Chapter 4

Waste Water Engineering-II

CHAPTER HIGHLIGHTS

- ☞ *General methods of disposal of sewage*
- ☞ *Noise pollution*
- ☞ *Air pollution and control*

General Methods of Disposal of Sewage

1. Dilution or disposal in water
2. Effluent irrigation or board irrigation or sewage farming

Disposal by Dilution in Water

When organic matter is discharged in to a large volume of water contained in their stream it gets rapidly dispersed and diluted

$$C = \frac{C_S Q_S + C_R Q_R}{(Q_S + Q_R)}$$

Where

C_S = Sewage concentration

C_R = River concentration before discharge effluent

Q_S = Sewage discharge rate

Q_R = River discharge

$(Q_S + Q_R)$ = Combined discharge rate

C = Concentration of resulting mixture

- In this method sewage is discharged into river stream, or a large body of water, such as a lake or sea.
- The ratio of quantity of diluting water to that of the sewage is known as dilution factor.
- Standards of dilution for discharge of waste waters into rivers.
- **Sedimentation:** Settleable solids will settle down into the bed of river. This helps in self-purification process.

Dilution Factors	Standards of Purification Required
Above 500	No treatment is required
Between 300–500	Primary treatment such as plain sedimentation is required
Between 150–300	Treatment such as sedimentation, screening, chemical precipitation are required
Less than 150	Complete thorough treatment should be given to sewage

- **Sunlight:** This has bleaching and stabilizing effect of bacteria and by process of photosynthesis it gives O_2. Algae plants absorb carbon dioxide and release oxygen by the process of photosynthesis.
- **Oxidation:** Organic matter gets oxidized into stale end products and oxygen required is supplied from atmosphere. Oxidation will continue till the organic matter has been completely oxidized. It is the most important action responsible for self-purification of rivers.
- **Reduction:** It occurs due to hydrolysis of organic matters settled at the bottom either chemically or biologically. Anaerobic bacteria at the bottom of the river bed will help

in spilling the complex organic constituents of sewage into liquids and gases and thus paving the way for their ultimate stabilization by oxidation.

- **Sludge banks:** Sewage solids thrown into sea water, chemically react with the dissolved matter of sea water, resulting in precipitating some of the sewage solids, giving a milky appearance to sea water and forming sludge banks.
- **Sleek:** The lighter and warmer sewage will rise up to the surface when thrown in to the sea water and will result in speeding of sewage at the top surface of the sea in a thin film of sleek.

Disposal of Sewage Effluent on Land for Irrigation

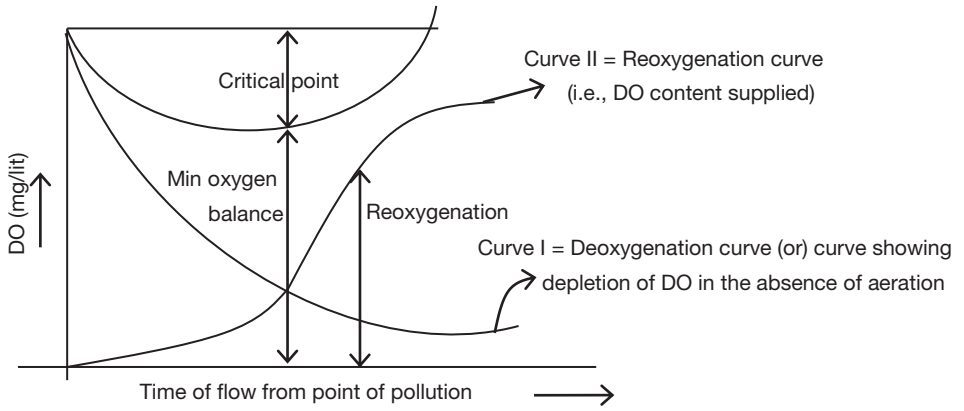
Disposal sewage disposal in land help in increasing crop yields.

Zone of Pollution in River Stream

Zone of pollution is generally divided into 4 zones.

1. **Zone of degradation:** In this zone the dissolved oxygen is reduced to 40% of saturation level. There is an increase in CO^2 content, certain typical bottom worms such as limnodrilus and tubifex appear with sewage fungi such as sphacrotilusnatans. In this zone water becomes dark and turbid with formation of sludge deposits.
2. **Zone of active decomposition:** It is the zone of heavy pollution. The water becomes grayish and darker than previous zone. In this zone the concentration falls down from 40 to zero and anaerobic conditions may set in. Fish life is absent, protozoa and fungi will disappear first and then reappear. Fish life will be absent, algae and tubifex will also be absent. Maggots and psycoda larvae will be present.
3. **Zone of recovery:** In this zone river stream tries to recover from its degraded condition. The BOD falls down and the DO content rises above 40% of the saturated value. The organic mineral will be mineralized to form nitrates, sulphates, phosphates, carbonates, etc.
4. **Zone of clean water:** It is the zone which recovers the original condition with DO rising up to saturation. Organisms and protozoa reappear. Usual aquatic life prevails.

Oxygen Deficit



- Oxygen deficit = Saturation DO – Actual DO
- The oxygen deficit curve is drawn by adding de-oxygenation and re-oxygenation curve. When de-oxygenation rate > re-oxygenation rate then sag is increasing. When de-oxygenation rate = re-oxygenation rate then the critical point is reached. When the de-oxygenation rate < re-oxygenation rate then oxygen deficit goes on decreasing and becomes zero.

$$\text{Self-purification constant, } \boxed{f = \frac{K_R}{K_D}}$$

Where

K_D = De-oxygenation rate

K_R = Re-oxygenation rate

$\therefore$ DO deficit of mixture in mg/lit after 't' days

$$= \frac{K_D L}{K_R - F_D}\left[10^{-K_D t} - 10^{-K_R t}\right] + \left[D_0 \cdot 10^{-K_R t}\right]$$

Where

L = Ultimate first stage BOD of mixture at the point of waste discharge in mg/lit

D_0 = Initial oxygen deficit of mixture in mg/lit at the mixing point.

Solved Examples

Example 1

The minimum flow of river is 50 m^3/s having a DO content of 7 mg/lit and BOD5 of 8 mg/lit. It receives a waste water discharge of 5 m^3/s with BOD5 of 200 mg/lit and rate constants of de-oxygenation and re-aeration (base) are $\frac{0.5}{d}$ and $\frac{1}{d}$, respectively and find the minimum DO which occurs at a distance from the point of waste water discharge.

Solution

$Q_S = 5\ m^3/s$

$Q_R = 50\ m^3/s$

$Y_S = 200$ mg/lit

$Y_R = 8$ mg/lit

$DO_s = 0$

$DO_R = 7$ mg/lit

$K_1 = 0.5$/day

$K_2 = 1$ day

$$DO_{min} = \frac{50 \times 7 + 5 \times 0}{50 + 5}.$$

$$= 6.63 \text{ mg/lit}$$

- **De-oxygenating curve (*i*):** The rate of de oxygenation depends on the amount of organic matter remaining to be oxidized at the given time $\left(\frac{dt}{dt} \propto L_t\right)$ as well as on the temperature.
- **Re-oxygenation curve:** Rate supply of oxygen from atmosphere depends upon:
  1. Depth of water
  2. Oxygen deficit
  3. Temperature and mixing water

Disposal of Solid Waste

Types of Solid Waste

- **Garbage:** It includes all sorts of putrescible organic wastes obtained from kitchens, hotels, restaurants, etc.
- **Rubbish:** It includes all non-putrescible wastes except ashes. It includes all combustible and non-combustible wastes such as rags, paper pieces, broken pieces of glass and furniture, etc.

Methods of Disposal of Refuse

Sanitary Land Filling

- The refuse is dumped in low lying area under an engineered operation.
- Refuse is dumped in layers of 1.5 m or so and each layer is covered by good earth of at least 20 cm thickness, so that refuse is not directly exposed.
- The waste is stabilized by aerobic as well as anaerobic bacterial process.
- The entire period of refuse stabilization can be divided into five phases.

Phase 1—Aerobic bacteria and fungi deplete the available oxygen to increase oxidation of organic matter.

Phase 2—Anaerobic and facultative bacteria develop to decompose organic matter and H^2 and CO^2 gases are thus evolved.

Phase 3—Methanogenic bacteria develop to cause evolution of methane gas.

Phase 4—Methanogenic activity gets stabilized.

Phase 5—Methanogenic activity subsides, representing depletion of organic matter and ultimately system returns to aerobic condition within land fill.

Disadvantages

1. **Leachate:** Excess of water when seeps, through the area, may come out of the dump, as coloured liquid called leachate.
2. **Foul gases production:** The gases produced due to the decomposition of solid wastes consist of methane and carbon dioxide.

Incineration and Thermal Pytolysis

Inceneration is the process of burning refuse at high temperatures in furnace. The large sized incinerators are called destructors.

Pyrolysis

The process of heating in an oxygen free atmosphere, and splitting the organic substances through thermal cracking and condensation reactions into gaseous, liquid and solid fractions is known as pyrolysis. It is also known as destructive distillation.

The following products are produced at different stages:

1. A gas stream containing hydrogen, methane, CO, CO_2.
2. A liquid fraction, containing tar and oil steam.
3. A solid fraction, containing charcoal like product of almost pure carbon.

Pulverization

The refuse pulverization is done in grinding machines so as to reduce its volume and to change its physical character. The grounded refuse becomes odourless and thus it is further disposed-off by filling in trenches.

Composting

It can be done in either aerobic or anaerobic conditions. The final product is a manure. Composting is a biological method of decomposing. This is generally considered as aerobic process in India. It can be done in two methods

Indore Method

In this method layers of refuse and right soils are alternatively piled in depth of 7.5–10 cm each. The mixture is kept aerobic by turning regularly for 2–3 months. The entire process takes four months.

Bangalore Method

This method is aerobic in nature. This method is widely adopted by municipal authorities throughout the country. Refuse and right soils are piled up in trenches and the top is covered with layers of earth and left for decomposition. Within 2–3 days of burial, biological action starts considerable heat is evolved in the process which rates the temperature of the decomposition mass to about 75°C. After about 4–5 months the refuse gets fully stabilized to form humus. Compost contains 1%, 1.1% P (as P_2O_5) and 1.5% (as K_2O) and is pathogen free and thus producing valuable nutrient for the soil.

Additional Process in Sanitary Engineering

Elutriation: It is solid liquid mixture intimately mixed with a liquid for the purpose of transferring certain components to the liquid.

Eutrophication: It is the process in which the presence of sunlight stimulates the growth of algae and aquatic plants.

Dano process: A long rotating drum called bio-stabilizer is used for decomposing the refuse. The entire process takes four weeks.

Tollemache process: In this refuse is pulverized in vertical pulverize and then passed though screen to remove paper and plastics.

Energy Content

1. **Dry basis:**

   kJ/kg (dry basis)

   $$= \frac{\text{kJ}}{\text{kg}} \text{ (discarded)} \times \frac{100}{(100 - \%\text{MC})}$$

2. kJ/kg cash free dry basis

   $$= \frac{\text{kJ}}{\text{kg}} \text{ (as discarded)} \times \frac{100}{100 - \%\text{ash} - \%\text{MC}}$$

Example 2

If the energy content of solid waste as discarded is 30000 kJ/kg. The energy content on dry basis of moisture contents of solid waste is 10%.

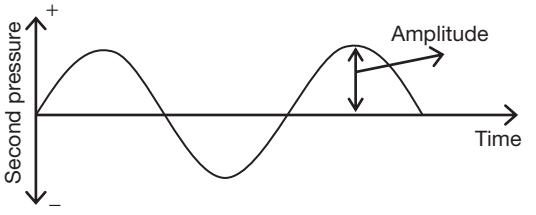
Solution

Energy content on dry basis

$$= 30000 \times \frac{100}{100 - 10} = 3333 \text{ kJ/kg.}$$

Noise Pollution

1. When sound waves are non-periodic, irregular and of short duration, they produce a displeasing effect and such sound is known as noise. The noise that pose greatest threat to human body are those with high pitch, high amplitude and longest duration.



2. **Characteristics of sound:**

   (a) Period (P) $= \dfrac{1}{\text{frequency}(f)}$

   $$C = f\lambda$$

   Where

   λ = Wavelength

   C = Velocity of sound

   (b) Sound pressure = Atmospheric pressure = Barometric pressure.

3. Sound is measured in units called decibels (dB). One dB is the smallest change of sound intensity which the human ear can hear. The pressure at which sound first becomes audible is known as **threshold of hearing** which for normal healthy ear is about 0.00002 N/m^2.

   $$\text{Sound pressure level} = 20 \times \log_{10}\left(\frac{P}{P_{ref}}\right)$$

   Where

   P = pressure of sound wave in N/m^2

   P_{ref} = refrence pressure in N/m^2

Example 3

A generator emitting a sound pressure of 1000 µbar. The noise produced by generator in dB _____.

Solution

1 µbar = 10^5 µPa

$\therefore$ 1800 µbar = 800×10^5 µPa

$$\text{SPL in dB} = 20 \log 10 \frac{P}{P_6}$$

$$= 20 \times \log 10 \frac{(1000 \times 10^5)}{20}$$

$$= 133.9 \cong 134 \text{ dB}.$$

4. **Power of sound:** The rate of doing work by a travelling sound wave in the direction of propagation of wave is known as power of sound.
5. **Intensity of sound:** Sound power average over the time per unit area normal to the direction of propagation of wave.

$$I = \frac{w}{a}$$

Where, a = Unit area perpendicular to the direction of wave motion

$$I = \frac{P_{rms}^2}{e \times v}$$

Where

P = Density of medium

V = Velocity in m/s

T = Temperature in K

6. **Level of noise:**

- $L = \log_{10}\left(\frac{Q}{Q_0}\right)$ bells

$$= 10 \log_{10}\left(\frac{\theta}{\theta_0}\right) \text{ decibels (dB)}$$

Where

Q = Measured quantity

Q_0 = Reference standard $\cong$ 20 µPa (if pressure)

- If reference power is 10^{-12} W

$$L_w = 10 \log_{10}\left(\frac{w}{10^{-12}}\right)$$

- In reference sound intensity Q_0 is 10^{-12} W/n^2

$$L_I = 10 \log_{10}\left(\frac{I}{10^{-12}}\right)$$

7. **Averaging sound pressure levels:**

$$L_P = 20\log_{10} \frac{1}{N} \sum_{n=1}^{N} (10)^{\frac{L_n}{20}}$$

Where

L_P = Average sound pressure level in dB

N = No of measurement reading

L_n = nth sound pressure level in dB

Example 4

A source emits 80 dB, and 120 dB at different times in a day. The average noise produced by source in a day is _____.

Solution

$$L_P = 20\log_{10} \frac{1}{N} \sum_{n=1}^{N} (10)^{\frac{L_n}{20}}$$

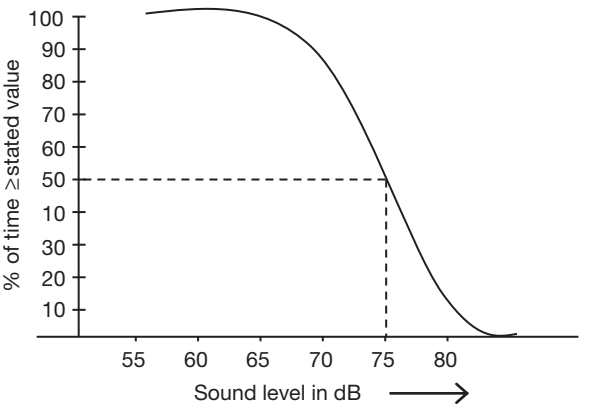
$$= 20\log_{10} \frac{1}{3}\left[10^{\frac{80}{20}} + 10^{\frac{60}{20}} + 10^{\frac{120}{20}}\right]$$

$$= 20\log_{10} \frac{1}{3} [10000 + 1000 + 1000000]$$

$$= 110.55 \text{ dB}$$

The effect of different sound pressure lasting different periods is worked out by using statistical measures such as L_N and L_{eq} systems.

8. **L_N concept:** It represents the sound pressure level that will be equalized of exceeded for N% of measuring time. For example the sound pressure level of 80 dB is equalized or exceeded for 60% of measuring time, the parameter L_N is represented as L_{50} = 75 dB.



9. **L_{eq} concept:** The parameter leq represents the sound pressure level which is equivalent to a number of different sound pressure levels produced at a place for different time intervals

$$L_{eq} = 10\log_{10}\left(\sum_{i=1}^{i=n} 10^{\frac{L_i}{10}} \times t_i\right)$$

Where

L_{eq} = Equivalent sound pressure level in dB

n = Total number of sound pressure levels recorded

L_i = Values of sound pressure levels recorded in dB with $I = 1, 2, 3 \ldots n$

T_i = Time duration of different sound pressure levels expressed as fraction of the total measuring or recording time.

L_{eq} is important parameter for evaluating the impact of fluctuating noise of all kinds.

10. Acceptable noise levels in dB for different structures:

Auditorium and music rooms	35–40
Small offices, court rooms, libraries	40–45
Schools	45–50
Large public offices, banks and stores	50–60
Factories	60–65

11. The noise can be classified in to three types:

- **Continuous noise:** It is an uninterrupted sound level that varies less than 5 dB during entire period of observation.
- **Intermittent noise:** It is a noise which continues for more than one second and is then interrupted for more than one second. A drilling machine used by a dentist produces such type of noise.
- **Impulse noise:** It is characterized by change of sound pressure of at least 40 dB within 0.5 second with a duration of less than one second. Noise produced from firing of a weapon would indicate such type.

12. Effects of noise:

(a) It has an influence on blood pressure.

(b) It leads to fatigue and the efficiency of person decreases considerably.

(c) It leads to cardiac disturbances in human beings.

13. Measures to control noise pollution:

(a) Design of excellent sound insulation doors and windows.

(b) Providing enclosures, shields and barriers so that some of sound waves are cut off from propagating.

(c) Planting of trees which act as noise barriers.

Air Pollution and Control

Air pollution is the excessive concentration of foreign matter in the air which adversely affects the wellbeing of individual, animals and buildings.

Sources of Air Pollution

Natural Sources	Man-made Sources
Products from atmospheric reactions	Combination of fuels
Aerosol particulates	Industries which emit gases such as SO_2, CO_2, NO_2, NH3, etc
Micro-organisms	Thermal power plants which emit sulphur dioxide
Pollens	Automobiles which contain carbon monoxide, methane, etc
Radioactive minerals	Agricultural activities
Volcanic ash and gases	Nuclear power plants
Gases and odour from swamps and marshy lands	

Classification of Air Pollutants

1. The primary pollutants:

(a) Particulate matter

(b) Pollens

(c) Sulphur compounds

(d) Nitrogen compounds

(e) Carbon monoxide (CO) and CO_2

(f) Photochemical oxidants

(g) Lead

(h) Hydrocarbons

(i) Radioactive materials

(j) Halogen compounds

2. Secondary air pollutants: These are the pollutants which are formed as a result of interaction between two or more primary air pollutants or by reactions with the normal atmospheric constituents with or without photo activation

(a) Sulphuric acid

(b) Ozone

(c) Formaldehyde

(d) Proxy-acetyl nitrate

(e) Photochemical smog

Characteristics of Air Pollutants

Sulphur dioxide (SO_2):

- It is an irritant gas.
- Thermal plants produce it in large quantity.
- Asthma patients are badly affected.

Carbon monoxide (CO):

- Generally generated from the automobile exhausts.
- It has 200 times affinity to haemoglobin than oxygen.
- It affects central nervous system which is responsible for heart attacks.

Oxides of nitrogen:

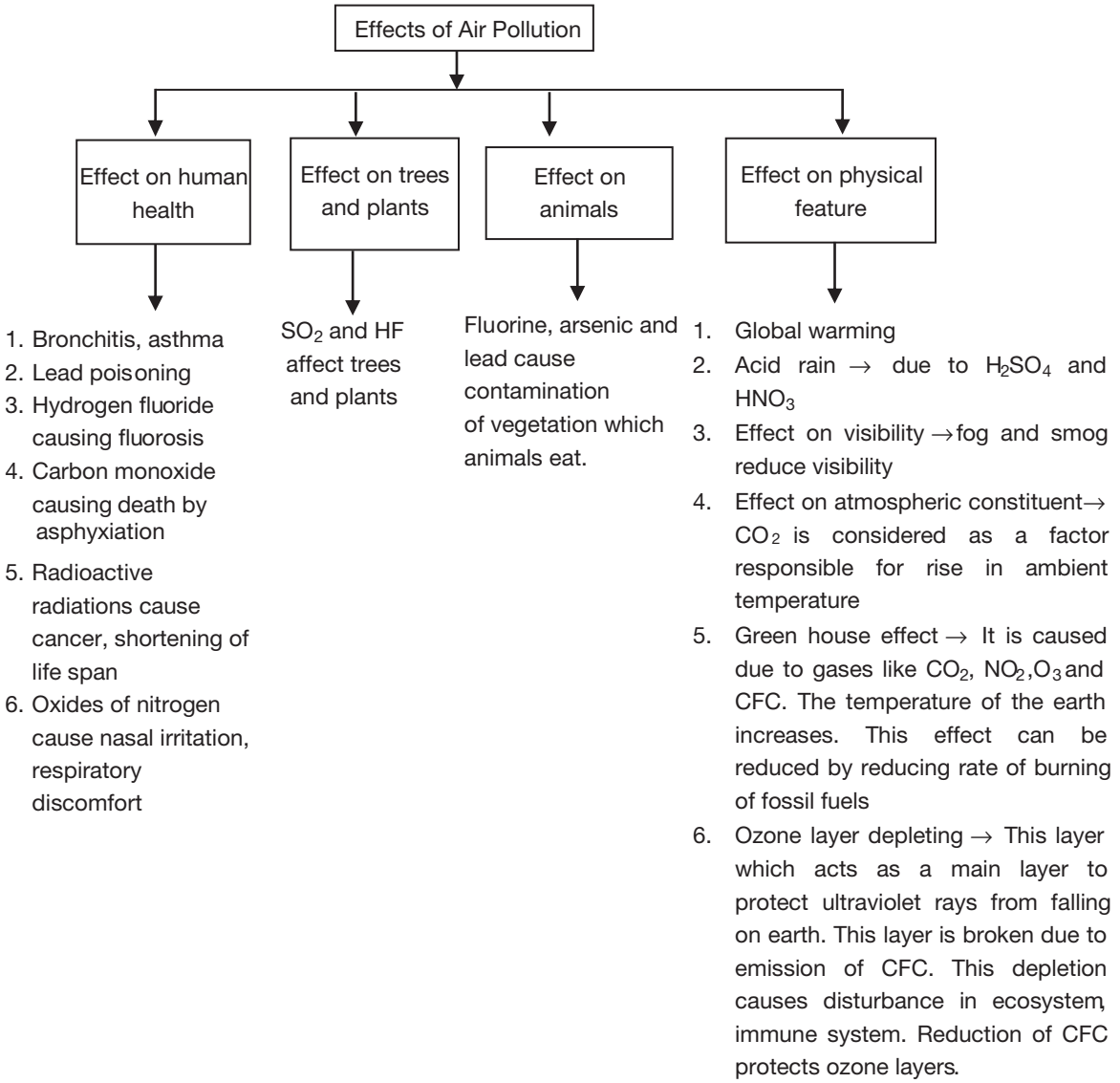
- They are second most abundant pollutants of air in many cities ranking next to SO_2.
- It causes eye and nasal irritations
- It originates from automobiles, incineration plants and furnace smokes.

Lead (Pb):

- It has foul smell of rotten egg.
- It causes irritation to the mucous and throat and affects liver and kidney.
- It retards mental growth of children.

Hydrocarbons:

- It is mainly released into the atmosphere by automobile exhausts.
- It is mainly produced from petroleum products.



Methods of Controlling Air Pollution

1. Control air pollution by zoning
2. Dilution of source discharge by use of chimneys
3. Control by using source correction methods
4. Reduction of pollutant discharge at source by use of controlling equipment

Control of Air Pollution by Zoning

City should be planned in such a way that the industries are not located near the residential areas providing green belt between the industries will reduce the impact of the air pollution.

Electro Static Precipitators

They use the electrical energy for removal of particulate matter from gaseous stream. Particles smaller than 0.14 size can be removed by these devices.

Scrubber or Wet Collectors

They utilize a liquid to assist in the removal of particulates from the gas stream. Generally particles less than 0.2 μ can also be removed.

Absorption

It is the process that involves the transfer of pollutants from gas phase to liquid phase across the interface generally sulphur dioxide, hydrogen sulphide, nitrogen oxides, etc., are controlled by this method.

Adsorption

It is the process of capturing and retention of gas molecules from gas phase by the surface of solid adsorbed or absorbent. The commonly used absorbers are activated carbon, activated alumina, etc.

Combustion or Incineration

It can be used when the pollutants in the gas stream are oxidizable to inert gas. Pollutants like hydrocarbons and carbon monoxides can be easily burnt, oxidized and removed.

Dispersion of Air Pollutants in the Atmosphere

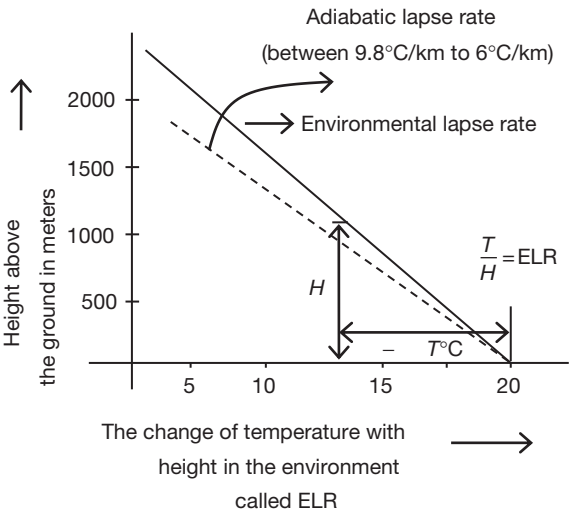
Lapse Rate

The rate of change of temperature of air with altitude is known as lapse rate (or) environmental lapse rate upto 11 km above the earth's surface, the temperature decreases linearly with increase in altitude. After 11 km to 32 km constant temperature prevails.

Adiabatic Lapse Rate (ALR)

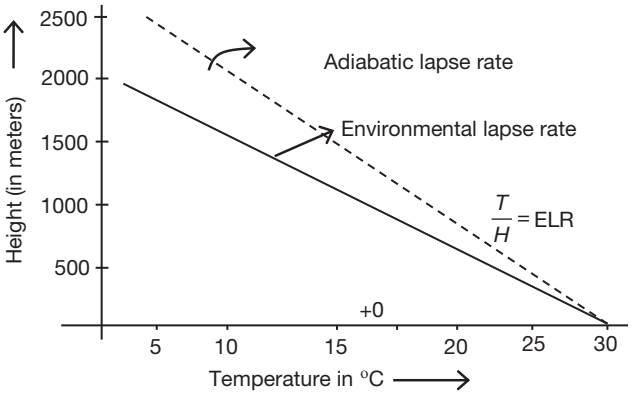
The rate of decrease of temperature with height within a mass or air pocket is called adiabatic lapse rate, when there is no heat exchange from surrounding.

$$\text{ALR} \rightarrow \text{Adiabatic lapse rate}$$



Super Adiabatic Lapse Rate (SALR)

In this case rising parcel of air will remain warmer than surroundings and will continue to rise and reverse is also true. In this case environmental lapse rate is greater than the adiabatic lapse late.



Sub-adiabatic Lapse Rate

The environment is said to be stable. In this case the rising parcel of air will be cooling more quickly than its surroundings and hence it will not be able to rise up to greater altitudes.

$$\text{ELR} < \text{ALR}$$

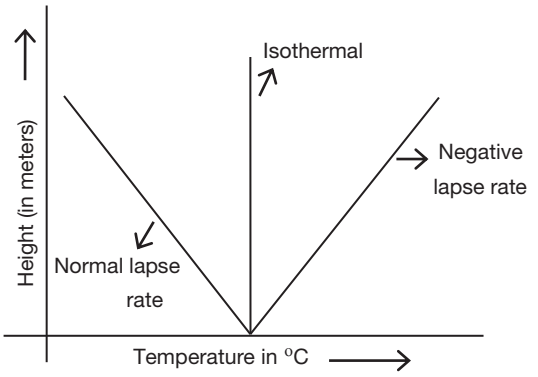
Neutral Atmosphere

In this case the prevailing ELR is equal to the ALR.

The atmospheric condition is said to be neutral.

Negative Lapse Rate

In this case the temperature increases with increase in altitude. This condition under which the negative lapse rate occurs is referred to an inversion. It results in no more pollution.



Inversion

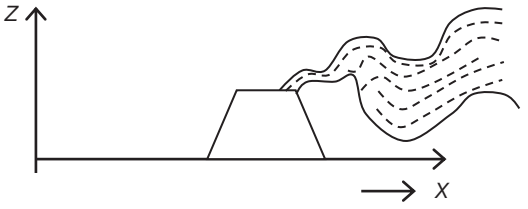
Inversion is of two types:

1. **Radiation inversion:** When earth cools rapidly and more quickly than air above it. This helps in formation of fog when air is wet and simultaneously catches gases and particulate matter as it stops the upward lifting which creates concentration of pollutions in close environment.
2. **Subsidence inversion:** It is associated with a high pressure system and is caused by the characteristic sinking motion of air in a high pressure area surrounded by low pressure area.

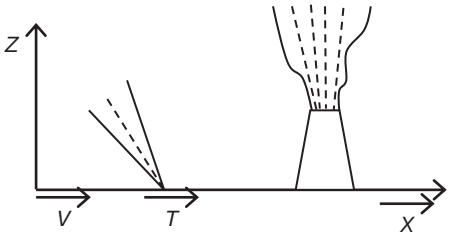
Plume

It is the path which is taken by the gaseous effluents emitted continuously from a specific outlet such as chimney. Plume can be of different types.

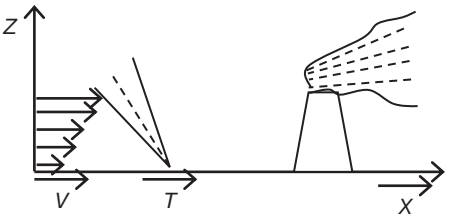
1. **Looping plume:** It produces highly unstable environment because of rapid mixing.



2. **Neutral plum:** It occurs when ELR = ALR

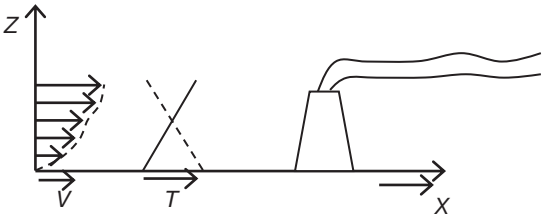


3. **Coning plume:**

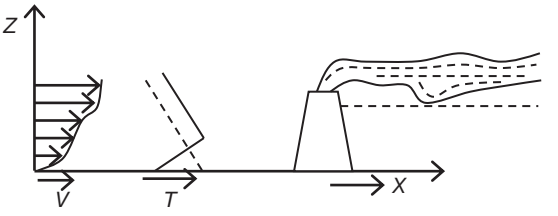


It occurs when the wind velocity is >32 km/h^2 and when clouds are present. It occurs under sub-adiabatic condition is ELR < ALR.

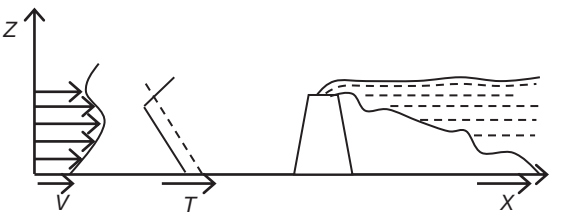
4. **Fanning plume:** It occurs under extreme in version conditions. Emission will spread only horizontally.



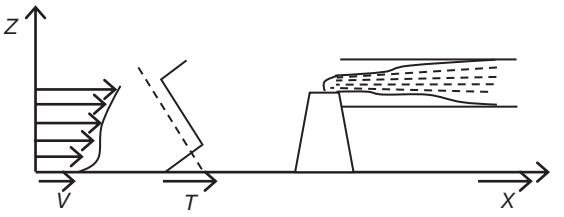
5. **Lofting plume:** In this condition plume has minimum downward mixing as its down word motion is prevented by inversion but upward mixing will be rapid and turbulent.



6. **Fumigating plume:** When inversion layer occurs at a short distance above top of stack and super adiabatic conditions prevail below the stack. Pollutants cannot escape above the top of stack because of inversion layer.



7. **Trapping plume:** It occurs when the version layer exists above the emission source as well as below the source. Naturally the emitted plume will neither group nor down.



Exercises

1. The 'sag' in the dissolved oxygen curve results because
   (A) it is a function of the rate of addition of oxygen to the stream.
   (B) it is a function of the rate of depletion of oxygen from stream.
   (C) it is a function of both addition and depletion of oxygen from the stream.
   (D) the rate of addition is linear but the rate of depletion is non-linear.

2. Secondary effluent from a municipal waste plant is discharged into a stream at the rate of 12,000 m^3/day at 20°C with a BOD_5 of 50 mg/lit, a dissolved oxygen concentration of 2 mg/lit. The stream flow is estimated to be 40,000 m^3/day, and water quality, parameters in the stream upstream of the effluent outfall are:
   BOD_5 of 3 mg/lit, dissolved oxygen 7 mg/lit 20°C.
   Assume a decay constant for the mixture to be $K = 0.23$ (to the base 'e' in the decay curve). Estimate
   (a) BOD of the mixture
   (b) Ultimate BOD
   (c) DO of the mixture

3. Match the following:

	List I (Characteristics of Sewage Discharged into Inland Waters)		List II (Allowable Limit, mg/lit)
P.	BOD_5	**1.**	250
Q.	COD	**2.**	30
R.	Oil and Grease	**3.**	20
S.	Total Suspended Solids	**4.**	10
		5.	5
		6.	3

Codes:

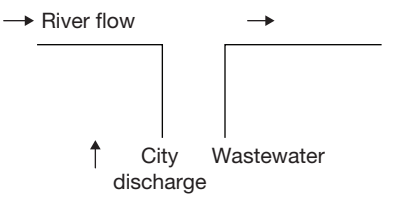
	P	Q	R	S		P	Q	R	S
(A)	2	5	4	2	(B)	4	1	6	4
(C)	3	1	4	2	(D)	2	1	6	3

4. In a certain situation, waste water discharged in to a river, mixes with the river water instantaneously and completely. Following is the data available:
   Waste water DO = 2.00 mg/lit
   Discharge rate = 1.10 m^3/s
   River water DO = 8.3 mg/lit
   Flow rate = 8.7 m^3/s
   Temperature = 20°C
   Initial amount of DO in the mixture of waste and river shall be
   (A) 5.3 mg/lit (B) 6.5 mg/lit
   (C) 7.6 mg/lit (D) 8.4 mg/lit

5. The minimum flow of a river is 50 m^3/s having a dissolved oxygen (DO) content of 7.0 mg/lit (80% saturation) and BOD_5 of 8.0 mg/lit. It receives a waste water discharge of 5 m^3/s with BOD_5 of 200 mg/lit and no DO. If the rate constants for de-oxygenation and reaeration (both base e) are 0.5/d and 1.0/d, respectively and the velocity of river flow is 0.8 m/s, Calculate the distance in kilometer downstream from the point of waste water discharge where the minimum DO occurs.

6. A waste water treatment plant discharges 1.5 m^3/s of effluent having an ultimate BOD of 40.0 mg/lit into a stream flowing at 10 m^3/s. Just upstream of the discharge point, the stream has an ultimate BOD of 3.0 gb/lit. The deoxygenating constant to the base 'e' is estimated as 0.32/day.
   (a) Assuming complete mixing, find the ultimate BOD of the mixture of waste and stream just downstream of the outfall.
   (b) Assuming a constant cross section area for the stream equal of 50 m^2, estimate the BOD of the stream at a point 2.5 km downstream from the outfall.

7. A city discharges waste water in a river. The waste water discharge has a flow rate of 5.0 m^3/s, an ultimate BOD of 49.2 mg/lit and DO of 1.6 mg/lit. Just upstream from this discharge the river has a flow of 50 m^3/s, a BOD of 3 mg/lit and DO of 6 mg/lit (Refer to the following figure). The reaeration coefficient of the river is 0.2/day and the BOD decay coefficient is 0.4/day. The river flow has a constant cross-sectional area of 200 m^2. The saturated DO concentration of the river water may be assumed to be 8.0 mg/lit.
   (a) Calculate the DO of the stream at a point 10 km downstream from the discharge.
   (b)



At which point in the downstream will the DO be minimum?

$Q_r = 50\ m^3/s$

$BOD_r = 3$ mg/lit

$DO_r = 6$ mg/lit

$Q_d = 5\ m^3/s$

$BOD_d = 49.2$ mg/lit

$DO_d = 1.6$ mg/lit

8. A synthetic sample of water is prepared by adding 100 mg kaolinite (a clay mineral), 200 mg glucose, 168 mg NaCl, 120 mg $MgSO_4$, and 111 mg $CaCl_2$ to 1 litre of pure water. The concentrations of total solids (TS) and fixed dissolved solids (FDS) respectively in the solution in mg/lit are equal to

(A) 699 and 599
(B) 599 and 399
(C) 699 and 199
(D) 699 and 399

9. The composition of a certain MSW sample and specific weights of its various components are given below

Component	Percent by Weight	Specific Weight (kg/m³)
Food waste	50	300
Dirt and Ash	30	500
Plastics	10	65
Wood and Yard waste	10	125

Specific weight (kg/m³) of the MSW sample is

(A) 319 (B) 217
(C) 209 (D) 199

10. Match List I with List II and select the correct answer using the codes given below the lists:

	List I		List II
a.	Sludge disposal	1.	Seeding
b.	Sludge digestion	2.	Biofilters
c.	Aerobic action	3.	Lagooning
d.	Recirculation	4.	Contact bed

Codes:

	a	b	c	d
(A)	3	1	4	2
(C)	1	3	2	4

	a	b	c	d
(B)	3	1	2	4
(D)	1	3	4	2

11. Bangalore and Indore process of composting are which of the following?

(A) Both anaerobic processes
(B) Both aerobic processes
(C) Anaerobic process and aerobic process, respectively
(D) Aerobic process and anaerobic process, respectively

12. Match List I with List II and select the correct answer using the codes given below the lists:

	List I		List II
a.	CO	1.	Greenhouse effect
b.	CO_2	2.	Acid rains
c.	SO_2	3.	Acute toxicity
d.	NO_x	4.	Ozoen liberation at ground level

Codes:

	a	b	c	d
(A)	3	2	1	4
(C)	3	1	2	4

	a	b	c	d
(B)	2	3	4	1
(D)	4	1	2	3

13. The sound pressure level for a jet plane on the ground with sound pressure of 2000 µbar should be

(A) 60 decibel (B) 100 decibel
(C) 140 decibel (D) 180 decibels

14. The mean indoor airborne chloroform ($CHCl_3$) concentration in a room was determined to be 0.4 µg/m³. Use the following data:

$T = 293K$, $P = 1$ atmosphere,

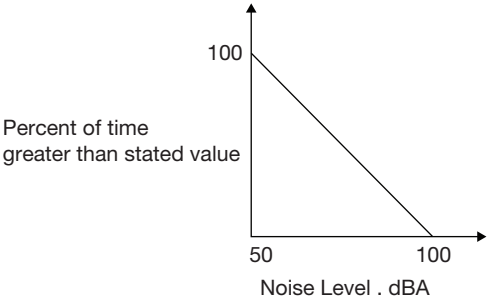
$R = 82.05 \times 10^{-6}$ atm-m³/mol-K,

Atomic weights:

C = 12, H = 1, Cl = 35.5. This concentration expressed in parts per billion (Volume basis, ppbv) is equal to

(A) 1.00 ppbv (B) 0.20 ppbv
(C) 0.10 ppbv (D) 0.08 ppbv

15. The cumulative noise power distribution curve at a certain location is given below. the value of L_{40} is equal to



(A) 90 dBA (B) 80 dBA
(C) 70 dBA (D) 60 dBA

16. Which of the following factors is primarily responsible for causing air pollution in modern days?

(A) Dust storms
(B) Forest fires
(C) Industries and automobiles
(D) None of these

17. The most hazardous gaseous air pollutant for human health is:

(A) Nitrogen (B) Carbondioxide
(C) Oxygen (D) Sulphurdioxide

18. Among the given choices below; which of the following is not a primary air pollutant?
(A) PAN
(B) Volatile organic compounds like hydrocarbon
(C) Suspended particulate matter
(D) Oxides of nitrogen

19. During temperature inversion in atmosphere, air pollutants tend to
(A) accumulate above inversion layer.
(B) accumulate below inversion layer.
(C) disperse laterally.
(D) disperse vertically.

20. For ambient air quality standard, the permissible SO_2 for residential and industrial areas in India is
(A) 40 $\mu g/m^3$ (B) 50 $\mu g/m^3$
(C) 65 $\mu g/m^3$ (D) 35 $\mu g/m^3$

21. The frequency of sound is measured in (units):
(A) Hertz (B) Doboson unit (DU)
(C) Decibel (dB) (D) None of these

22. As per IS:4954–1964; An acceptable noise level for residential and business urban areas is
(A) 40–50 dB (B) 30–40 dB
(C) 15–25 dB (D) 50–60 dB

23. Noise is measured in units of:
(A) Bacqueral (B) Doboson
(C) Hertz (D) Decibel

24. The method of refuse disposal, involving burial in trenches, is called
(A) incineration (B) composting
(C) polverisation (D) None of these

25. The quantity of refuse produced in an average Indian city or a town is of the order of:
(A) $\frac{1}{4}-\frac{1}{5}$ t/c day (B) 4 – 6 t/c day
(D) 2 – 4 t/c day (D) 1 – 2 t/c day

26. The sound pressure level for a Jet plane on the ground with sound pressure of 200 µbar should be
(A) 40 dB (B) 80 dB
(C) 100 dB (D) 120 dB

27. Express 350 $\mu g/m^3$ of SO_2 in ppm at STP?
(A) 0.122 (B) 0.142
(C) 0.20 (D) 0.31

28. An air parcel having 50°C temperature moves from ground level to 800 m elevation in dry air following the adiabatic lapse rate. The resulting temperature of air parcel at 800 m elevation will be?
(A) 40°C (B) 35°C
(C) 42°C (D) 50°C

29. The maximum dispersion of pollutants in atmosphere occur when
(A) environmental lapse rate is equal to adiabatic lapse rate.
(B) environmental lapse rate is less than adiabatic lapse rate.
(C) environmental lapse rate is greater than adiabatic lapse rate.
(D) None of these

30. Elevation and temperature data for a place are tabulated below:

Elevation, m	Temperature °C
10 m	25.25°C
250 m	15.70°C

Based on the above data, lapse rate can be referred as:
(A) Sub-adiabatic (B) Super adiabatic
(C) Neutral (D) inversion

31. If energy content of solid waste as discarded is 14,700 kJ/kg. Find energy content on dry basis if moisture content of solid waste is 20%.
(A) 18,375 kJ/kg (B) 18,000 kJ/kg
(C) 14,700 kJ/kg (D) 15,000 kJ/kg

32. The composition of certain MSW sample and specific weight of its various components are given below:

Component	Percent by Weight	Specific Weight (kg/m^3)
Food waste	70	300
Dirt ash	20	500
Plastics	10	65

The specific weight (kg/m^3) of the MSW sample is
(A) 209 (B) 319
(C) 217 (D) 234

33. A waste water stream (flow = 3 m^3/s) with ultimate BOD 110 mg/lit is joining a small river (flow = 10 m^3/s), ultimate BOD = 5 mg/lit. Both water streams get mixed up simultaneously at where cross sectional area of the river is 70 m^2. Assuming $K = 0.25$/day, the BOD (in mg/lit) of the river water, 10 km downstream of the mixing point is
(A) 8.832 gm/m^3 (B) 24 gm/m^3
(C) 15 gm/m^3 (D) None of these

34. The reference pressure used in determination of sound pressure level is:
(A) 20 db (B) 10 µPa
(C) 20 µPa (D) 10 db

35. Which one of the following is the correct sound intensity expression with usual notations?
(A) $dB = 10\log_{10}(I/I_0)^2$
(B) $dB = 10\log_{10}(I/I_0)$
(C) $dB = 10\log_{10}(I - I_0)^2$
(D) $dB = 10\log_{10}(I - I_0)$

36. A source emitting 40 dB, 70 dB, 110 dB of different times in a day. What is average noise produces by source in a day?
(A) 220 dB (B) 80 dB
(C) 74 dB (D) 100 dB

37. Which among the following are two biodegradable components of municipal solid waste?
(A) leather and tin cans
(B) plastics and wood
(C) cardboard and glass
(D) food waste and garden trimmings

38. Two electrostatic precipitators are in series. The fractional efficiencies of the upstream and downstream ESPS for size dp are 90% and 80% respectively. What is the overall efficiency of the system for same dp?
(A) 93%
(B) 95%
(C) 98%
(D) 90%

39. SO_2 and CO adversely effects
(A) oxygen carrying capacity of blood and functioning of lungs respectively.
(B) functioning of the respiratory system and brain respectively.
(C) functioning of the respiratory system and oxygen carrying capacity of blood respectively.
(D) functioning of air passage and chess respectively.

40. Two air pollution control devices that are usually used to remove very fine particles from the flue gas are:
(A) cyclone and venture scrubber.
(B) cyclone and packed scrubber.
(C) electrostatic precipitator and fabric filter.
(D) settling chamber and tray scrubber.

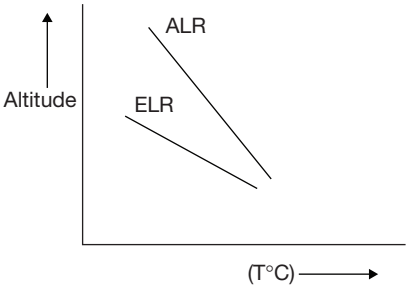
41. SO_x in atmosphere is measured by
(A) non-dispersive infrared analyzer.
(B) west and gack method.
(C) sodium arsenate method.
(D) gas chromatography.

42. Algae dies out, though fish life may survive, in a river zone, known as
(A) zone of degradation.
(B) zone of active decomposition.
(C) zone of recovery.
(D) None of these

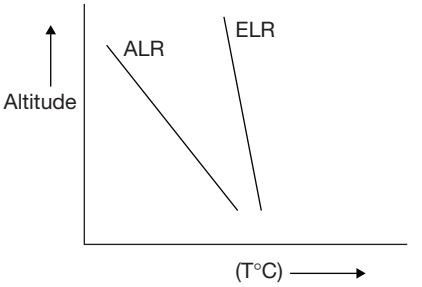
43. Match List I (Lapse rate) with List II (Different types of plumes) at stack level.

List I (Lape rate)

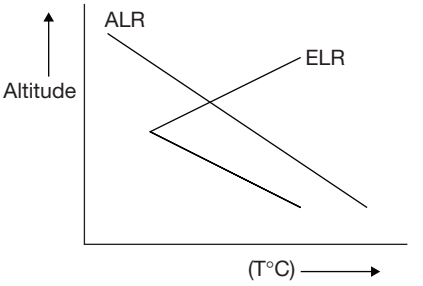
P.



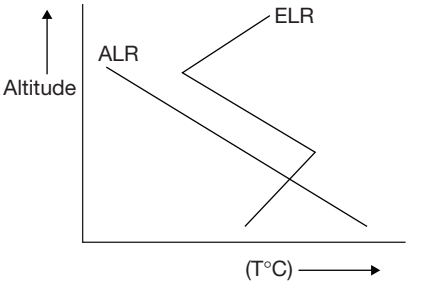
Q.



R.

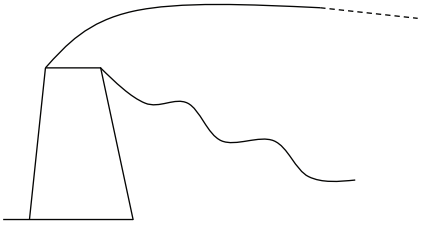


S.



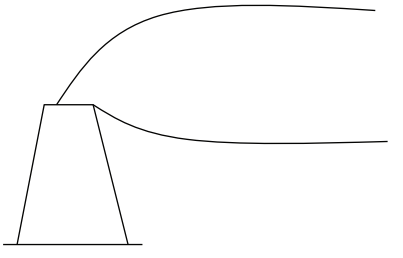
List II

1.



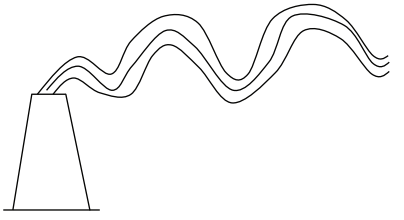
Fumigation plume

2.



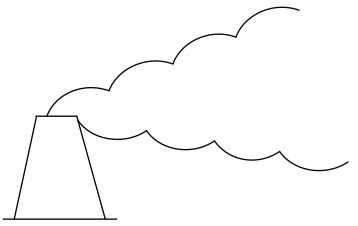
Trapping plume

3.



Looping plume

4.



Coning plume

Codes:

	P	Q	R	S		P	Q	R	S
(A)	3	4	1	2	(B)	3	1	2	4
(C)	1	4	2	3	(D)	4	2	1	3

44. Find the equivalent noise level for fluctuating noise level of 95 minutes. The one with 80 dB lasted for 10 minutes, followed by 60 dB for 80 minutes followed by 100 dB for 5 minutes.
(A) 68 dB
(B) 74 dB
(C) 87 dB
(D) 96 dB

45. When environmental lapse rate is more than adiabatic lapse rate, then the enviroment is said to be
(A) stable
(B) unstable
(C) neutral
(D) None of these

46. Two sources generate noise levels of 90 dB and 94 dB respectively. The cumulative effect of these two noise levels on the human ear is _____.
(A) 184 dB (B) 95.5 dB
(C) 94 dB (D) 92 dB

47. Match List I (Equipment) with List II (Pollutants removed).

	List I		List II
a.	Electrostatic precipitators	**1.**	Coarse particles
b.	Cyclones	**2.**	Fine dust
c.	Wet scrubbers	**3.**	Gas
d.	Adsorbers	**4.**	Sulphur dioxide

Codes:

	a	b	c	d		a	b	c	d
(A)	1	2	3	4	(B)	2	1	3	4
(C)	2	1	4	3	(D)	1	2	4	3

48. The sound pressure level is measured as 6×10^{-4} N/m^2. It's noise level in dB is _____.
(A) 32.5 dB
(B) 29.5 dB
(C) 26.5 dB
(D) 22.5 dB

49. The energy content of a municipal solid waste is given as 12000 kJ/kg (as discarded). If the moisture content of MSW is 18% ad ash content is 4%, the energy content on an ash-free dry basis is _____.
(A) 14635 kJ/kg
(B) 15385 kJ/kg
(C) 9360 kJ/kg
(D) 10680 kJ/kg

50. An air parcel having 42° temperature moves from ground level to 600 m elevation in dry air following adiabatic lapse rate. The resulting temperature of air parent at 600 m elevation will be _____.
(A) 30°C (B) 36°C
(C) 42°C (D) 48°C

Previous Years' Questions

1. 50 g of CO_2 and 25 g of CH_4 are produced from the decomposition of municipal solid waste (MSW) with a formula weight of 120 g. What is the average per capita green house gas production in a city of 1 million people with a MSW production rate of 500 ton/day? **[GATE, 2007]**
(A) 104 g/day (B) 120 g/day
(C) 208 g/day (D) 313 g/day

2. The dispersion of pollutants in atmosphere is maximum when **[GATE, 2007]**
(A) environmental lapse rate is greater than adiabatic lapse rate.
(B) environmental lapse rate is less than adiabatic lapse rate.
(C) environmental lapse rate is equal to adiabatic lapse rate.
(D) maximum mixing depth is equal to zero.

3. Two electrostatic precipitators (ESPs) are in series. The fractional efficiencies of the upstream and downstream ESPs for size d_p are 80% and 65%, respectively. What is the overall efficiency of the system for the same d_p? **[GATE, 2007]**
(A) 100% (B) 93%
(C) 80% (D) 65%

4. Two biodegradable components of municipal solid waste are **[GATE, 2008]**
(A) plastics and wood.
(B) cardboard and glass.
(C) leather and tin cans.
(D) food wastes and garden trimmings.

5. Two primary air pollutants are **[GATE, 2008]**
(A) sulphur oxide and ozone.
(B) nitrogen oxide and peroxyacetylnitrate.
(C) sulphur oxide and hydrocarbon.
(D) ozone and peroxyacetylnitrate.

6. Particulate matter (fly ash) carried in effluent gases from the furnaces burning fossil fuels are better removed by **[GATE, 2009]**

(A) cotton bag house filter.
(B) electrostatic precipitator (ESP).
(C) cyclone.
(D) wet scrubber.

7. Match List I with List II and select the correct answer by using the codes given below the lists **[GATE, 2009]**

	List I		List II
a.	Coriolis effect	**1.**	Rotation of earth
b.	Fumigation	**2.**	Lapse rate and vertical temperature profile
c.	Ozone layer	**3.**	Inversion
d.	Maximum mixing depth (mixing height)	**4.**	Dobson

Codes:

	a	b	c	d		a	b	c	d
(A)	2	1	4	3	(B)	2	1	3	4
(C)	1	3	2	4	(D)	1	3	4	2

8. The reference pressure used in the determination of sound pressure level is **[GATE, 2009]**

A) 20 μPa (B) 20 db
(C) 10 μPa (D) 10 db

9. A coastal city produces municipal solid waste (MSW) with high moisture content, high organic materials, low calorific value and low inorganic materials. The most effective and sustainable option for MSW management in that city is **[GATE, 2010]**

(A) composting
(B) dumping is sea
(C) incineration
(D) landfill

10. An air parcel having 40°C temperature moves from ground level to 500 m elevation in dry air following the 'adiabatic lapse rate'. The resulting temperature of air parcel at 500 m elevation will be **[GATE, 2010]**

(A) 35°C (B) 38°C
(C) 41°C (D) 44°C

11. According to the noise pollution (regulation and control) rules, 2000 of the Ministry of Environment and Forests, India, the day time and night time noise level limits in ambient air for residential areas expressed in dB (A) leg are **[GATE, 2010]**

(A) 50 and 40 (B) 55 and 45
(C) 65 and 55 (D) 75 and 70

12. Consider four common air pollutants found in urban environments, NO, SO_2, Soot and O_3. Among these which one is the secondary air pollutant? **[GATE, 2011]**

(A) O_3 (B) NO
(C) SO_2 (D) Soot

13. Total suspended particulate matter (TSP) concentration in ambient air is to be measured using a high volume sampler. The filter used for this purpose had an initial dry weight of 9.787 g. The filter was mounted in the sampler and the initial air flow rate through the filter and the initial air flow rate through the filter was set at 1.5 m^3/min. Sampling continued for 24 hours. The airflow after 24 hours was measured to be 1.4 m^3/minute. The dry weight of the filter paper after 24 hours sampling was 10.283 g. Assuming a linear decline in the air flow rate during sampling, what is the 24 hour average TSP concentration in the ambient air? **[GATE, 2011]**

(A) 59.2 μg/m^3 (B) 118.6 μg/m^3
(C) 237.5 μg/m^3 (D) 574.4 μg/m^3

14. Elevation and temperature data for a place are tabulated below:

Elevation, *m*	Temperature °C
4	21.25
444	15.70

Based on the above data, lapse rate can be referred as **[GATE, 2013]**

(A) super-adiabatic (B) neutral
(C) sub-adiabatic (D) inversion

15. A waste water stream (Flow = 2 m^3/s, Ultimate BOD = 90 mg/lit) is joining a small river (Flow = 12 m^3/s, Ultimate BOD = 5 mg/lit). Both water streams get mixed up instantaneously, cross-sectional area of the river is 50 m^2, Assuming the de-oxygenation rate constant, K = 0.25/day, the BOD (in mg/lit) of the river water, 10 km downstream of the mixing point is **[GATE, 2014]**

(A) 1.68 (B) 12.63
(C) 15.46 (D) 1.37

16. The two air pollution control devices that are usually used to remove very fine articles from the flue gas are **[GATE, 2014]**

(A) cyclone and venturi scrubber.
(B) cyclone and packed scrubber.
(C) electrostatic precipitator and fabric filter.
(D) settling chamber and tray scrubber.

17. Solid waste generated from an industry contains only two components, X and Y as shown in the table below **[GATE, 2015]**

Component	Composition (% weight)	Density (kg/m^3)
X	c1	ρ_1
Y	c2	ρ_2

Assuming $(c_1 + c_2) = 100$, the composite density of the solid waste (ρ) is given by

(A) $\dfrac{100}{\frac{c_1}{\rho_1} + \frac{c_2}{\rho_2}}$ (B) $100\dfrac{\rho_1}{c_1} + \dfrac{\rho_2}{c_2}$

(C) $100(c_1\,\rho_1 + c_2\,\rho_2)$ (D) $100\dfrac{\rho_1\rho_2}{c_1\rho_1 + c_2\rho_2}$

18. The concentration of Sulfur Dioxide (SO_2) in ambient atmosphere was measured as 30 µg/m^3. Under the same conditions, the above SO_2 concentration expressed in ppm is _____

Given: $P/(RT) = 41.6$ mol/m^3; where, P = Pressure; T = Temperature; R = universal gas constant; Molecular weight of $SO_2 = 64$. **[GATE, 2015]**

19. SO_2 and CO adversely effect **[GATE, 2015]**

(A) oxygen carrying capacity of blood and functioning of lungs respectively.
(B) functioning of the respiratory system and brain respectively.
(C) functioning of the respiratory system and oxygen carrying capacity of blood respectively.
(D) functioning of air passages and chest respectively.

20. Pre-cursors to photochemical oxidants are **[GATE, 2016]**

(A) NO_X, VOCs and sunlight
(B) SO_2, CO_2 and sunlight
(C) H_2S, CO and sunlight
(D) SO_2, NH_3 and sunlight

21. An electrostatic precipitator (ESP) with 5600 m^2 of collector plate area is 96 per cent efficient in treating 185 m^3/s of flue gas from a 200 MW thermal power plant. It was found that in order to achieve 97 per cent efficiency, the collector plate area should be 6100 m^2. In order to increase the efficiency to 99 per cent, the ESP collector plate area (expressed in m^2) would be _____. **[GATE, 2016]**

22. The atmospheric layer closest to the earth surface is **[GATE, 2016]**

(A) the mesosphere
(B) the stratosphere
(C) the thermosphere
(D) the troposphere

23. The sound pressure (expressed in µPa) of the faintest sound that a normal healthy individual can hear is **[GATE, 2016]**

(A) 0.2
(B) 2
(C) 20
(D) 55

24. A noise meter located at a distance of 30 m from a point source recorded 74 dB. The reading at a distance of 60 m from the point source would be _____. **[GATE, 2016]**

Answer Keys

Exercises

1. C **2.** $L = 20.26$ mg/lit; $(DO)_m = 5.85$ mg/lit; $(BOD)_m$ 13.85 mg/lit; **3.** C **4.** C
5. 83.37 km **6.** 9.80 mg/lit; 0.4431 mg/lit **7.** 2.16 km **8.** D **9.** B **10.** A **11.** C
12. C **13.** C **14.** D **15.** B **16.** C **17.** D **18.** A **19.** B **20.** B **21.** A
22. A **23.** D **24.** B **25.** A **26.** D **27.** A **28.** C **29.** C **30.** B **31.** A
32. D **33.** A **34.** C **35.** A **36.** D **37.** D **38.** C **39.** C **40.** C **41.** B
42. A **43.** A **44.** C **45.** B **46.** D **47.** B **48.** B **49.** B **50.** B

Previous Years' Questions

1. D **2.** A **3.** B **4.** D **5.** C **6.** B **7.** D **8.** A **9.** A **10.** A
11. B **12.** A **13.** C **14.** A **15.** C **16.** C **17.** A **18.** 0.01 to 0.012 **19.** C
20. A **21.** 8012.38 **22.** D **23.** C **24.** 67.98 dB