fluctuating in an interval of time[5]
NC = L_{10} - L_{90}

Hence, Leq in the above example is -

Leq = 69 + (76 - 64)^2 /60 = 71.4 dB.
and noise climate, NC = 76 - 64 = 12 dB/sampling time.

Aircraft Noise

The noise of aircraft is described in terms of Perceived Noise Levels (PNL), a scale of noisiness, expressed in pNdB. There is no simple relationship between the dB(A) value and pNdB value for all noises. However, a useful statement is that, the pNdB value for a noise is approximately 13 units greater than the dB(A) value for thenoise.

Afurther refinementresultingfromthestudyofaircraftnoiseistheEffectiveNoiseLevel,a scale of noisiness of a time-varying event, expressed in EPNdB. It is used to describe the noise of a single aircraft activity. In order to describe the noise exposure associated with an airport,

the EPNdB values are supplemented with such information as the number of flights of each aircraft type, the flight paths that the aircraft use and the time of day at which the operations occur. The resulting picture is often presented in such terms as Noise Exposure Forecast (NEF) contours, which are intended to represent the long-term average noise exposure in communities around airports. More detailed information on the subject is available with Ref.9.

Impacts of noise

Why bother about noise? Often neglected, noise induces a severe impact on humans and on living organisms. Some of the adverse effects are summarised below.

- **Annoyance:** It creates annoyance to the receptors due to sound level fluctuations. The aperiodic sound due to its irregular occurrences causes displeasure to hearing and causesannoyance.
- **Physiological effects:** The physiological features like breathing amplitude, blood pressure, heart-beat rate, pulse rate, blood cholesterol areeffected.
- **Loss of hearing:** Long exposure to high sound levels cause loss of hearing. This is mostly unnoticed, but has an adverse impact on hearingfunction.
- **Human performance:** The working performance of workers/human will be affected as they'll be losing theirconcentration.
- **Nervous system:** It causes pain, ringing in the ears, feeling of tiredness, thereby effecting the functioning of humansystem.
- **Sleeplessness:** It affects the sleeping there by inducing the people to become restless and loose concentration and presence of mind during theiractivities
- **Damage to material :** The buildings and materials may get damaged by exposure to infrasonic / ultrasonic waves and even getcollapsed.

Control of Noise Pollution

Noise generation is associated with most of our daily activities. A healthy human ear responds to a very wide range of SPL from - the threshold of hearing at zero dB, uncomfortable at 100-120 dB and painful at 130-140 dB[3]. Due to the various adverse impacts of noise on humans and environment (See LO-5), noise should be controlled. The technique or the combination of techniques to be employed for noise control depend upon the extent of the noise reduction required, nature of the equipment used and the economy aspects of the available techniques.

The various steps involved in the noise management strategy is illustrated at Fig 4. Reduction in the noise exposure time or isolation of species from the sources form part of the noise control techniques besides providing personal ear protection, engineered control for noise reduction at source and/or diversion in the trajectory of sound waves.
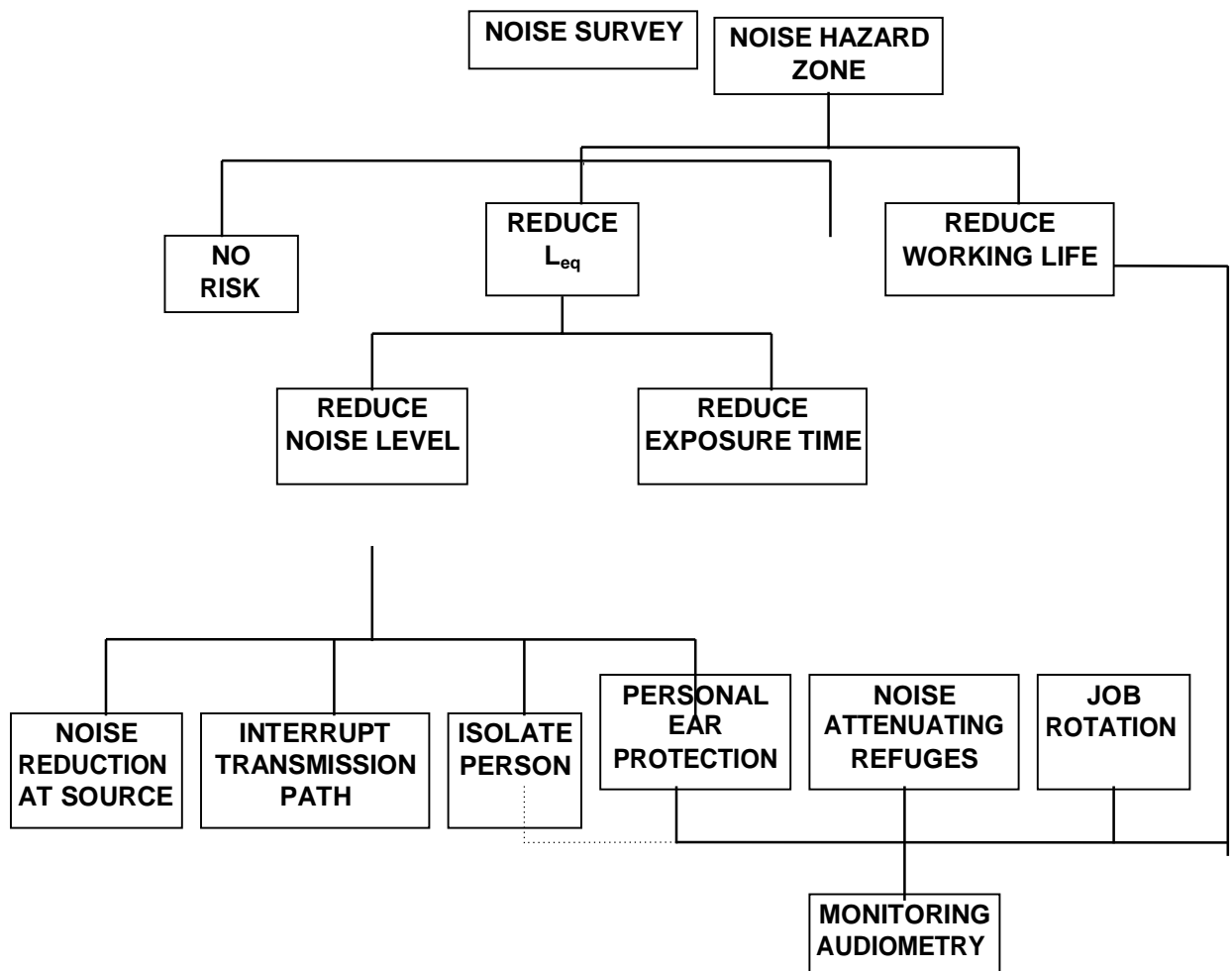

Fig.4   Noise Management Strategy

The techniques employed for noise control can be broadly classified as [4,5,9,10]
☐ Control atsource
☐ Control in the transmissionpath
☐ Using protective equipment.

Noise Control at Source

The noise pollution can be controlled at the source of generation itself by employingtechniques like-

☐ **Reducing the noise levels from domestic sectors:** The domestic noise coming from radio, tape recorders, televisionsets, mixers, washing machines, cooking operations can be minimisedby their selective and judicious operation. By usage of carpets or any absorbing material, the noise generated from felling of items in house can beminimised.

☐ **Maintenance of automobiles:** Regular servicing and tuning of vehicles will reduce the noise levels. Fixing of silencers to automobiles, two wheelers etc., will reduce the noise levels.

☐ **Control over vibrations:** The vibrations of materials may be controlled using proper foundations, rubber padding etc. to reduce the noise levels caused byvibrations.

☐ **Low voice speaking:** Speaking at low voices enough for communication reduces the excess noiselevels.

☐ **Prohibition on usage of loud speakers:** By not permitting the usage of loudspeakers in the habitant zones except for important meetings / functions. Now-a-days, the urban Administration of the metro cities in India, is becoming stringent on usage of loudspeakers.

☐ **Selection of machinery:** Optimum selection of machinery tools or equipment reduces excess noise levels. For example selection of chairs, or selection of certain machinery/equipment which generate less noise (Sound) due to its superior technology etc. is also an important factor in noise minimisationstrategy.

☐ **Maintenance of machines:** Proper lubrication and maintenance of machines, vehicles etc. will reduce noise levels. For example, it is a common experience that, many parts of a vehicle will become loose while on a rugged path of journey. If these loose parts are not properly fitted, they will generate noise and cause annoyance to the driver/passenger. Similarly is the case of machines. Proper handling and regular maintenance is essential not only for noise control but also to improve the life of machine.

Control in the transmission path

Please recall the Fig 4 wherein the inter-relationship between elements of noise was represented. The change in the transmission path will increase the length of travel for the wave and get absorbed/refracted/radiated in the surrounding environment. The available techniques are briefly discussedbelow.

Installation of barriers: Installation of barriers between noise source and receiver can attenuate the noise levels. For a barrier to be effective, its lateral width should extend beyond the line-of-sight at least as much as the height (See Fig. 5). It may be noted that, the frequencies, represented on the X-axis of the graph in Fig. 5, are the centre frequencies of the octave band. The barrier may be either close to the source or receiver, subject to the condition that, R <<D or in other words, to increase the traverse length for the sound wave. It should also be noted that, the presence of the barrier itself can reflect sound back towards the source. At very large distances, the barrier becomes less effective because of the possibility of refractive atmospheric effects. Another method, based on the length of traverse path of the sound wave is given at Fig. 6.
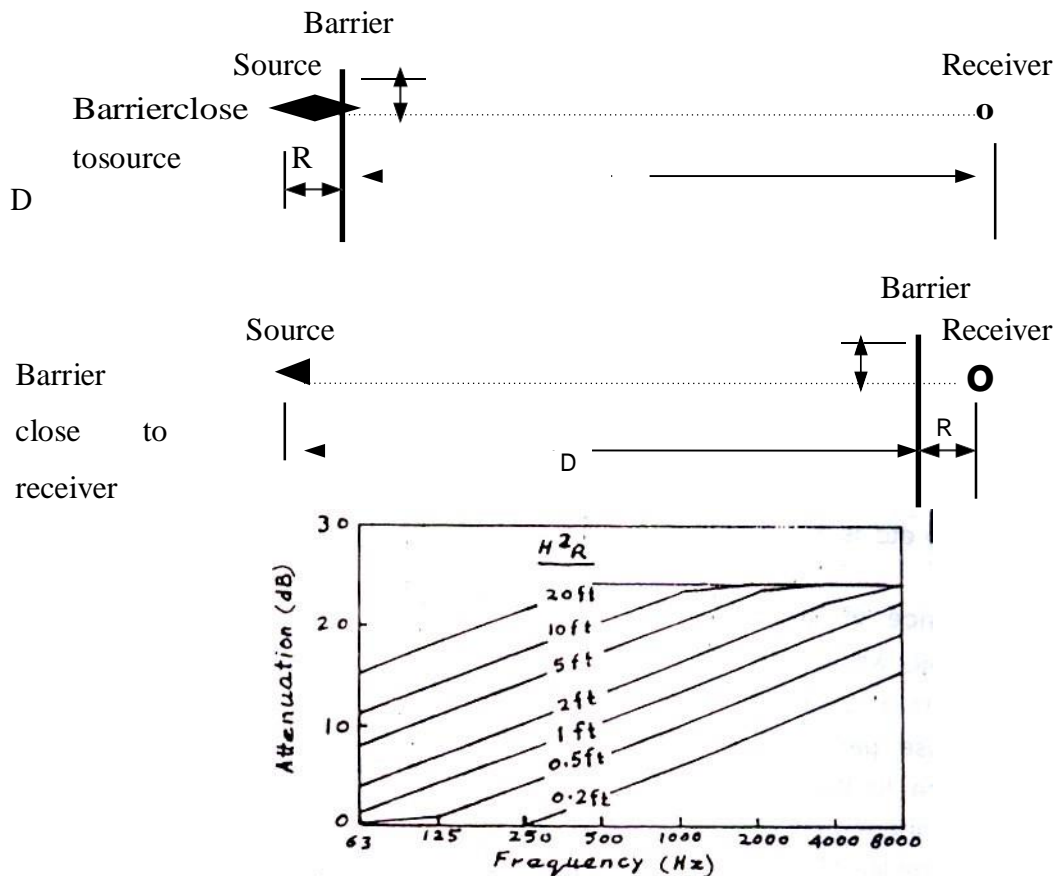
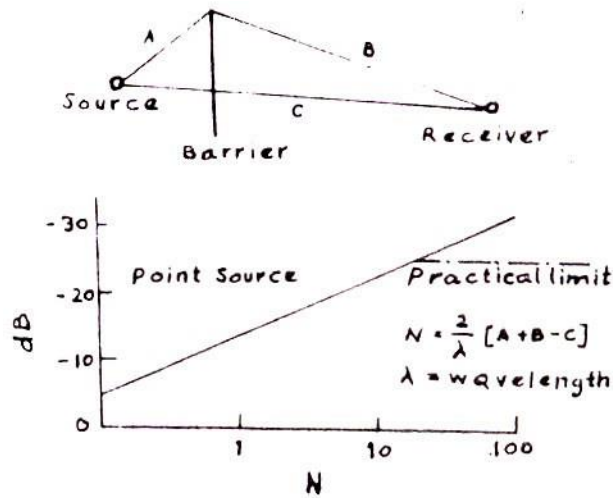Fig. 5   Attenuation of noise levels using barriers

Fig.6   Attenuation of noise levels usingbarriers

Design of building: The design of the building incorporating the use of suitable noise absorbing material for wall/door/window/ceiling will reduce the noise levels.   The approximate reduction of outside noise levels using typical exterior wall construction is given at Table 6. The reduction in noise levels for various frequencies and the A-weighted scale are shown. Variations in spectrum shape may change this A-weighted value by as much as +/- 3dB.

☐ **Installation of panels or enclosures:** A sound source may be enclosed within a paneled structure such as room as a means of reducing the noise levels at the receiver. The actual difference between the sound pressure levels inside and outside an enclosure depends not only on the transmission loss of the enclosure panels but also on the acoustic absorption within the enclosure and the details of the panel penetrations which may include windows ordoors.

The product of *frequency of interest and surface weight of the absorbing material* is the key parameter in noise reduction through transmission loss. With conventional construction practices, the high-frequency transmission loss of a panel becomes limited to around 40 dB, owing to the transmission of sound through flanking paths other than the panel itself. Examples of such flanking are structural connections or ducts joining the two spaces on either side of the panel of interest.

Table6

**Approximatereductionofoutsidenoiseprovidedbytypicalexteriorw
all construction**

Octave Band Center Frequency (Hz)	A	B	C	D	E	F	G	H
63	0	9	13	19	14	24	32	21
125	0	10	14	20	20	25	34	25
250	0	11	15	22	26	27	36	30
500	0	12	16	24	28	30	38	37
1,000	0	13	17	26	29	33	42	42
2,000	0	14	18	28	30	38	48	44
4,000	0	15	19	30	31	43	53	45
8,000	0	16	20	30	33	48	58	46
approx. dB(A)	0	12	16	24	27	30	38	33

A: No wall; outsideconditions.

B: Anytypicalwallconstruction,withopenwindowscoveringabout5%ofexteriorwallarea.

C: Any typical wall construction, with small open air vents of about 1% of exterior wall area, all windows closed.

D: Any typical wall construction, with closed but operable windows covering about 10-20% of exterior wall area.

E: Sealedglasswallconstruction,1/4-
inglassthicknessoverapproximately50%ofexteriorwallarea.   F:
Approximately20lb./ft^{2}solidwallconstructionwithnowindowsandnocracksoropeni
ngs.

G: Approximately50lb/ft^{2}solidwallconstructionwithnowindowsandnocracksoropenings.

H: Anytypicalwallconstruction,withcloseddoublewindows
(panesatleast3/32"thick,airspaceatleast4 in.) and solid-core gasketed exteriordoors.

☐ **Green belt development:** Green belt development can attenuate the sound levels. The degree of attenuation varies with species of greenbelt. The typical attenuation of noise levels by shrubs and trees is presented at Fig. 7 (a) and (b).The statutory regulations direct the industry to develop greenbelt four times the built-up area for attenuation of various atmospheric pollutants, including noise.

Using protection equipment

Before employing the use of protective equipment, please recall the Fig. 4, wherein the various steps involvedin the noise management strategy are illustrated. Protective equipment usage is the *ultimate* step in noise control technology, i.e. after noise reduction at source and/or after the diversion or engineered control of transmission path of noise.
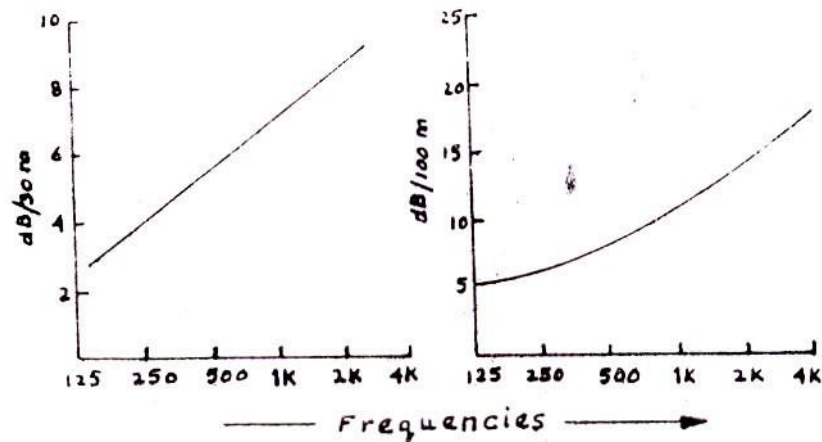

Fig. 7 (a) & (b) Noise level attenuation by shrubs and trees

Thefirststepinthetechniqueofusingprotectiveequipmentistogaugetheintensityofthe problem, identification of the sufferer and his exposure to the noise levels. For the Regulatory standards pertaining to time of exposure vs. maximum noise levels permitted in a workspace environment, please refer toLO-8.

The usage of protective equipment and the worker's exposure to the high noise levels can be minimisedby -

☐ **Job rotation:** By rotating the job between the workers working at a particular noise source or isolating a person, the adverse impacts can bereduced.

☐ **Exposure reduction:** Regulations prescribe that, noise level of 90 dB (A) for more than 8 hrcontinuous exposure is prohibited. Persons who are working under such conditions will be exposed to occupational health hazards. The schedule of the workers should be planned in such a way that, they should not be over exposed to the high noiselevels.

☐ **Hearing protection:** Equipment like earmuffs, ear plugs etc. are the commonly used devices for hearing protection. Attenuation provided by ear-muffs vary widely in respect to their size, shape, seal material etc. Literature survey shows that, an average noise attenuation up to 32 dB can be achieved using earmuffs [7]. Details of some of the suppliers of the protective equipment are given in Ref.3.

Documentation of noise measurements

Please recall the Fig. 4, where noise survey is the first step of noise management strategies. By now, the reader might be conversant with the terminology, impacts, significance and control technology of noise pollution. Hence, it is felt to place this section just before the end of the module to avoid any confusion for the reader.

Noise surveys will be conducted in an area (or zone) to find out the ambient noise levels or noise levels at the work environment. The field data will be analysedand documented for decision making. The parameters to calculate however, vary with the objective. But in most cases, Leq, Ldn, NC are the likely deciding parameters (See Table 7 and8).

For a systematic presentation, the noise survey reports for a typical industrial noise level survey should contain the following information [3]

☐ Reference to individualstandard(s)
☐ Description of the machine and its conditions of installation andoperation
☐ Description of the test environment with respect to its ability to reflect, dissipate or absorb noise and location of themachine.
☐ Number of workers exposed and duration ofexposure
☐ Description of the measuring apparatus used and method ofcalibration
☐ Time constant and weighting networkused
☐ Position of measuring points.
☐ Results of SPL instruments either A -scale or octave bandanalysis
☐ Background noise levels and sound pressure values corrected for background noise, if any.

The same principles can be applied for documentation of community (ambient) noiselevels and is left as an exercise to thereader.

Regulatory guidelines

Statutory Regulatory guidelines were prescribed both for the ambient noise levels (Table 7) and for workspace environment noise levels (table 8). Factories Act, 1948 prescribes the protection of workers against high noise levels (noise level > 90 dB (A)). The State Pollution Control Board and Inspector of Factories have powers to administer the control of noisepollution.

Table 7 Indian Standards for ambient noise levels [1]

Area	Noise Limits, Leq, dB (A)	
	Day Time [2]	Night Time [3]
Silence zone [4]	50	45
Residential area	55	45
Commercial area	65	55
Industrial area	75	65

1. Ministry of Environment and Forest (MOEF) Guidelines vide Environment (Protection) Act, 1986 third amendment rules, dated 26/12/89 (Ref.6)
2. Day time from (600 hrs to 2100 hrs,IST)
3. Night time from (2100 hrs to 600 hrsIST)
4. Silencezone:Upto100maroundhospitals,educationalinstitutionsandcourts.Thezones aretobe declared by competent authority. Use of vehicle horns, loud speakers and bursting of crackers shall be banned in thesezones.

Table 8 Damage risk criteria for hearing loss Occupational Safety & Health Administration (OSHA) regulations

Maximum allowable duration per day hours	Sound pressure level, dB (A)
8	90
6	92
4	95
3	97
2	100
1.5	102
1	105
0.75	107
0.5	110
0.25	115

No exposure in excess of 115 dB(A) is permitted.

Application in Environmental Impact Assessment (EIA) studies

The **EIA** study will be carried out to evaluate and assess the impacts of any proposed (or existing) activity on the environment. Noise is one of the environmental attributes, on which the likely impacts due to the proposed (or existing) activity need tostudied.

The likely steps to be carried out while conducting noise level studies for an EIA project are summarisedbelow. The EIA wiilbe carried out for either proposed or existing activities. The sequential steps involved will be same for both theactivities.

- ☐ The likely activities that generate noise from the proposed activity are to beidentified
- ☐ The typical sound (noise) levels of the noise generating sources are to be assessed either from literature or from a similarsource
- ☐ The likely exposure time of a worker at a noise generating source is to be assessed from the plant / utilityrecords
- ☐ The workspace environment noise levels are to be checked with OSHA standards (Table 1.8). If the noise exposure levels are higher, suitable noise control measures like personal protective equipment, installation of barriers, enclosures etc., need to be suggested
- ☐ The EIA will usually be carried out in an impact circle of radius 3 Km to 25 Km or even more depending on the objective and the likely activities of the proposed project. The representative baseline (or back ground) status of the ambient noise levels need to be collected by monitoring at various stations in the studyzone
- ☐ The ambient noise levels are to be analysedfor the prescribed parameters like, Leq, Ldn etc., and compared with the ambient noise level standards (Table 1.7) for the study region. If these values are higher than the prescribed limits, the likely causes for the high values need to beassessed
- ☐ The likely impact of the noise levels from the proposed activity on the local environment keeping in view the baseline status of noise levels need to bepredicted
- ☐ If the predicted impact is adverse, suitable measures for attenuating the noise levels like, green belt development, in-plant control measures etc., need to besuggested.
- ☐ The objective of the EIA study is to make ensure that, the local environment, say noise, will **not** get affected by the noise levels emanated from the proposed activity. If the ambient noise levels are high, then control measures be suggested to the project proponent to ensure that, ambient noise levels will not increase due to the proposed activity