LEC-01

AIR POLLUTION:

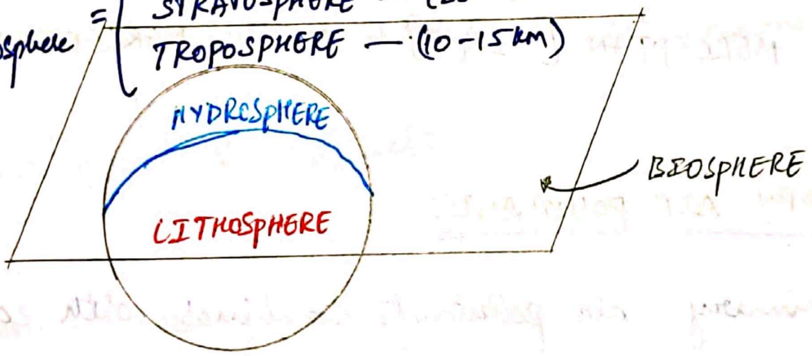
- PRESENCE of one (or) more air pollutants/contaminants in such concentration and for such duration that the life in bio sphere gets effected is termed as air pollution.

- Air pollutants are classified into following.

  (a) Primary AIR POLLUTANTS

  (b) SECONDARY AIR POLLUTANTS.

		Thickness
Atmosphere =	EXOSPHERE	— ∞
	THEROMOSPHERE	— 420 km
	MESOSPHERE	— (30 km)
	STRATOSPHERE	— (30 – 40 km)
	TROPOSPHERE	— (10 – 15 km)



(A) PRIMARY AIR POLLUTANTS:

- All those pollutants which are emitted directly from the identifiable source, either naturally (or) Artificially. are termed as primary air pollutants.

Ex Pollutants released after dust storm, Volcanic erruption, burning of coal, oil in industries(or) Automobiles, households.

- primary air pollutants are as follows.

(a) oxides of sulphur (SO_2, SO_3)

(b) oxides of carbon [CO, CO_2]

(c) Oxides of Nitrogen [NO, NO_2]

(d) Hydrocarbons (HC)

(e) suspended particulate matter (spm)

(f) H_2S, H_2F

(g) LEAD(Pb)

in LPG added to notice odour

(h) EHTYL MERCAPTAN [C_2H_6S] & METHYL MERCAPTAN (CH_4S)

(B) SECONDARY AIR POLLUTANTS:

- when primary air pollutants combines with each other (or) with water vapours in the presence of sunlight results in the formation of secondary air pollutants.

$$\boxed{PAP + H_2O \xrightarrow{SUNLIGHT} SAP}$$

PHOTOCHEMICAL REACTION (in presence of light)

- The above reaction is termed as "photochemical reaction"

Ex H_2SO_4 , O_3 , FORMALDEHYDE, PAN [PER-OXY-ACETYL NITRATE].

$$\underset{PAP}{SO_3} + H_2O \xrightarrow{\text{SUNLIGHT}} \underset{SAP}{H_2SO_4}$$

$$\underbrace{NO_x + \underset{\text{Hydro Carbon}}{HC} + H_2O}_{PAP} \xrightarrow{\text{SUNLIGHT}} \underbrace{O_3 + \text{FORMALDEHYDE} + PAN.}_{SAP}$$

– This mixture is also termed as

"PHOTOCHEMICAL SMOG" (SMOKE+FOG).

NOTE:

The concentration of air pollutants is reported as mass (or) wt/volume

[The reason for this is that pollutants are consumed per unit volume

but their effect is due to mass].

Ex $1\,ppm = \dfrac{1 \text{ part of any gas/pollutant}}{10^6 \text{ parts of air}}$

– 1 mole of any gas at STP ($P = 1\,atm$, $T = 0°C$ (or) $273K$) occupies

22.4 lit.

– 1 mole of any gas at some different temp & pressure occupies.

V lit.

$PV = nRT$ (ideal gas eq) . (T in K°)

for 1 mole $\Rightarrow n = 1$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}.$$

$$\Rightarrow \frac{1 \times 22.4}{273} = \frac{P \cdot V}{(273+T)}.$$

$$\boxed{V = \left(\frac{273+\overset{\nearrow {}^{\circ}C}{T}}{273}\right) \times \frac{22.4}{P}}$$

Q Express the concentration of 20 ppm of CO at 20°C and 3 atm in $\mu g/m^3$?

Sol-

$$1 \text{ ppm of } CO = \frac{1 \text{ part of } CO}{10^6 \text{ part of air}} = \frac{1 m^3 \text{ of } CO}{10^6 m^3 \text{ of air}}$$

1 mole of CO at STP has volume of 22.4 lit.

1 mole of CO @ 20°C & 3 atm is V lit

$$V = \frac{273+20}{273} \times \frac{22.4}{3} = 8.01 \text{ lit}$$

$\therefore$ 28 gm of CO @ 20°C & 3 atm has vol. of 8.01 lit.

$1m^3$ of CO at $20°c$ & 3atm has mass of $= \frac{28}{8.01} \times 10^3$

$= 3494.02 gm$

28gm 8.01

$= 3494.02 \times 10^6 \mu g$

~~1m³~~

$1m^3$ of CO @ $20°c$ & 3 atm has mass of $= 3.494 \times 10^9 \mu g$

$1 ppm$ of $CO = \frac{1m^3 \text{ of } CO}{10^6 m^3 \text{ of air}} = \frac{3.494 \times 10^9}{10^6} \frac{\mu g}{m^3} = 3.494 \times 10^3 \frac{\mu g}{m^3}$

$= 3494 \mu g/m^3$

For 20 ppm of $CO \big|_{T=20°c, P=3atm} = 20 \times 3.494 = 69880 \frac{\mu g}{m^3}$

$ppb = 10^9$

HARMFUL EFFECTS of AIR POLLUTANTS:

(a) SUSPENDED PARTICULATE MATTER (SPM): Ex (Pm2.5, Pm10)

- These are solid particles like dust, smoke & fume and liquid particles like mist & fog
- They are released from burning of fossil fuels, garbage and dust storm.
- They effects breathing & respiration system, causes cardiovascular disease, lungs problems and causes still birth etc.

(b) OXIDE OF SULPHUR (SO_2):

- It is odourless gas having taste thershold of $\boxed{0.3 ppm}$
- It is released due to combustion of oil and coal in power station (or) Automobile.
- It effects breathing respiratory illness, breakdown of lungs. causes cardiovascular disease, causes bronchial spasms [It is sudden blockage of (or) choking of walls of bronchials]

(c) OXIDES OF CARBON (CO, CO_2):

- (CO) It is colourless, tasteless, odourless gas at atmospheric concentration
- (CO) It is evolved due to incomplete combustion of coal and oil & fuels of fossil
- (CO) It leads to cardiovascular disease, combines with hemoglobin 200 faster than O_2 and forms Carboxy-hemoglobin & may also lead to death
  (PINK-COLOUR) BLOOD
- (CO) It results in headache, dizziness, nausea, heart palpitation, difficulty in breathing

(d) OXIDES OF NITROGEN (NO_x):

- It is reddish brown, highly reactive gas; Odour threshold is at 0.2ppm.
- It is emitted from high temp combustion in Automobile and for thermal powerstations.
- Nitrogen monoxide (NO) plays a major role in "TROPOSPHERIC OXZONE (O_3)" formation
- It combaines 3 lakh times faster than O_2 with haemoglobin
- It also results in "ASPHYXIATION" [choking / suffocation].
- NO_2 is responsible for eyes and nasal irritation, respiratory discomfort & may also leads to swelling

(e) HYDROCARBON (HC):

- These are being released from the exhaust of automobile
- They lead to irritation of eyes & respiratory tract

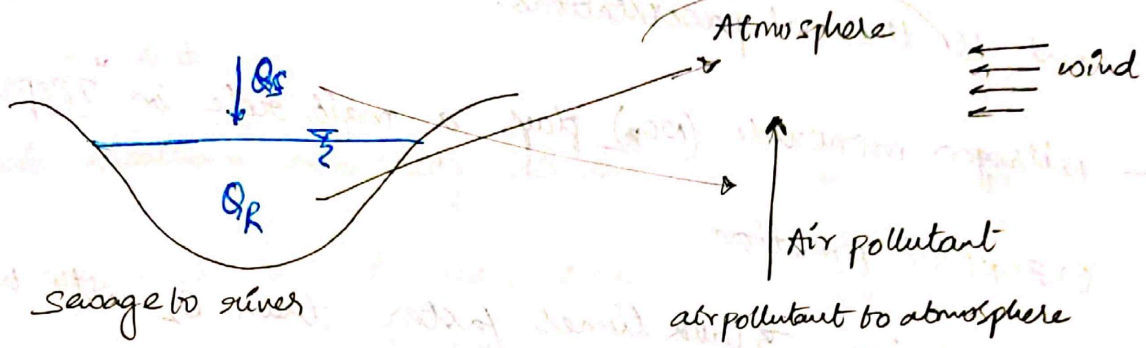
NOTE!

In order to identify and quantify the quality of air in a particular area, a parameter termed as AQI ["Air quality index" is used]

DISPERSION OF AIR POLLUTANT:

- Dispersion of air pollutant into the atmosphere depends upon following factors

① **WIND:**



- Dispersion of the pollutant into the atmosphere depends upon the wind speed directly.

  [Hence conc of the pollutant is inversely proportional to wind velocity].

- wind speed is measured using device termed as "ANEMOMETER." and velocity of wind at any can be found using [$\frac{1}{7^{th}}$ power law]

$$\boxed{u = u_0 \left[\frac{z}{z_0}\right]^k}, \quad \boxed{k = 1/7}$$

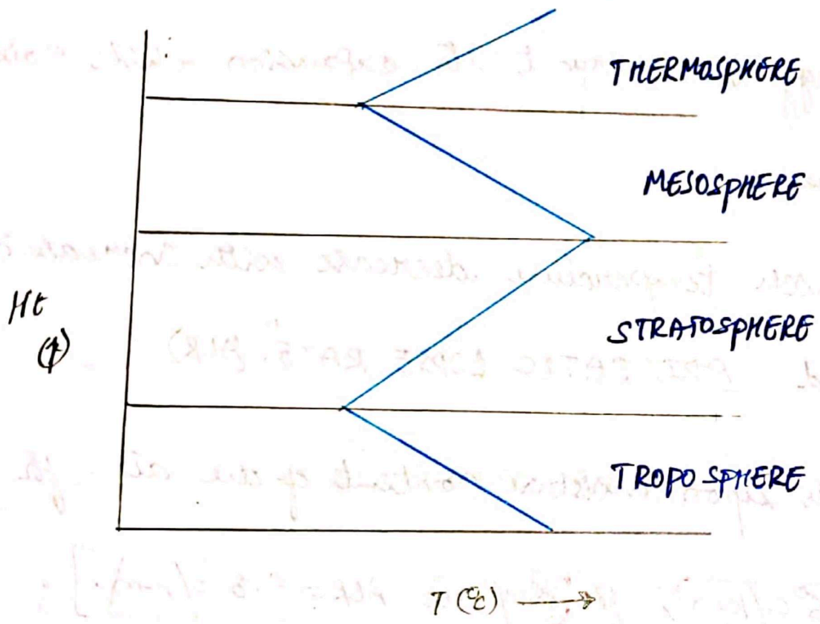
u_0 - is wind velocity measured by anemometer at height 'z_0'

(ii) TEMPERATURE!

- Temperature of the air decreases with increase in height above the surface of the earth and the rate at which it decreases with increase in height is termed as "ENVIRONMENTAL LAPSE RATE(ELR)"

$$\text{Lapse rate} = (-)\left[\frac{dT}{dH}\right]$$

- ELR varies from height to height and can be computed seperately and its value approx $6.5°c/km$.

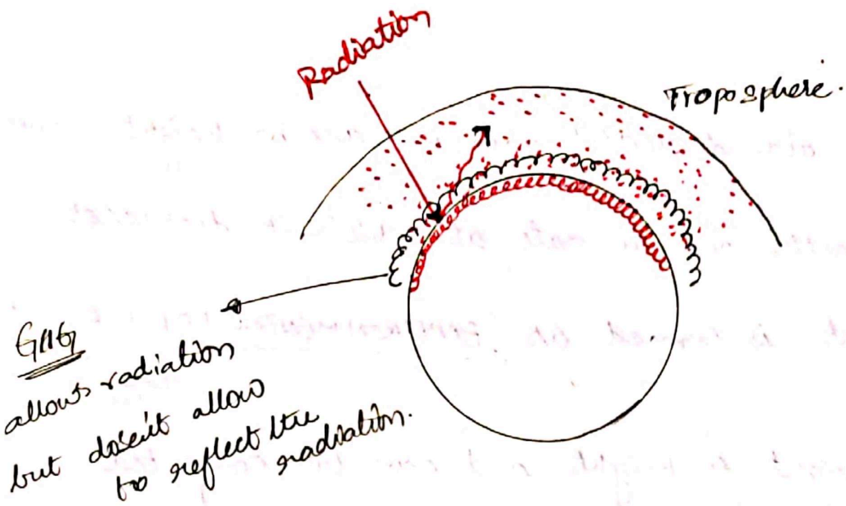


$\uparrow V \rightarrow$ Dispersion $\uparrow \rightarrow$ Conc $\downarrow$

Ht $\uparrow \rightarrow$ Pre $\downarrow \rightarrow$ Energy $\downarrow \rightarrow$ Vol $\uparrow$, T $\downarrow$

NOTE! Temp decreases in troposphere with height, since the main heat source is solar radiation which is absorbed majorly at ground level

- In stratosphere temperature of air increases with height and this warmth is due to absorption of UV rays from Sun. by O_2 & O_3 of this layer.



Adiabatic is
No heat exchange takes
place

- when pollutant raises into the atmosphere its temperature also decreases with increase in height ~~due~~ to at the expense of its internal energy to carryout its expansion while raising into the atmosphere

- The rate at which temperature decrease with increase in height is termed "ADIABATIC LAPSE RATE." (ALR)

[This ALR depends upon moisture content of the air, for wet air ALR = 6°c/km; for dry air ALR = 9.8°c/km.].

Q SO_2 is released from the exhaust pipe of the automobile at 80°c in "dry air", Compute its temperature 1.5km above the Surface of the earth?

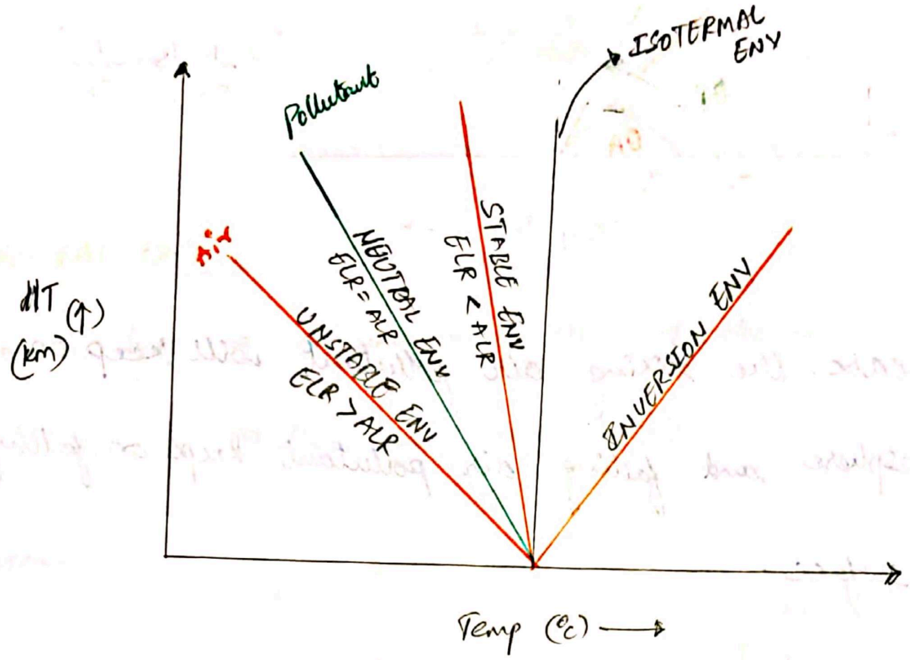
Sol:-

$T_0 = 80°c$

$T = T_0 \pm \frac{dT}{dH}(H) = 80 + (-) 9.8 \times 1.5 = 65.3°c$

TYPES OF ENVIRONMENT:

- Depending upon relative magnitude of ELR & ALR following types of environment are being defined.

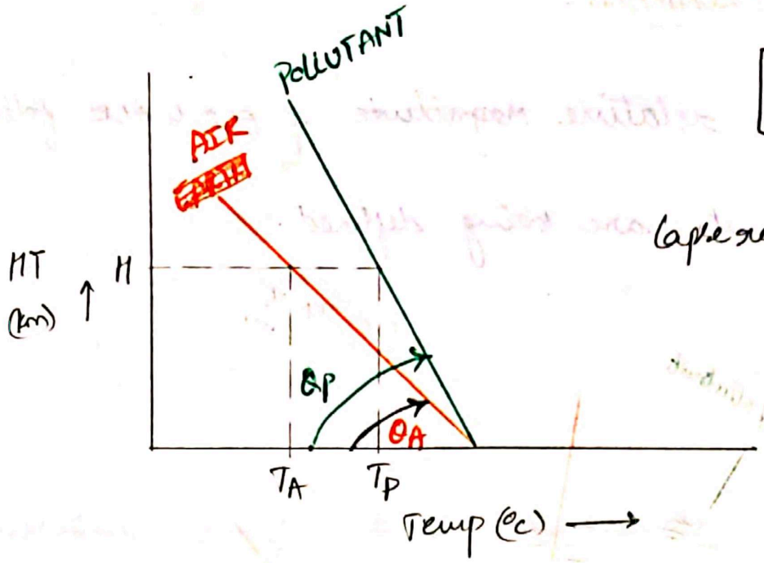


LEC-03

(i) UNSTABLE/SUPER ADIABATIC ENV:

- It is the type of ENVIRONMENT in which rate of decrease of temperature with increase in height above the surface of the earth for air (ELR) is more than that of pollutant (ALR).

- Rapid mixing of the pollutants takes place in this case, when they are released in this Environment.



$\boxed{ELR > ALR.}$

$$\text{lapse rate} = \frac{1}{\text{slope}}$$

$$\left(\frac{1}{\theta_A} > \frac{1}{\theta_P}\right)$$

- In such case, the rising air pollutant will keep on rising into the atmosphere and falling air pollutant keeps on falling on the earth surface.

(ii) <u>STABLE / SUB-ADIBATIC ENV:</u>

- It is the type of environment in which rate of decrease of temperature for air (ELR) is less than that of pollutant (ALR).
- Thus prevailing environmental lapse rate in such case is termed as "SUB-ADIBATIC LAPSE RATE". and environment is termed as "SUB- ADIABATIC ENV."

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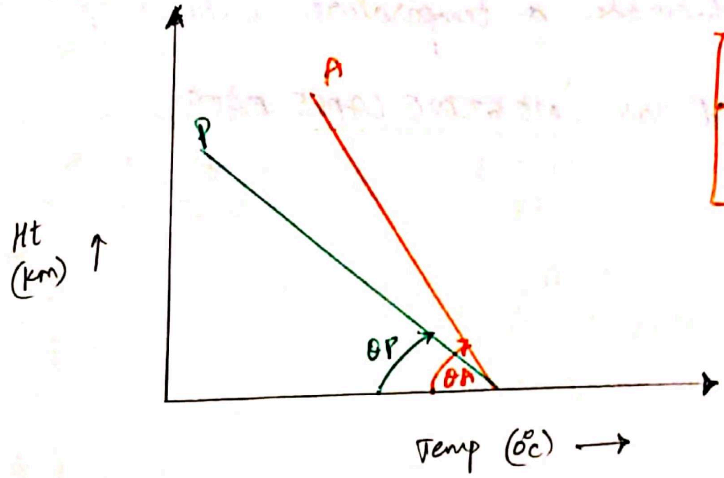
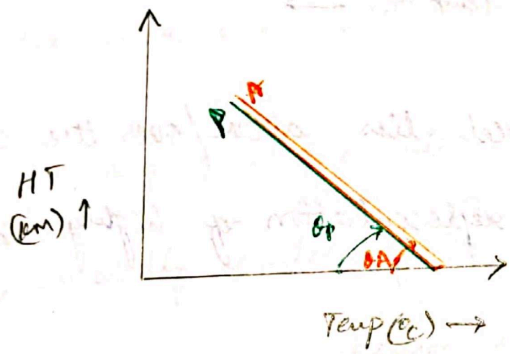


ELR (<) ALR
$\frac{1}{\theta_A} < \frac{1}{\theta_P}$

(iii) NEUTRAL ENV:

- In this type of environment rate of decrease of temperature for both air ~~ER~~ (ELR) and pollutant (ALR) w.r.t height remains same



ELR = ALR

$\frac{1}{\theta_A} = \frac{1}{\theta_P}$

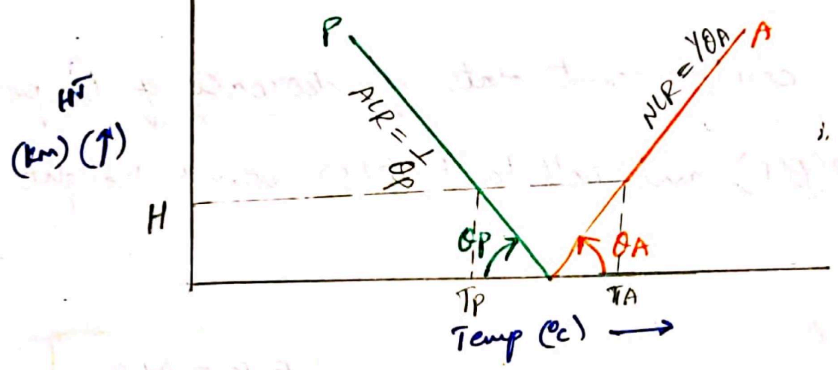
$\theta_A = \theta_P$

(iv) INVERSION ENV:

- It is an unusual case in which temperature of the environment is increases with increase in height above the surface of earth in troposphere instead of decreasing, thereby it is termed as "INVERSION CONDITION".

- The rate of increase of temperature with height for this case is termed as "NEGTIVE LAPSE RATE"

$PV = mRT$
$PV = nRT$
$P = \rho RT$



- In this warmer air parcel lies above/over the colder ~~air~~ pollutant below it leading to the representation of highly stable ENVIRONMENT.

- These inversion conditions are of two types

(i) RADIATION INVERSION

(ii) SUBSIDENCE INVERSION.

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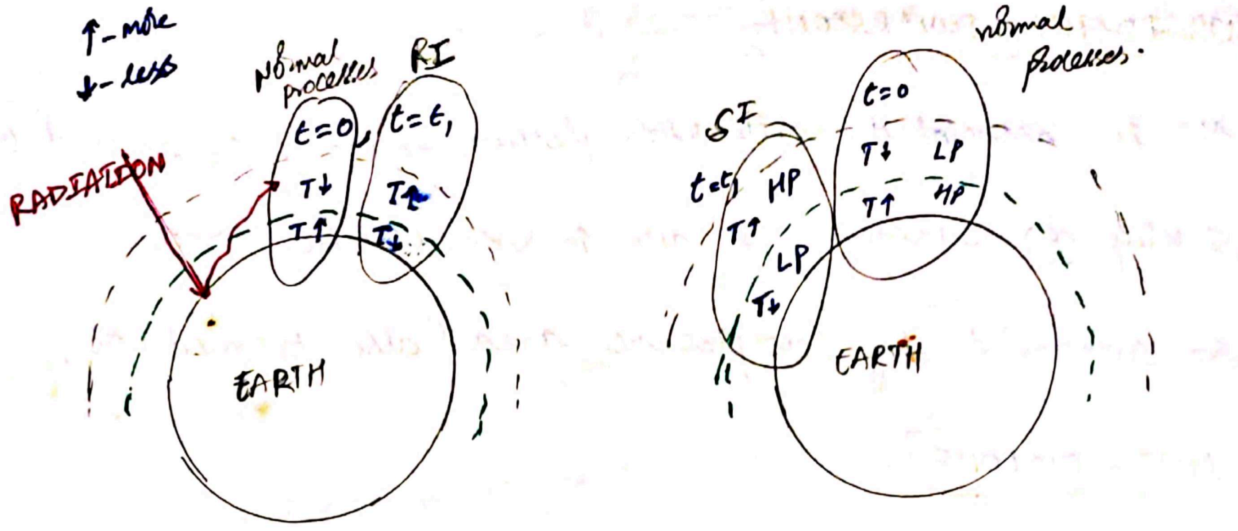

RADIATION INVERSION

SUBSIDENCE INVERSION

(i) RADIATION INVERSION:

- It is the phenomenon ~~which~~ occuring from unequal rate of cooling for the earth and surranding air
- Earth cools rapidly than the air above it [as it may happen in night, specially winter nights] when the earth looses heat by radiation and thereby cooling the surrounding air.
- Then the temperature in the environment would be less at the surface of the earth ~~incomparison~~ and more above it.
- This may also be found in valley regions (&) in desert areas

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(iii) SUBSIDENCE INVERSION!

- It is associated with high pressure region & is caused by sinking (or) subsidence of air in high pressure area so surrounded by low pressure area [also termed as "ANTI - CYCLONE"].

Q For the following information, identify the type of Environment for location A, B, C and D above the surface of the earth, when the pollutant is released in dry state $ALR = 9°c/km$

LOCATION	HT (m)	Temp (°c).
	200	19
A	320	30
B	650	25
C	800	23.95
D	900	22.97.

Sol:- Location A: $\underset{G=}{\overset{NLR}{\cancel{ELR}}} \frac{dT}{dH} = (-)\frac{(30-19)}{(320-200)\times10^{-3}} = \frac{(-)11}{120\times10^{-3}} = \cancel{0.0916}$ 91.66 °c/km

~~ELR > ALR — Unstable~~ Inversion ENV.

Location B: $ELR = \frac{dT}{dH} = \frac{25-30}{(650-320)\times10^{-3}} = \frac{\cancel{(-)5}}{330\times10^{-3}} = 15.5°c/km$

ELR > ALR – unstable / super adiabatic ENV

Location C : $ELR = \frac{dT}{dH} = \frac{(-)\,25-23.95}{(800-650)\times10^{-3}} = -\frac{1.05}{150\times10^{-3}} = 1.7^{\circ}C/km$

$ELR < ALR$ = stable / Sub adiabatic

Location D : $ELR = \frac{dT}{dH} = \frac{(23.95-23.97)}{(900-800)\times10^{-3}} = \frac{0.98}{(100)\times10^{-3}} = 9.8\ ^{\circ}C/km.$

$ELR = ALR \rightarrow$ Neutral ENV.

Q If the state of variation of temp with height in air and pollutant is given by the following relationship.

$Ht_p = (-)0.0133\ T_p + 0.4$ Here 'H' is in km and temp is in (°c).

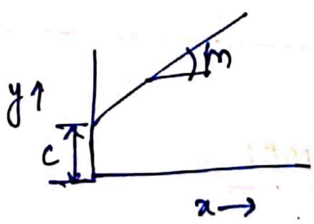
$Ht_A = (-)0.04\ T_A + 0.8$

(a) Identify the type of Environment

(b) Find the height at which temp of both air & pollutant is same?

Sol-

$y = mx + c$



$ALR = \frac{1}{\theta_p}$

$ELR = 1/\theta_A.$

(a)

$H_p = (-)0.0133\ T_p + 0.4$

$ALR = (-)\frac{1}{0.0133} = (-)75.18^{\circ}C/km$ (~~HI↑, T↓~~)

$ALR > ELR$ – Stable ENV.

$H_A = (-)0.04\ T_A + 0.8$

$ELR = (-)\frac{1}{0.04} = (-)25^{\circ}c/km$ (~~HI↑, T↓~~)

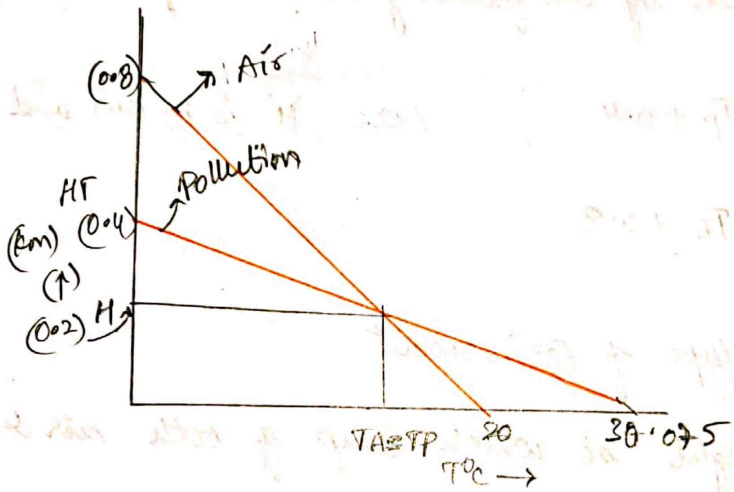
(b) Let at Ht 'H' the temp of Air & pollutant is same

~~tp~~ $T_P = T_A$.

$$\frac{(H-0.4)}{(-0.0133)} = \frac{(H-0.8)}{(-0.04)}.$$

$$\Rightarrow (H-0.4)(-0.04) = (H-0.8)(-0.0133).$$

$$\boxed{H = 0.2 \text{ km}.}$$

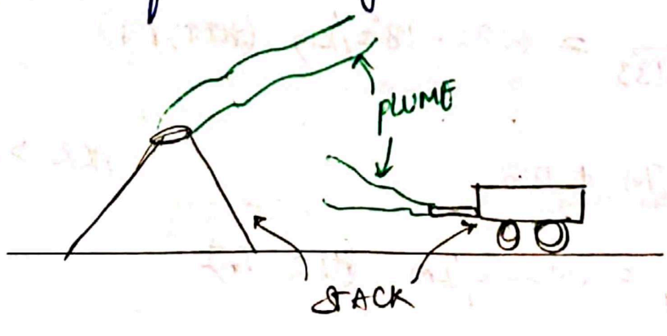


$y=0 \rightarrow T_P, T_A$

LEC-04

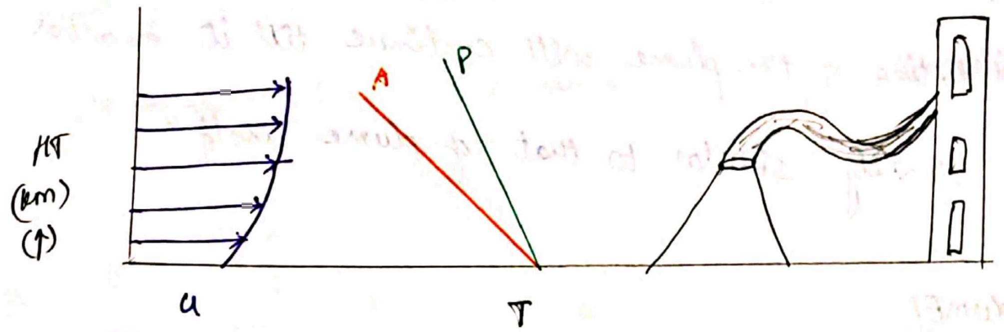
TYPES OF PLUME:

- Gases being released into the atmosphere is termed as "PLUME" and the source of their origin is termed as "STACK"



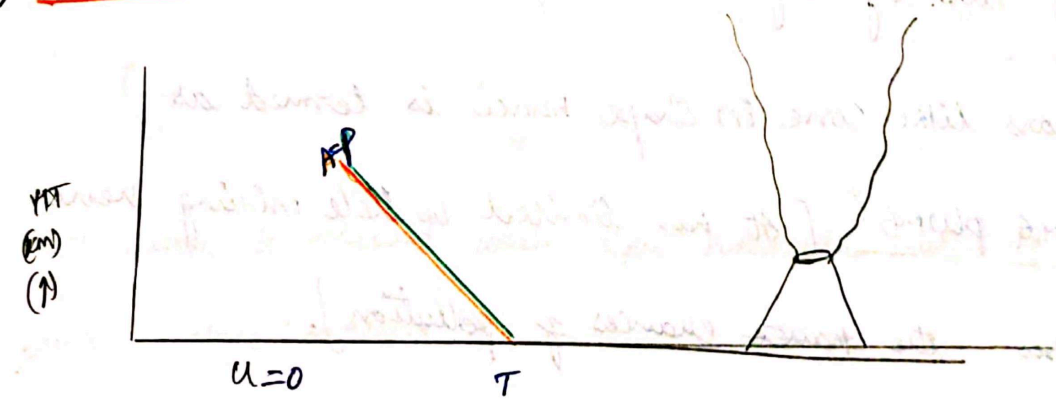
- Depending upon given environmental condition following types of plumes are formed

@ Looping plume:



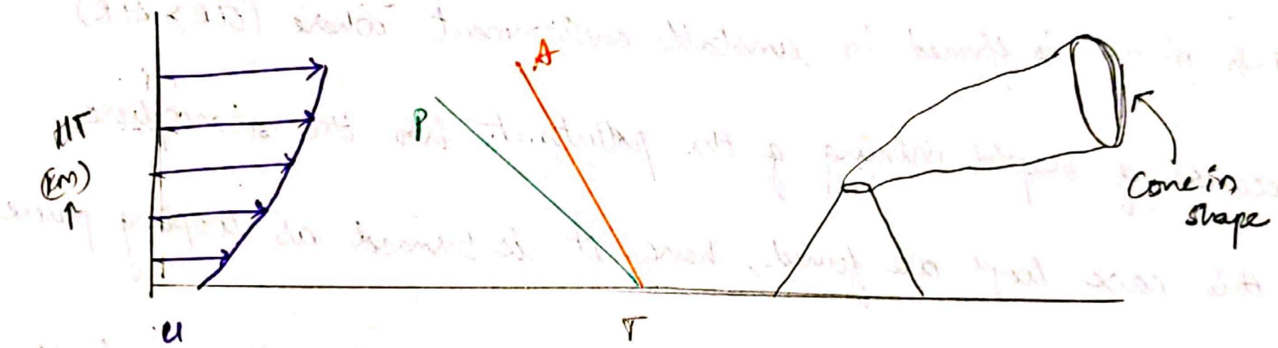
- This plume is formed in unstable environment where (ELR > ALR)
- Because of rapid mixing of the pollutants into the atmosphere in this case loops are found, hence it is termed as looping plume
- During the high degree of turbulence of the dispersion of plume would be rapid., hence higher concentration of the pollutants near the ground may occur.

ⓑ NEUTRAL PLUME:



- It is the type of plume which is formed in neutral environment where ELR = ALR
- It is charaterised with verticle rise of pollutants into the atmosphere.
- The upward lifting of the plume will continue till it reaches an air of density similar to that of plume itself.

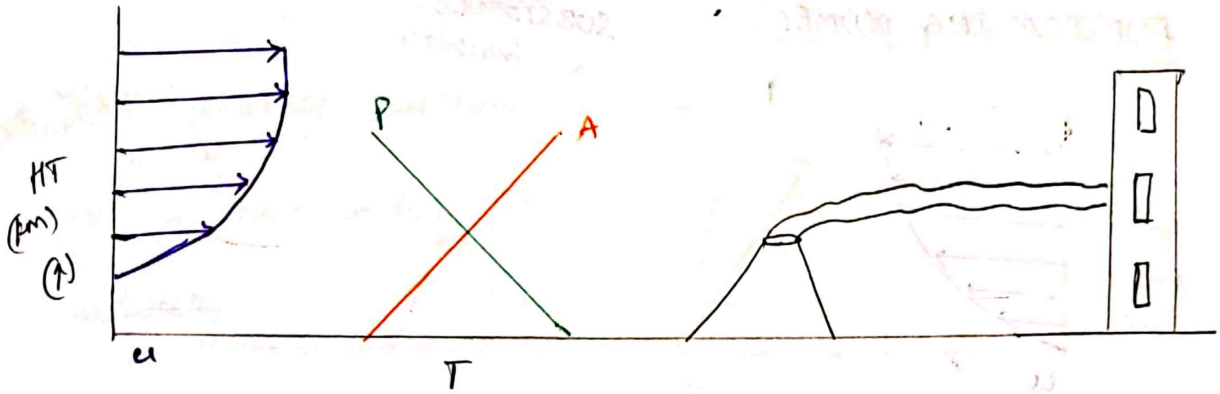
ⓒ CONING PLUME:



- This plume is observed in stable environment where ELR (<) ALR and wind velocity is greater than (32 km/hr)
- It is observed when cloud cover blocks the solar radiation in day and by night terrestrial radiations are blocked.
- It appears like cone in shape hence is termed as 'CONNING PLUME.' [It has limited verticle mixing hence increases the ~~rance~~ chances of pollution].

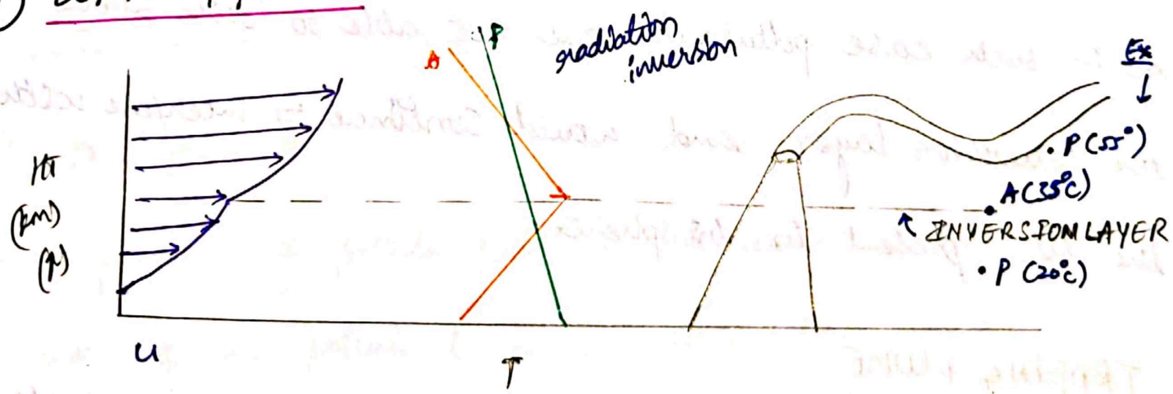
(D) FANNING PLUME:

- This plume is observed in extreme inversion condition in which negtive lapse rate is observed.
- This plume is charaterised with horizantal spread into the atomosphere due to the limited tendency to raise vertically.



- In order to avoid interference with life in this case, Ht of stack is to be properly designed.

(E) LOFTING PLUME:

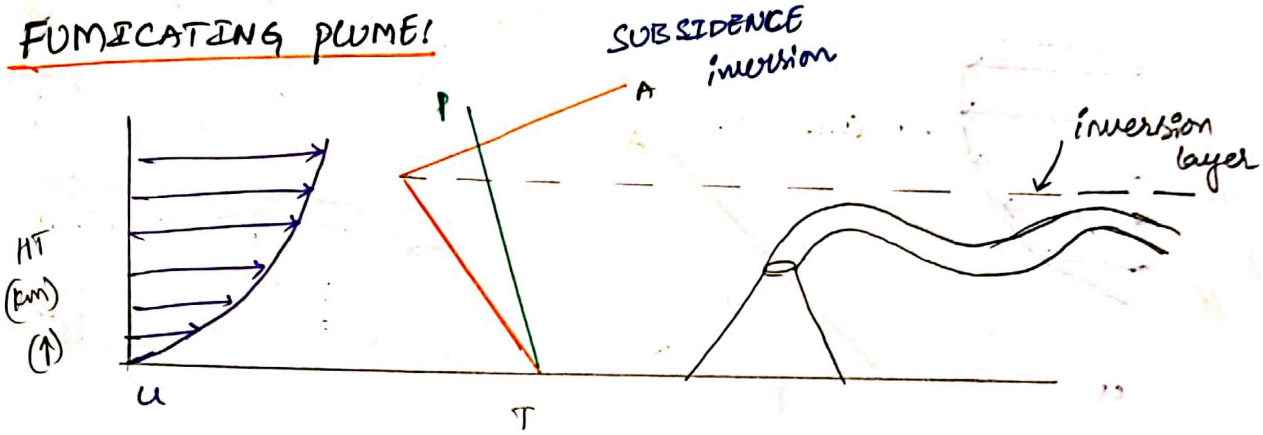


- This plume is observed when super adiabatic environment exist over surface inversion
- This plume has minimum downward mixing due to the

presence of inversion layer below it.

- This plume is regarded as most idle plume as it would have very less concentration of pollutant over the surface of the earth.
- It's tendecy of formation is more during winter nights

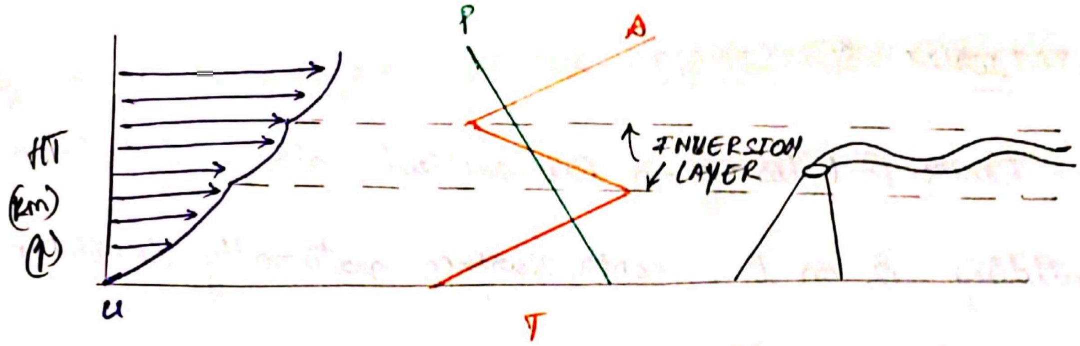
(F) FUMICATING PLUME:



- This plume is formed when inversion condition exist over super adiabtic environment.
- It is considered to be worst type of plume if formed as in such case pollutants are not able to rise above the inversion layer. and would continue to interfere with the life present in biosphere.

(G) TRAPING PLUME:

- It is the type of plume that is formed when super adiabtic environment exists between two inversion conditions



- In this case pollutants are trapped between two inversion layers, thereby it is termed as trapping plume.

AIR POLLUTION CONTROL:

- Air pollution control can be done either artificially (or) naturally

(a) NATURAL METHODS:

- Natural self cleansing properties of the environment are due to following mechanisms

LEC-05

(i) DISPERSION:

- dispersion of ~~polluta~~ pollutant by wind reduces the concentration of air pollutant at one place but does not remove them as a whole

(ii)

(ii) GRAVITATIONAL SETTLING:

- Large heavy particles from the ambient air, settledown on building & on the earth surface naturally thereby helps the air to get to purified.

(iii) ABSORPTION:

- Gases as well as particulate pollutant get collected in rain droplets and settels out with that moisture.

(iv) RAIN OUT:

- Process involving precipitation above the cloud level is termed as RAINOUT.
- It removes fine particulate matter present in the atmosphere

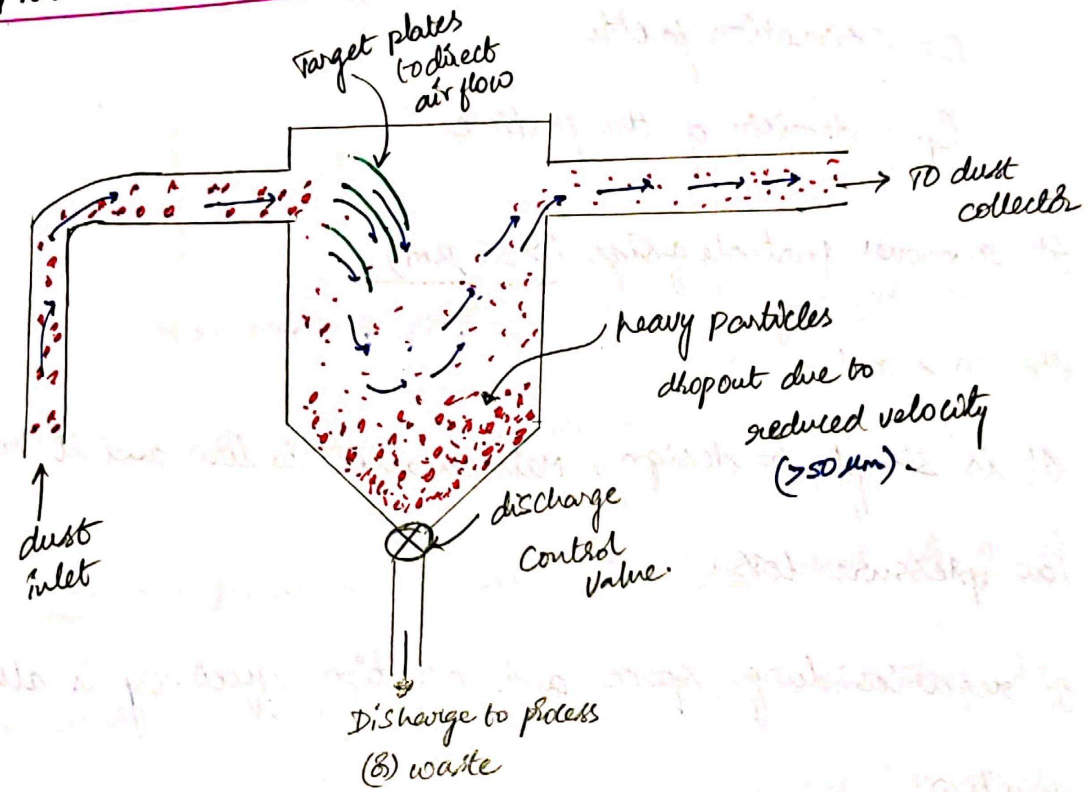
(v) ADSORPTION:

- It is a phenomenon in which the solid, liquid & gasesous pollutant present in the ambient air are attracted by a surface like raindrop, grass, rocks, buildings etc. and gets removed from air.

(B) ARTIFICIAL METHODS FOR AIR POLLUTION CONTROL:

- Air pollution can be controlled by use of following artificial devices.

(i) GRAVITATIONAL SETTELING CHAMBER:



- In this case the emitted pollutant, when made to pass through a setteling chamber it drops some of their large sized particles in it [following STOKE'S LAW].

- The larges size of particle with 100% removal effeciency can be computed as follows

$$\boxed{d = C \cdot \sqrt{\frac{18 \cdot \mu \cdot v_H \cdot H}{g \cdot L \cdot \rho_p}}}$$

v_h = horizantal velocity of gas

μ = viscocity of air

H = ht. of chamber

L = length of chamber

C = correction factor

ρ_p = denisty of the particle

- It removes particle of size "($> 50\ \mu m$)"
- Its $\eta < 50\%$
- It is simple to design, maintenance is low and it has low pressure loss.
- It requires large space and collection effeciency is also very low.
- only large sized particle can be removed in it.

(ii) ~~CYCLONE~~ CENTRIFUGAL COLLECTOR:

(a) CYCLONE COLLECTOR

(b) DYNAMIC PRECIPITATOR

- A cyclone collector is designed in such a way, the velocity of inlet gas is transformed into spinning motion (vortex) and the particles get removed from the gas under the action of centrifugal force, which are further collected from bottom.

- The effeciency of this unit depends upon the velocity, mass of particle and radius of the cyclone, as centrifugal force is given by

$$\boxed{F_c = M_p \cdot \frac{v^2}{R}}$$

M_p – Mass of particle ; v = inlet gas velocity

R – Radius of cyclone

- It removes particles of size "5–25 μm" and its "η = 50 – 90%"
- It is relatively inexpensive [but more expensive than Gravitational settling chambers], Simple to design, requires less area.
- It ensures dry & continous disposal of collected dust particles more over it can handle large volume of gases upto temperature 90°C.
- It requires much head room, collector effeciency is low for smaller particles.

- It is sensitive to variable dust loading & flow rates.

NOTE:
In order to increase its effectiveness dynamic precipitator is used, which imparts centrifugal force to the entering gases with the help of rotating vane [It is '7' times more effective than cyclone precipitator].

(iii) WET SCRUBBERS:

	(a) SPRAY TOWER	(b) WET CYCLONIC SCRUBBER	(c) VENTURI SCRUBBER
d -	> 10 μm	> 2.5 μm	> 0.5 μm
η -	< 80 %	< 80 %	< 90 +

- In these devices the flue gases is made to pushup against a down falling water in which the particulate matter mixes up with water droplets & thus falls down and gets removed
- water solution, when replaced with other chemical solution like pottasium chromite (K_2CrO_7), slurry of MnO and MgO etc helps in removing gaseous pollutants also with particulate matter.

- In this process corrosive gases can also be removed
- A lot of waste water is generated in this which requires disposal
- It's maintenance cost is more.

(iv) ELECTROSTATIC PRECIPITATOR:

- In this unit flue gases are made to pass through a highly ionized zone. where the particles gets electrically charged and are seperated from gas, with the help of electrostatic forces.
- They are widely used in thermal powerplants, pulp and paper industry.
- It removes particles of size $>1\,\mu m$
- It's $\eta \in 95-99\%$ and can be found as follows.

$$\boxed{\eta = 100\left[1 - e^{\frac{-vA}{Q}}\right]}$$

Q - flow rate of air

A - collector plate area

v - velocity of air

- It can remove particles in wet (or) dry state.
- It offers very high effeciency
- Its maintenance cost is nominal & even dust particles can also be removed.
- It is sensitive to variable dust loading and flow rates
- It uses high voltage. hence power required is more.

(v) FABRIC (OR) BAG FILTER:

- In such unit the flue gases are allowed to pass through a bag filter which filters out the particulate matter and allows the gases to pass.
- small particles are retained on the fabric intially through interception and electrostatic attraction but once this dust mat is formed now the particles starts getting to be removed more effectively
- It removes particles of size $< 1\,\mu m$ & $\eta > 99\%$
- It can remove particle in dry state only
- high temperature gases are needed to be cooled down upto range of 100-450°C before processing.

- The flue gas must be dry otherwise chances of condensation inside the filter increases.

LEC – 06

NOTE!

Treatment units of water, waste water and air can be in general classified as follows.

UNIT OPERATION	UNIT PROCESSES.
- These operations are reversible	- These operations are irreversible
- It involves physical changes	- It involves chemical changes.
- It is just a primary activity	- It is a secondary activity
Ex sedimentation, Filteration, ~~Set~~ Screening etc	Ex Disinfection, coagulation chlorination. etc

Q A gas contains two types of suspended particle having average size of 2μ and 50μ amongst the option given, the most suitable pollution control strategy for removal of these particles is

(a) ESP followed by cyclonic seperator

(b) settling chamber followed by bag filter ✓

(c) bag filter followed by ESP

(d) ESP followed by venturimeter

GSC > 50 μm

CS = 5-25 μm

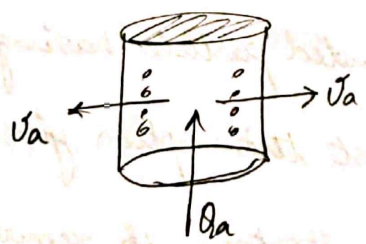
WS-VS > 0.5 μm

ESP > 1 μm

BF < 0.1 μm.

Q It was decided to construct a fabric filter bags of 0.45 mm ϕ and 7.5 m long, for removal of industrial stack gas containing particulates. The expected rate of inflow into the filter is 10 m³/sec. If filtering velocity is 2 m/sec. compute the min. no. of bags required for continuous cleaning operation?

Sol:-



$$A_T = \frac{Q_a}{V_a} = \frac{10}{2} = 5\,m$$

$$A_I = \pi D \cdot H = 3.14 \times (0.45 \times 10^{-3}) \times 7.5$$

$$A_I = 0.0106 = 1.06 \times 10^{-2}\,m$$

$$N = \frac{A_T}{A_I} = \frac{5}{1.06 \times 10^{-2}} = 472 \text{ bags.}$$

Q An ESP with 5600 m^3 of collector plate area is 96% effecient in treating 185 m^3/sec of flue gas from 200 MW thermal power plant. It was found that in order to achieve 97% η, the collector plate area should 6100 m^2. In order to increase the effeciency to 99%, How much area of ESP collector plate is required?

Sol:-

$$\eta = 100\left[1 - e^{-\frac{vA}{Q}}\right]$$

$$96 = 100\left[1 - e^{-5600\frac{v}{185}}\right]$$

$$v = 0.1063 \text{ m/sec}$$

for $$97 = 100\left[1 - e^{-6100\, v/185}\right]$$

$$v = 0.1063 \text{ m/sec}$$

$$99 = 100\left[1 - e^{-A\frac{(0.1063)}{185}}\right]$$

~~A = 8037~~. $A = 8014.64\ m^2$

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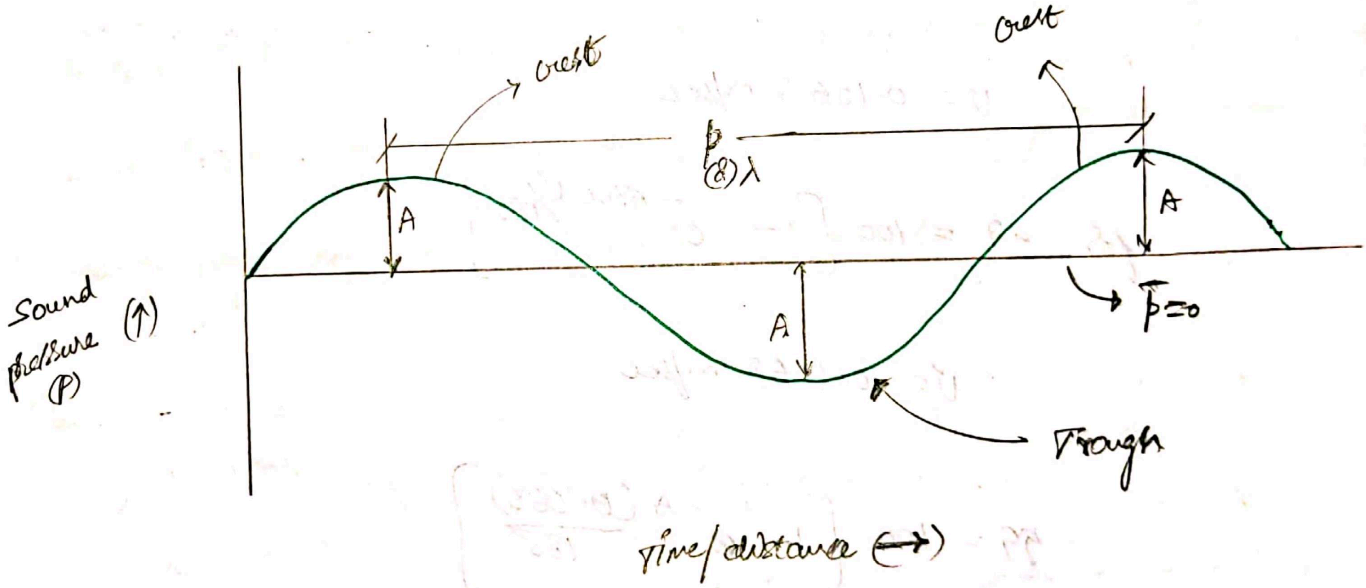
NOISE POLLUTION

- presence of one & more sound for such duration at such pressure level and at such frequancy that the life in the biosphere gets effected is termed as "NOISE POLLUTION."

PROPERTIES OF AND ITS MEASUREMENT:

- sound in any medium travels (or) propogates (or) travels in the form of pressure waves undergoing compression and rare faction



(i) TIME PERIOD: (P)

- Time between two successive crest (or) trough is termed as "TIME PERIOD"

$$p = 1/f$$

f - frequancy

(ii) wave length (λ):

- Distance between two crest and two trough is termed as wavelength

$\lambda = c \cdot p$	
$\lambda = \frac{c}{f}$	$\rightarrow c = f \cdot \lambda$

c - speed of sound

(iii) Amplitude (A):

- max (or) min pressure over & below the mean pressure ($\bar{P} = 0$) is termed as Amplitude.

NOTE!

- All the sound measuring devices are designed to give root mean squre pressure (P_{rms}).

$$P_{rms} = \sqrt{\frac{1}{T}\int_0^T p^2(t)\, dt}$$

$$\left[\sigma = \sqrt{\frac{\Sigma (x_i - \bar{x})^2}{n}} = \sqrt{\frac{1}{T}\int_0^T (p(t) - 0)^2\, dt} = \sqrt{\frac{1}{T}\int_0^T p^2(t)\, dt} \right.$$

For example If $p(t) = A \sin \omega t$ find $p_{rms} = ?$

$$P_{rms} = \sqrt{\frac{1}{T}\int_0^T (A \sin \omega t)^2\, dt}.$$

$$p_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} A^2 \sin^2\omega t \, dt}$$

$$= A/\sqrt{2}$$

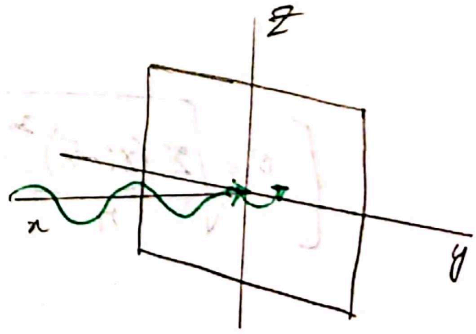
(iv) POWER OF SOUND (W):

- It is defined as the rate of work done by travelling sound wave in the direction of propogation of wave (or) may also be termed as energy transmitted by a sound wave in direction of its propogation

(v) SOUND INTENSITY (I):

- It is defined as the sound power averaged over the time, per unit area, normal to the direction of propogation of sound wave.

$$\boxed{I = \frac{W}{a} \quad \left(\frac{\text{watts}}{m^2}\right)}$$



W - power of the sound (watts)

A - Area ⊥er to direction of propogation of sound wave (m^2)

NOTE!

(1) $I = \frac{P_{rms}^2}{\rho c}$ $[I \propto P_{rms}^2]$.

ρ - density of air (given medium)

c - velocity of sound wave

(2) Smallest level of noise that can be heard by the human ear is $\boxed{20\,\mu Pa}$. and highest may extend upto $\boxed{200\,Pa}$

LEVEL OF NOISE (L):

- Level of noise of any given sound pressure is always measured w.r.t standard reference pressure.

$$\boxed{L = \log_{10}\left(\frac{Q}{Q_0}\right) \text{ (B dB)}.}$$

Q = Measured quantity of sound pressure (P) (or) sound intensity (I).

Q_0 = Reference std quantity of sound pressure (P_0) (or) sound intensity. (I_0)

$$\boxed{L = 10\log\left(\frac{Q}{Q_0}\right) dB \qquad [1 \text{ Bell} = 10\, dB].}$$

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Case (i) Sound intensity level (L_i):

$$\boxed{L_i = 10 \log_{10}\left(\frac{I}{I_0}\right)} \quad (dB).$$

Here, $\boxed{I_0 = 10^{-12}}$ (watt/m^2).

Case (ii) Sound pressure level (L_p).

$$L_p = 10 \log_{10}\left(\frac{P_{rms}}{P_{rms_0}}\right)^2 dB.$$

$$\boxed{L_p = 20 \log_{10}\left(\frac{P_{rms}}{P_{rms_0}}\right) dB.}$$

Here, $P_{rms_0} = 20 \mu pa$

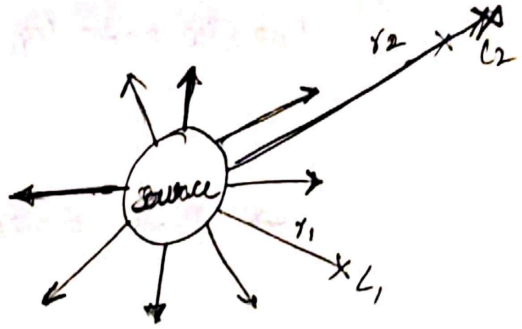
NOTE: (i) An increase in '20dB' in sound pressure level will correspond to ↑ sound pressure (or) loudness of sound increasing by '10 times.'

(2) '1 dB' is the faintest (smallest) sound which can be heard by the human ear and Max. level can be upto '180 dB.'

(3) In real medium, level of noise varies with distance as follows.

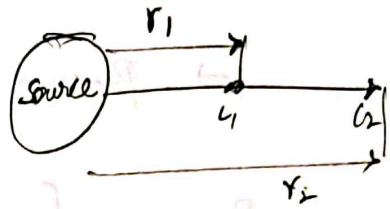
ⓐ FOR POINT SOURCE:

$$\boxed{L_2 = L_1 - 20\log_{10}\left(\frac{r_2}{r_1}\right).}$$



ⓑ For linear source:

$$\boxed{L_2 = L_1 - 10\log_{10}\left(\frac{r_2}{r_1}\right)}$$



LEC-07

NOTE

(4) Addition of two different level of noise is NOT the simple arithmetic addition, due to the involvement of log scale.

Ex $40\,dB + 50\,dB \neq 90\,dB.$

$$E \propto P_{rms}^2$$

$$E_R = E_1 + E_2$$

$$k\,P_{rms_R}^2 = k\,P_{rms_1}^2 + k\,P_{rms_2}^2$$

$$P_{rms_R} = \sqrt{P_{rms_1}^2 + P_{rms_2}^2}$$

$$L_r = 20\log_{10}\left(\frac{P_{rms_R}}{20\,\mu Pa}\right)\ dB.$$

E_R - resultant Energy

L_r - resultant level of noise

$$L_1 = 40 = 20 \log_{10}\left(\frac{P_{rms1}}{20\mu pa}\right)$$

$$\rightarrow P_{rms1} = 2000\ \mu pa.$$

$$L_2 = 50 = 20 \log_{10}\left(\frac{P_{rms2}}{20\mu pa}\right).$$

$$\rightarrow P_{rms2} = 6324\ \mu pa.$$

$$P_{rmsR} = \sqrt{2000^2 + 6324^2} = 6632.$$

$$L_R = 20 \log_{10}\left(\frac{6632}{20}\right). = 50.41\ dB.$$

NOTE ⑤

Addition of two similar sound pressure levels. results in the ~~increase in~~ pressure level which is greater than given sound pressure level by 3dB

$$\boxed{L_r = L + L = (L+3)}$$

$$L = 20 \log_{10} \frac{P_{rms}}{20\ \mu pa} \rightarrow P_{rms} = x$$

$$P_{rmsR} = \sqrt{x^2 + x^2} = \sqrt{2} \cdot x.$$

$$L_r = 20\log_{10}\frac{P_{rms,R}}{20\mu pa} = 20\log_{10}\left(\frac{\sqrt{2}\cdot x}{20\mu pa}\right) dB.$$

$$= 20\log_{10}\sqrt{2} + 20\log_{10}\left(\frac{x}{20}\right)\mu pa.$$

$$\boxed{L_r = 3 + L}$$

Ex

① $20 + 20 = 23$ dB.

② $\underbrace{30 + 20}_{33} + \underbrace{30 + 30}_{33} = 36$ dB.

③ $40 + 50 = € 50 - 53$

$50 + 60 + 70 + 100 + 150 = €150 - 153.$ [€ Highest value to Highest value +3].

$50 + 60 + 70 + 150 + 100 = €150 - 153.$

NOTE ⑥ Average of different sound pressure level is not the simple arthematic average, due to the involvement of log scale and is given by

$$\boxed{L_{avg} = 20\log_{10}\left[\frac{1}{N}\sum_{i=1}^{n} 10^{L_i/20}\right]}$$

Ex 50, 60, 70, 100, 150

$$L_{avg} = 20 \log_{10} \left\{ \frac{1}{5} \left[10^{50/20} + 10^{60/20} + 10^{70/20} + 10^{100/20} + 10^{150/20} \right]. \right\}$$

$$L_{avg} = 136.05\, dB.$$

(8) $L_{avg} = 20 \log_{10} \frac{1}{5} \left[10^{2.5} + 10^{3} + 10^{3.5} + 10^{5} + 10^{7.5} \right].$

$$10^{7.5} + 10^{x} \simeq 10^{7.5} \qquad (x < 7.5)$$

$$\simeq L_{avg} = 20 \log_{10} \frac{1}{5} \times 10^{7.5}$$

$\log_{10} 2 =$

$$= 20 \left[\log_{10} 10^{7.5} - \log_{10} 5 \right].$$

$\log_{10} 3 =$

$\log_{10} 5 = 0.6989$

$$= 20 \left[7.5 - 0.6987 \right].$$

$$L_{avg} = 20 \left[6.8 \right] = 136.049\, dB.$$

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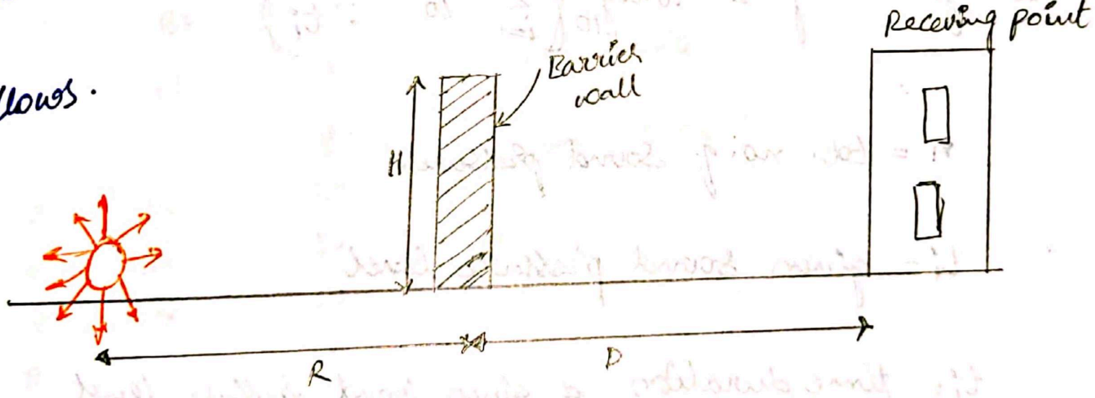
Ambient air quality standard w.r.t noise as per EPA.

Area Code	Category of Area/Zone	Limit (dB) [Leq]	
		DAY TIME	NIGHT TIME.
A	Industrial area	75	70
B	commercial area	65	55
C	Residential area	55	45
D	silence area	50	40.

NOTE: In order to reduce the noise pollution obstruction and barrier between the noise source and point of impact can be constructed which reduces the noise as follows.



~~where~~ when $D \geq R$ and $R >> H$.

$$\boxed{\text{noise reduction (dB)} = 10 \log_{10}\left(\frac{20 H^2}{\lambda R}\right)}$$

RATING OF NOISE:

- As different types of noise exists in the system at different pressure level, for different duration and at different frequancy, In order to find the equivalent effect of all these noises, rating is done as follows.

(a) Lequivalent CONCEPT (Leq):

- It is the constant sound pressure level which over a given period of time expands the same amount of energy as is being expanded by fluctuating sound pressure levels

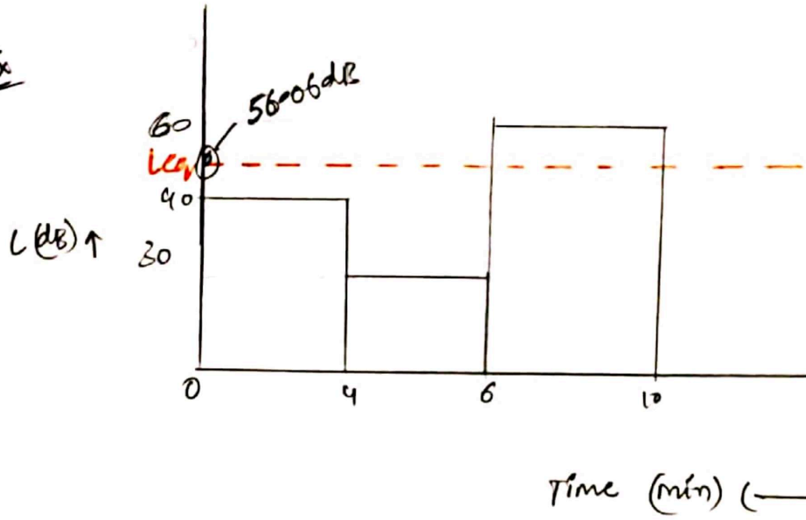
- Leq is given by $= 10\log_{10}\left(\sum_{i=1}^{n} 10^{L_i/10} \cdot t_i\right)$

n = tot. no. of sound pressures

L_i = given sound pressure level

t_i = time duration of given sound pressure level expressed in terms of total time.

Ex



$$L_{eq} = 10\log_{10}\left[10^{40/10}\cdot\frac{4}{10} + 10^{30/10}\cdot\frac{2}{10} + 10^{60/10}\cdot\frac{4}{10}\right]$$

$L_{eq} = 56.06$ dB.

(b) L_N CONCEPT :

- L_N represents the sound pressure level that is exceeded for N% of gauging time.

Ex

	L(dB)	descending order
1	20	100
2	80	95
3	95	86
4	100	80
5	40	40
6	35	35
7	86	30
8	15	20
9	30	19
10	19	15

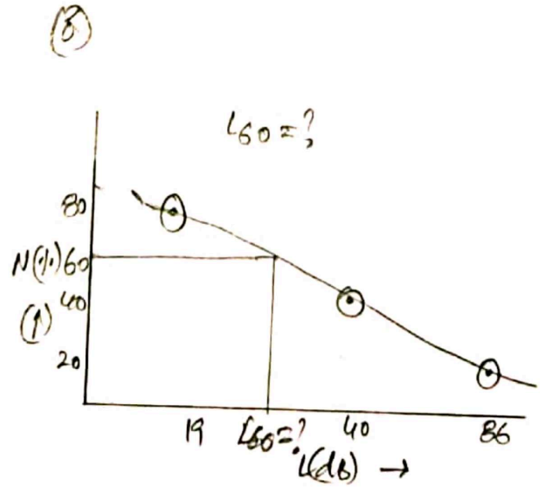
$L_N = x$ dB ↑.

$L_{20} = 86$ dB

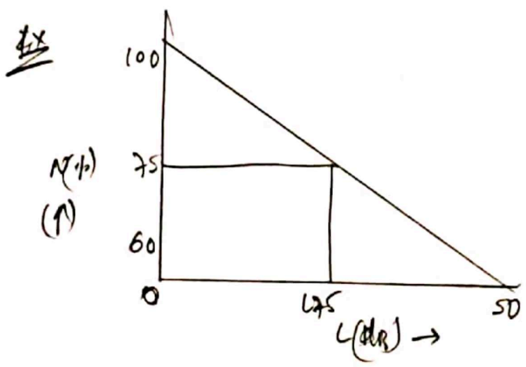
$L_{40} = 40$ dB

$L_{80} = 19$ dB

(8)



Ex



$$\frac{100-60}{50-0} = \frac{100-75}{L_{75}-0} \Rightarrow L_{75} = 31\cdot65\,dB$$