AIR POLLUTION.

→ Presence of one or more air pollutant. in such concentration and for such duration that the life in the biosphere gets effected is termed as air pollution.

→ All these pollutants which are emitted directly from the identifiable sources either from natural process like dust storm, volcanic eruption etc or from human activities like burning of coal, oil in industries, houses, automobile etc are termed as "primary air pollutant".

eg. Oxides of Sulphur (SO_2, SO_3)
oxides of carbon (CO, CO_2)
oxides of nitrogen (NO, NO_2)
Hydrocarbons (HC)
Suspended Particulate matter (SPM)

These contribute 90% of global air pollution.

H_2S, H_2F
lead (Pb)
Ethyle Mercaptan (C_2H_6S) gas cylinder & Methyl Mercaptan (CH_4S).

→ These primary ~~air~~ pollutant often combine with each other or with water vapours in the presence of sunlight and leads to formation of "secondary air pollutants".

$$PAP + H_2O \xrightarrow{\text{sunlight}} SAP$$

Note:→ The above reaction is termed as photochemical reaction.

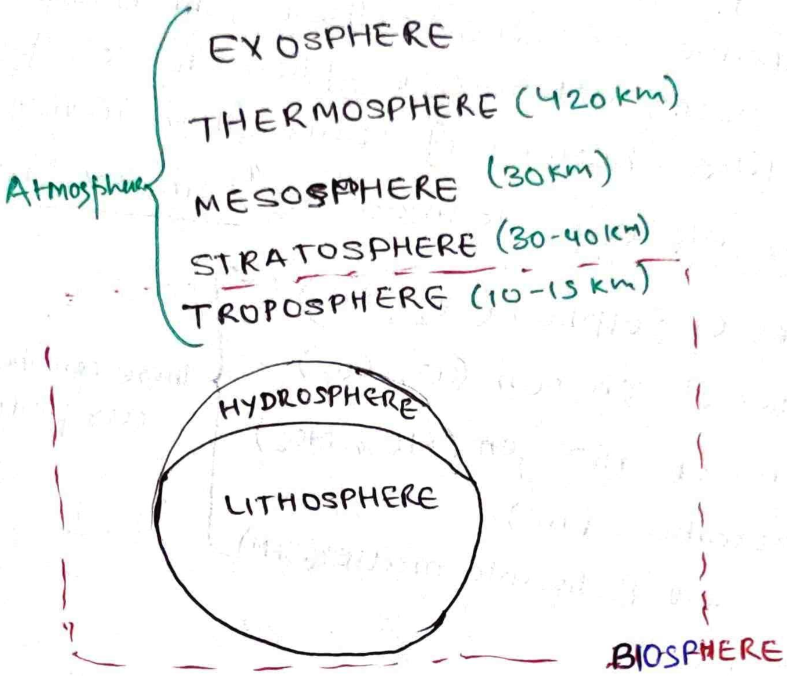
→ The secondary air pollutant can be more dangerous than original basic primary air pollutant.
like, Sulphuric acid, Ozone, formaldehydes, Peroxy Acetyl Nitrate (PAN)

$SO_2 + H_2O \xrightarrow{sunlight} H_2SO_4$ (Sulphuric acid)

$NOx + HC + H_2O \xrightarrow{sunlight} \{O_3 + \text{Formaldehydes} + PAN\}$

photochemical smog.

SMOG: It is mixture of SMOKE and FOG.



Note:-

The concentration of suspended particle and gaseous pollutants are generally expressed as weight/volume at a given pressure and temperature.

→ The reason for expressing the pollutants as mass per unit volume of air is that. living things breathe air by volume but are affected by mass of the pollutant absorbed by them.

$$1\ ppm = \frac{1 \text{ part of any gas/pollutant}}{10^6 \text{ parts of air}} = \frac{1m^3 \text{ of any gas}}{10^6\ m^3 \text{ of air}}$$

1 mole of any gas at STP occupies volume of 22.4l (1 atm, 0°c)

1 mole of any gas at different temp. pressure has volume of V_2 l is given by.

$$PV = nRT$$

$$n = 1 \text{ moles.}$$

$$\frac{PV}{T} = \text{constant}$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$\boxed{V_2 = \frac{P_1V_1}{T_1}\left(\frac{T_2}{P_2}\right)}$$

Q Express the concentration of 10ppm of sulphur dioxide at 20°c & 2atm is Mg/m³

Sol^n = 1ppm = $\frac{1 \text{ part of } SO_2}{10^6 \text{ part of air}} = \frac{1m^3 \text{ of } SO_2}{10^6\ m^3 \text{ of air.}}$

1 mole of SO_2 at STP has vol of 22.4 lt.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

0° = 273 Kelvin

$$\frac{1 \times 22.4}{273} = \frac{2V_2}{293}$$

$V_2 = 12.02$ lt.

1 mole of SO_2 at 20°C, 2atm has volume of 12.02 liter

64 gm of SO_2 ——— 12.02 l

12.02 lt. of SO_2 ——— 64 gm.

$1\ m^3$ of SO_2 at $20°c$ and $2\ atm = \frac{64}{12} \times 10^3 = 5324.5\ gm$

$1\ ppm$ of $SO_2 = \frac{1 m^3 \text{ of } SO_2}{10^6 m^3 \text{ of air}} = \frac{5324.5 \times 10^6}{10^6} \frac{\mu g}{m^3}$.

$1\ ppm$ of $SO_2 = 5324.5 \frac{\mu g}{m^3} \Big|_{at\ 20°c,\ 2 atm}$.

$10\ ppm$ of $SO_2 = 5324.5 \times 10 \frac{\mu g}{m^3} \Big|_{at\ 20°c,\ 2 atm}$

$= 5.324 \times 10^4 \frac{\mu g}{m^3} \Big|_{at\ 20°c,\ 2 atm}$.

~~Q The mean indoor airborne chloroform~~

Q The concentration of sulphur dioxide (SO_2) in ambient atmosphere was measured as $30\ \mu g/m^3$. Under the same condition the above SO_2 concentration expressed in ppm is ______

Given, $\boxed{\frac{P}{RT} = 41.6\ mol/m^3.}$

where P = Pressure,
T = temp.
R = universal gas constant
M. weight of SO_2 = 64.

$30\ \mu gm/m^3 \longrightarrow ppm$

$1\ ppm = \frac{1 m^3 \text{ of } SO_2}{10^6 m^3 \text{ of air}}$

1 mole of SO_2 at STP has vol. of 22.4 l. ✗

$\frac{P}{RT} = 41.6\ mole/m^3$.

$PV = nRT$

$V = n \cdot \frac{RT}{P} = 1 \cdot \frac{RT}{P} = 1 \times \frac{10^3}{41.6}$

$V = 24.03$ lts.

1 mole of SO_2 at STP has volume of 24.03 l

64 gm of SO_2 ——— 24.03 l

~~$1 m^3$ of SO_2 at STP~~

24.03 lts of SO_2 ——— 64 gm.

$1 m^3$ of SO_2 ——— $\frac{64 \times 10^3}{24.02} = 2664.49$ gm.

$$1 \text{ ppm of } SO_2 = \frac{1 m^3 \text{ of } SO_2}{1 m^3 \text{ of air}} = \frac{2664.44 \times 10^6}{10^6} \frac{\mu g}{m^3}$$

$$1 \text{ ppm of } SO_2 = 2664.44 \frac{\mu g}{m^3}.$$

$$= \frac{1 \mu g}{m^3} = \frac{1}{2664.44} \text{ ppm}$$

$$30 \frac{\mu g}{m^3} = \frac{30}{2664.44} \text{ ppm}$$

$$= 0.0113 \text{ ppm}$$

* Harmful Effects of Air pollutants on Human Health.

(i) Suspended Particulate Matter (SPM)

- → These are solid particles like dust, smoke, fumes and liquid particles likes mist & fog.
- → These are released during dust storm, smoke, burning of garbage & fossil fuels.
- → It effects breating & respiration, causes cardiovascular disease. lungs problem effects still births etc. (dead born).

(ii) Oxide of Sulphur (SO_2)

- → It is colourless gas having tasle thresold at about 0.3ppm.
- → It is released due to combiustion of oil & coal in power station or automobiles.
- → If effects breathing, respiratory illness than breakdown of lung defence cause cardio-vascular disease, bronchial spams (Bronchial spams -clot is sudden blockage of musceles in walls of bronchoiles)

(iii) Oxides of Carbon (CO and CO_2)

- → It is colourless, teste less, odourless gas at atmospheric concentration.
- → It is evolved due to incomplete combustion of coal & oil & fuels.
- → It leads to cardio vascular disease, combines with the hemoglobin 200 times fasler than oxygen. forms Carboxy hemoglobin (pink in colour) and may also lead to death.
- → If result in headace, dizziness (चक्कर), nausea (vomiting), heart palpitation, difficulty in breathing.

(iv) Oxides of Nitrogen.

→ It is reddish brown highly reactive gas. odour thresold is at 0.2ppm.

→ It is emitted from high temperature combostion in automobile and from thermal power station.

→ Nitrogen oxide plays a major role in tropospheric ozone formation. ~~it combines~~

→ It combines 3 lakh time faster with haemoglobin than oxygen hence is also the cause of "ASPHYXIATION". (Chocking/Suffocation).

→ NO_2 is responsible for eyes & nasal, irritation, respiratory discomfort and may also lead to emphysema (swelling due to air in body).

(v) Hydrocarbon (HC)

→ These are being released from the exhaust of automobile

→ they lead to irritation of eyes and 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 used).

Dispersion of Air pollutant into the atmosphere

→ Dispersion of air pollutants into the atmosphere depends upon prevailing wind, temperature and pressure condition

(i) wind

→ ~~wind speed is inversely p~~

→ Dispersion of pollutant into the atmosphere is directly depended upon wind speed. (hence concentration of pollutant is inversely proportional to wind speed)

→ wind speed is measured by ANEMOMETER and velocity of wind at any height can be found using $\frac{1}{7}$ powerth law.

$$\boxed{U = u_0 \left(\frac{Z}{Z_0}\right)^k} \qquad \boxed{k = \frac{1}{7}}$$

U_0 is wind velocity is measured by anemometer at height Z_0.

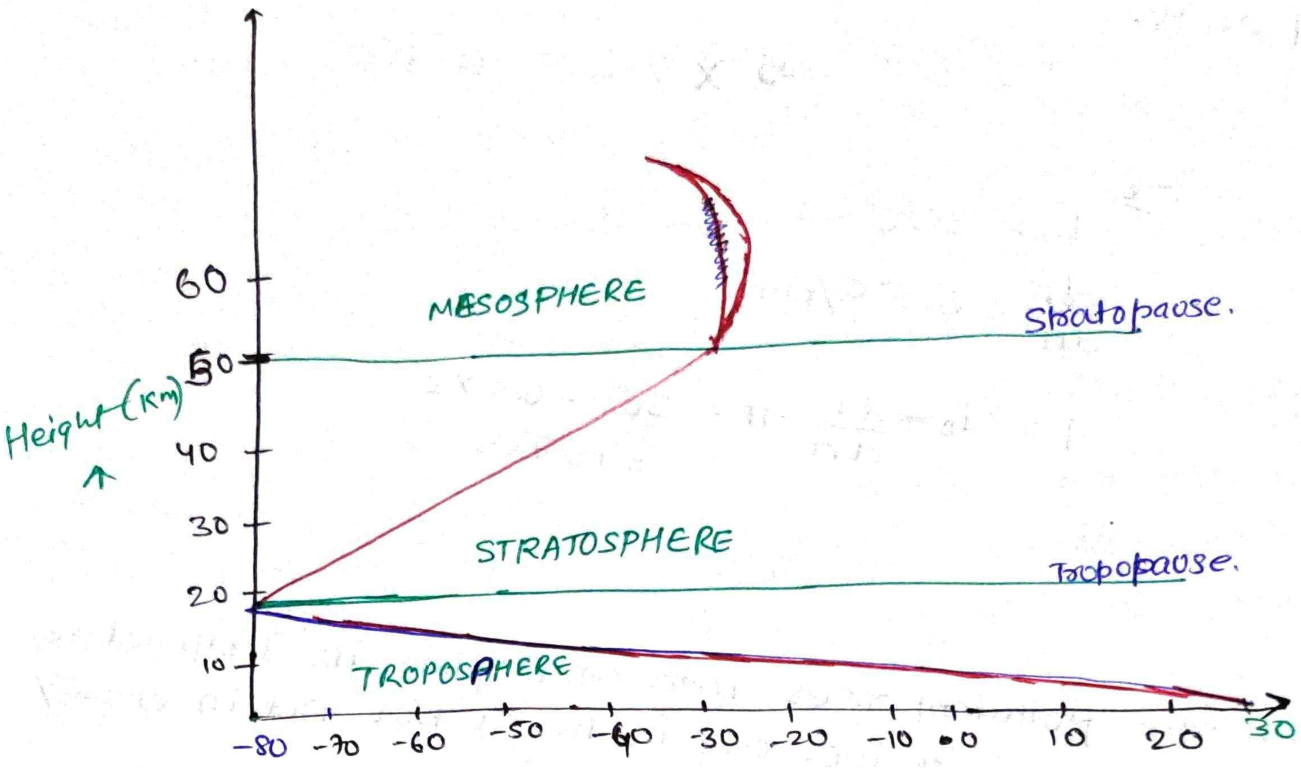
(ii) Temperature.

→ Temperature of the air decreases with increase in height above the surface of earth in toposphere. and the rate at which it decreases with increase in height is termed as "Environmental Lapse Rate". (ELR)

→ ELR varies from height to height and can be computed seprately for different height but if not given it may be assumed to approximately 6.5°c/km.

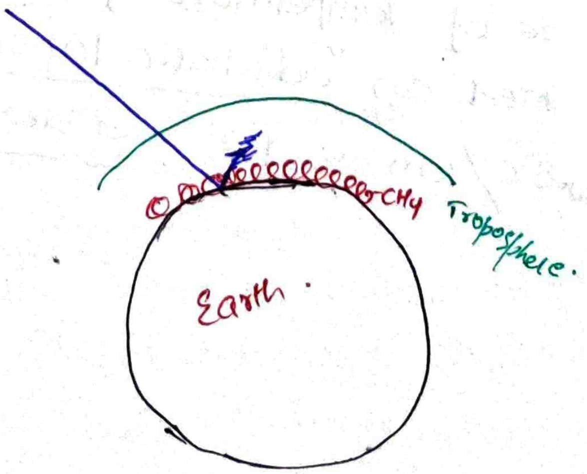
Note:-
(i) Temperature decreases with height in toposphere since the main heat source is solar radiation which is absorded majorly at ground level.

(ii) Variation of temperature in different layers of atmosphere is as follows:-



Note!- Temp of air increases in stratosphere. and is almost same as that of temperature on the earth surface at stratopause.

→ Its warmth is due to absorption of UV rays from sun by oxygen and by O_2 & ozone of this layer.



Q The temperature of ambient air over the surface of earth is 30°c. find its temp at height of 2.2km from the surface of earth.

$$T = 30°c - 6.5 \times 2.2 = 15.7°C$$

Or,

$$T_0 = 30°C$$

$$\frac{dT}{dH} = 6.5°C/km$$

$$T = T_0 - \frac{dT}{dH} \cdot H = 30°C - 6.5 \times 2$$

$$= 15.7°C.$$

→ When the pollutant rises into atmosphere its temperature also decreases with increase in height but not in a pattern observed in case of air.

→ Hence its analysis is carried out by assuming the variation to be "adiabatic." (The process which takes place at constant heat is termed as adiabatic process), $PV^{\gamma} = C$]

→ hence the temperature of pollutant decrease due to expense of its own internal energy to carry out expansion (when it rises into the atmosphere).

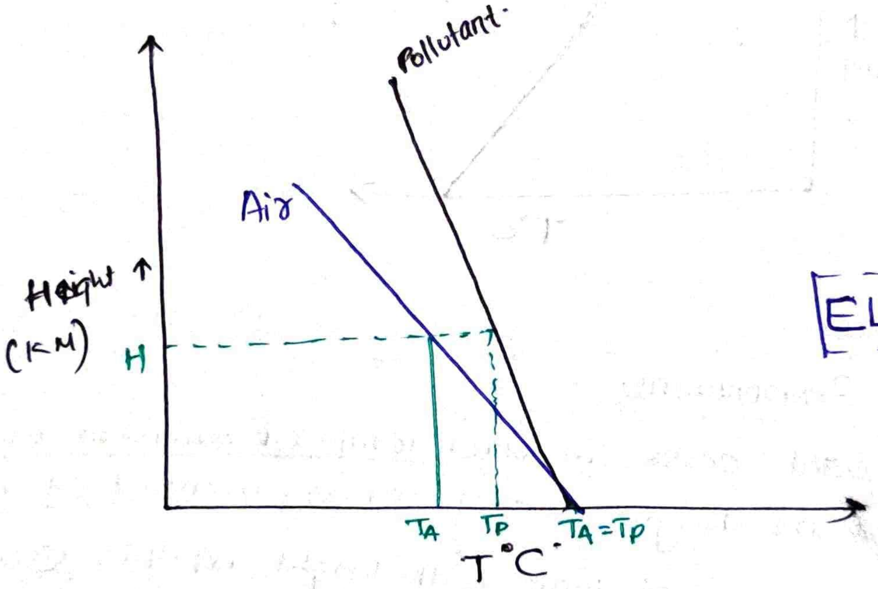
→ The rate of decrease of temperature of air pollutant with increase in height. is termed as "adiabatic lapse Rate" which for dry air is 9.8°C/km & for wet air is 6°C.

→ Depending upon the relative magnitude of ~~AB~~ ELR and ALR different types of environment are being defined.

(i) Unstable Environment / Super Adiabatic Environment

→ It is type of environment in which rate of decrease of temperature with height for air (ELR) is more than that of pollutant (ALR), due to which rapid mixing of pollutants takes place when released in this environment.

→ In such a case the rising parcel of air will always remain warmer then the surrounding air hence it keep on rising into the atmosphere, and a decending parcel of heavier air will keep on falling on to the earth surface.

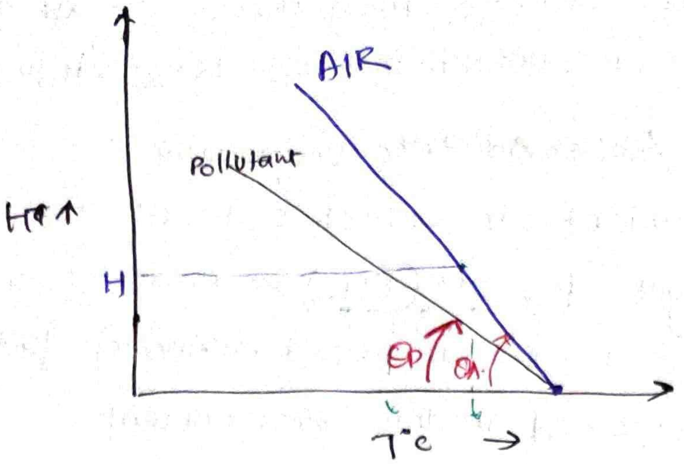


ELR > ALR

(ii) Stable or Subadiabatic Environment

→ It is the type of environment in which rate of decrease of temperature for air (ELR) is less than that of pollutant (ALR)

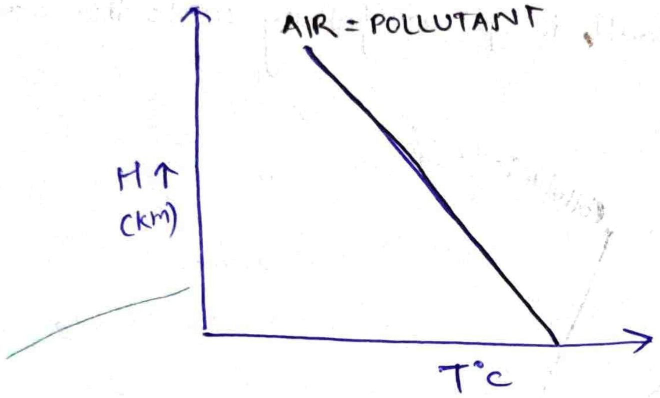
→ This prevailing environmental lapse rate in such case is termed as sub-adiabatic lapse rate. & environment is termed as sub-adiabatic environment.



ELR < ALR

(iii) Neutral Environment

→ It is type of environment in which ELR = ALR

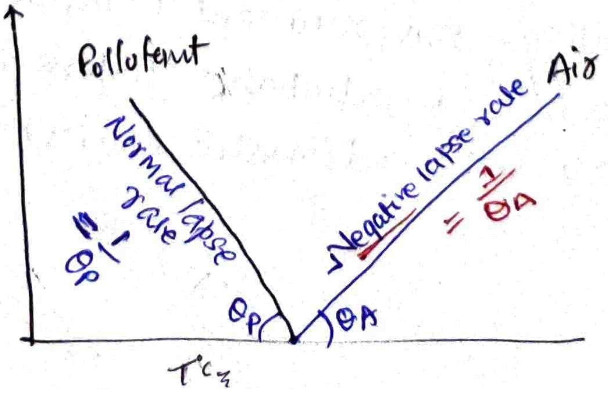


(iv) Inversion Environment

→ It is an unusal case in which temp. of environment increases with increase in height in troposphere instead of decreasing

→ The rate of increase of temp with height in this case is termed as negative lapse rate.

→ In this case warmer air lies over the colder air ~~below~~ parcel [illegible] (pollutant) below, leading to represent a highly stable environment.



→ These inversion condition are of two types:-

(i) Radiation inversion.

(ii) Subsidence Inversion.

Radiation Inversion

→ It is a phenomenon occuring from the unequal cooling rates for earth and air above the surface of the earth.

→ Earth cools rapidly or more quickly than the air above it (as may happen at ~~the~~ night when the earth may loose heat by radiation there by cooling the surrounding air) the naturally the temperature in environment will be less at the earth and will increase above it., causing the negative lapse rate.

→ This type of inversion is prominent in nights in winters and may extend to few hundred meters above the surface of the earth.

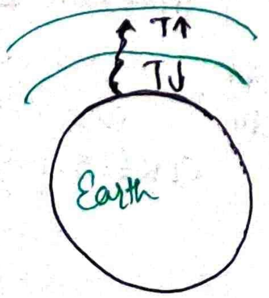
→ This inversion may also be found in valley regions.

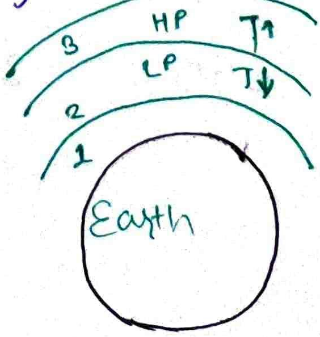
Subsidence Inversion.

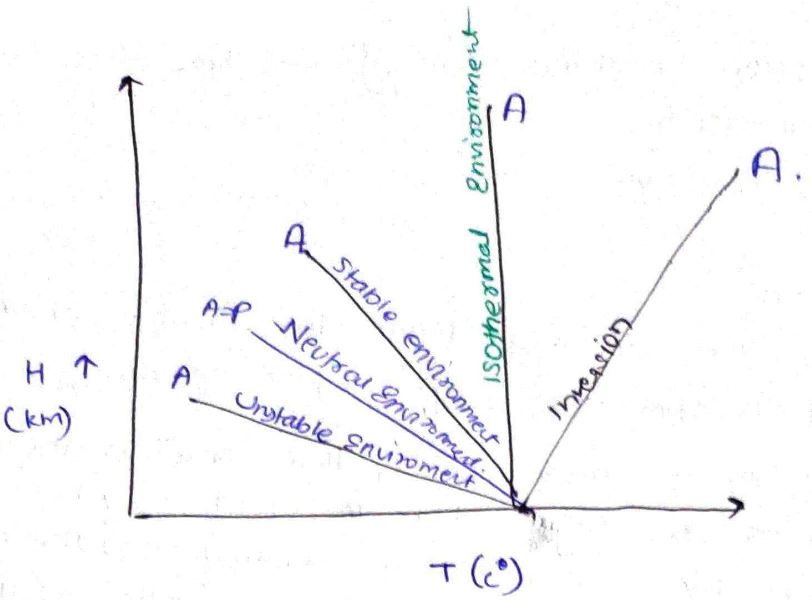
→ It is associated with the high pressure region system and is caused by sinking or subsidence of air in high pressure area surrounded by low pressure area. (ie anti-cyclone).

→ The air around high pressure region gets compressed and descend thereby gets heated to form a warm dense layer over the ground surface. upto the height of 1.5-2 km.

→ Such inversion layer may by stopping upward movement of pollution causes the air pollution.







Q. For the following information identify the type of environment for location A. B, C D above the surface of the earth when the pollutant is released in dry air

Location	Height(m)	Temp°c
	20	19
A ⟶	320	30
B ⟶	650	25
C ⟶	800	23.95
D ⟶	900	22.97

Solⁿ

	HT (m)	T°C
	20	19
A	320	30
B	650	25

$$\frac{dt}{dh} = \frac{-(30-19)}{320-20 \times 10^{-3}}$$

$$= -36.66^\circ \frac{C}{km}$$

Inversion Environment.

$$\frac{dt}{dh} = \frac{-(25-30)}{(330-320)} = 15.15 \frac{^\circ C}{KM}$$

ELR 15.15°C/km > ALR$_{DRY}$ (9.8°c)

— Unstable.

→ superadiabatic.

	650	~~23.95~~25
C	800	23.95
D		
Ⓓ	900	22.97

$\frac{dT}{dh} = -\frac{(23.25-25)}{(800-650)\times 10^{-3}} = 7°C/km$

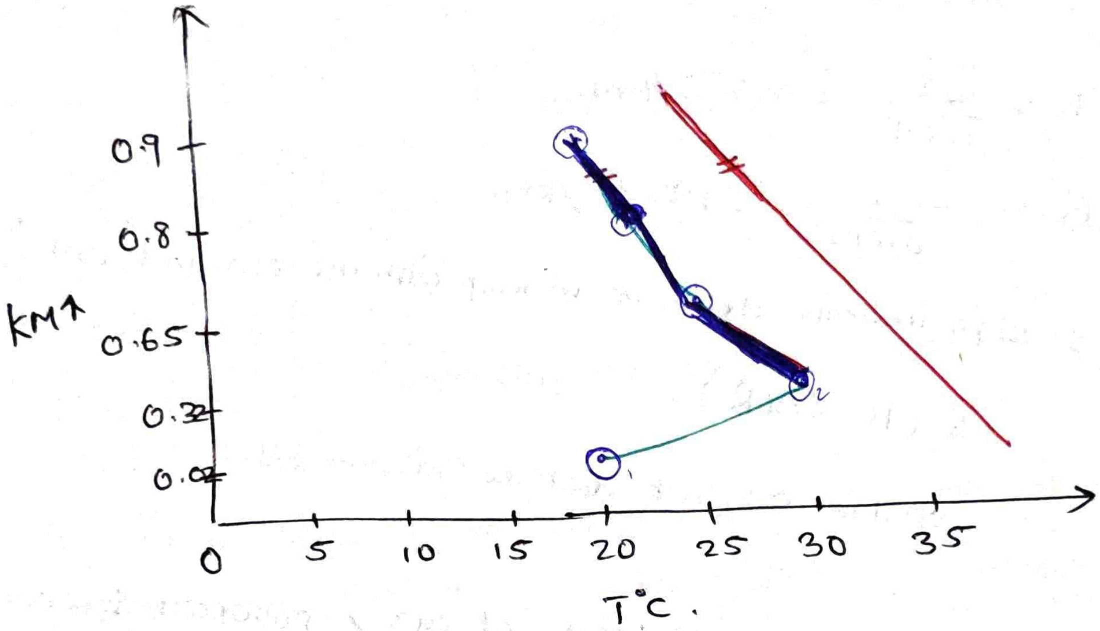
ELR (7°C/km) < ALR_{Dry} (9.8°C/km)

Stable or sub adiabatic.

$\frac{dT}{dh} = -\frac{(22.97-23.95)}{(900-800)\times 10^{-3}} = 9.8°C/km$

ELR (9.8°C) = ALR (9.8°C/km)

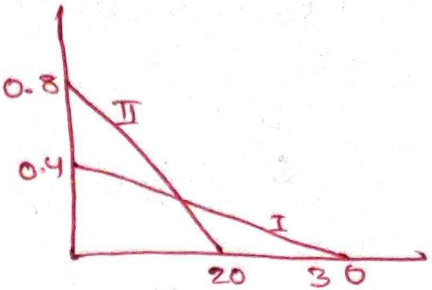
- Neutral



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

$H_{P_{polluti}} = -0.133 T_P + 0.4$

$H_{Air} = -0.04 T_P + 0.8$



$\frac{x}{a} + \frac{y}{b} = 1$

Here, HT is in KM & tem in °c.

(i) Identify the type of environment.

$y = mx + c$

$\text{ELR} = \frac{-1}{0.04} = -25\,°C/km$

$\text{ALR} = -\frac{1}{0.0133} = -75.2\,°C/km.$

(minus sign indicate decrease in temp. with increase in height)

(ELR < ALR)

stable or subadiabatic Environment.

(ii) Find the height at which temp. of air & pollutant become same.

Let at height H, $T_A = T_P$

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

$H = 0.2\,km.,\ T = 14.98°C.$

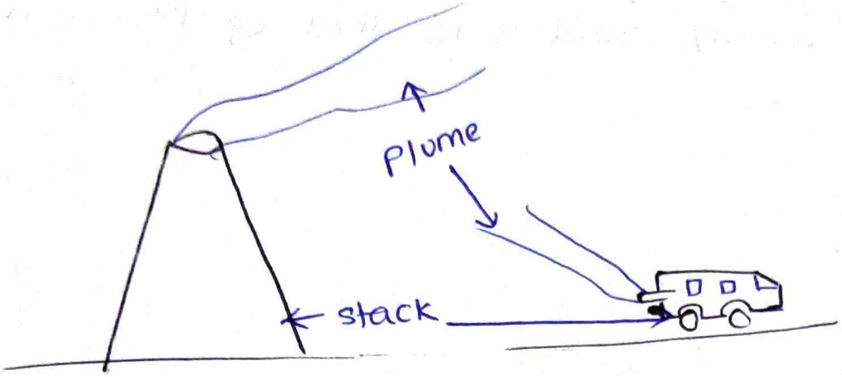
$T_A > T_P$

↑
0.2 km
↓

$T_A < T_P$

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

- Depending upon the prevailing environmental condition following types of flume may be observed:-

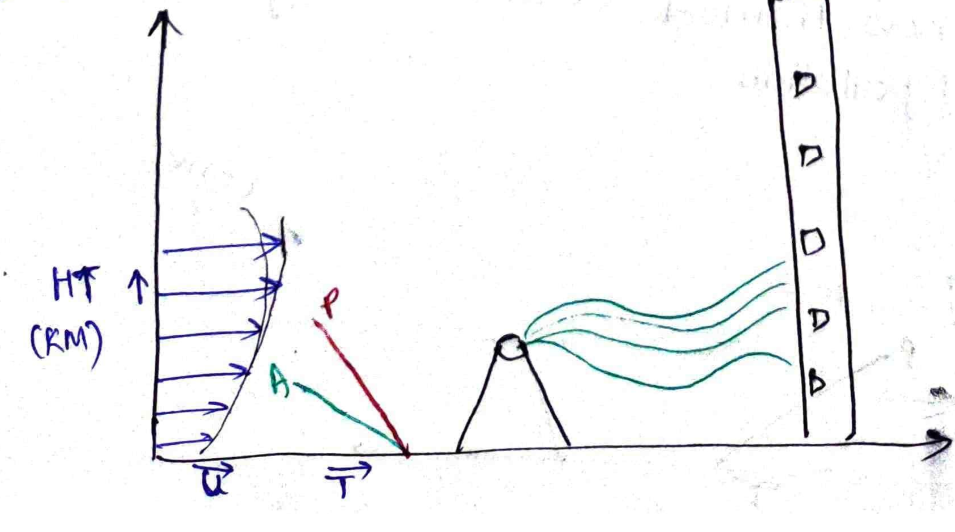


(i) Looping Plume

- This plume is formed in unstable environment where ELR > ALR.

- Because of rapid mixing of the pollutant in this case loops are formed wave character is observed hence it is termed as looping plume.

- During the high degree of turbulence the dispersion of plume would be rapid, yet higher concentration near the ground may occur due to the turbulence, before the dispersion is finally completed.



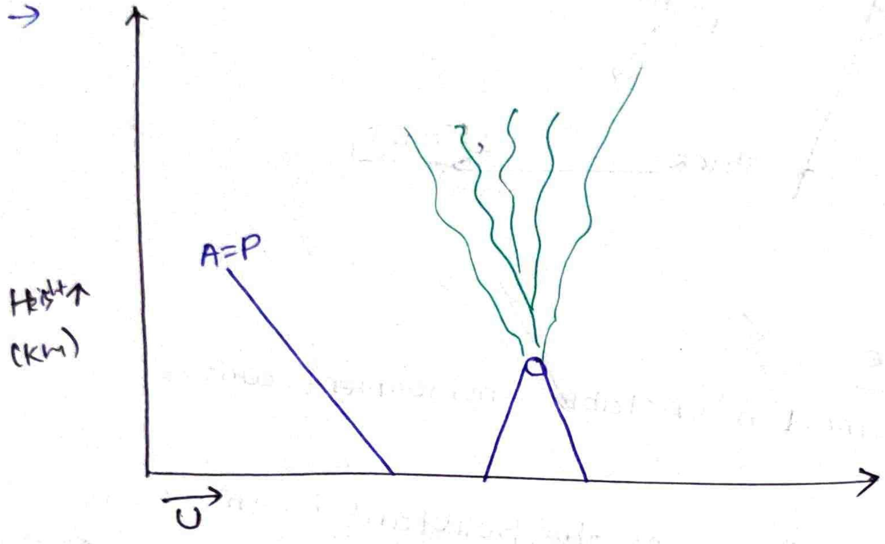
(ii) Neutral Plume

→ It is type of plume which is formed in neutral environment where ELR = ALR

→ It is characterised with the vertical rise of the pollutant from the stack

→ The upward lifting of the plume will continue till it reaches an air of density similar to that of plume itself.

→

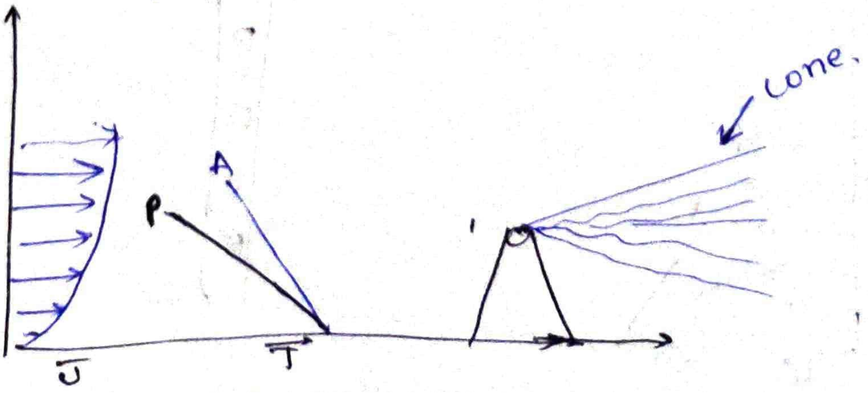


(iii) Coning Plume

→ This plume is observed in stable environment where environment ELR < AlR and wind velocity is greater than 32 km/hr

→ It is observed when cloud cover blocks the solar radiation by day and by night ~~radiation are~~ terrestrial radiation are blocked.

→ It appears like cone in shape hence is termed as coning plume. (ie it has limited vertical mixing. hence increases the chances of pollution.

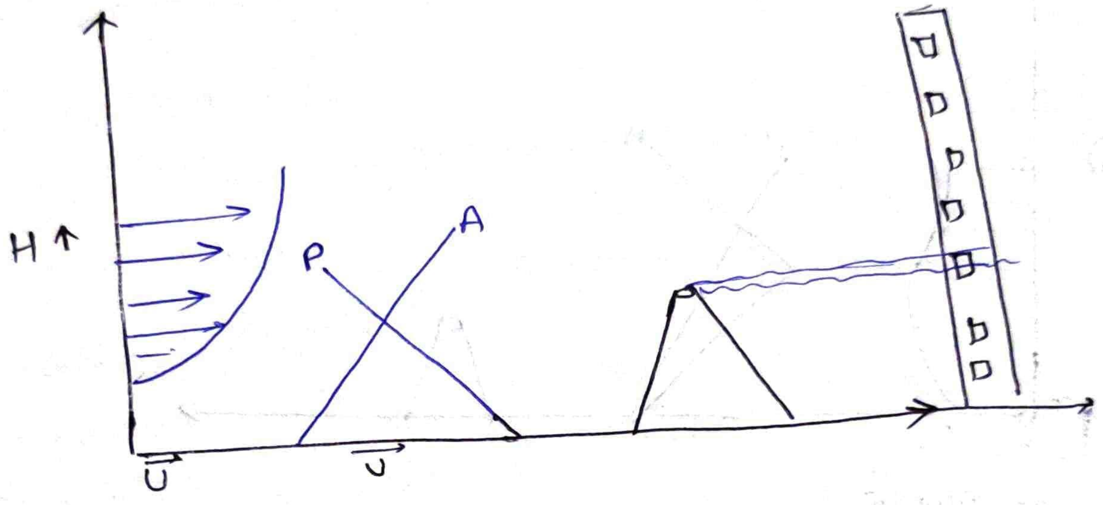


(iv) Fanning Plume

→ This plume is observed in extreme inversion condition in which negative lapse rate is observed

→ This plume is characterised with horizontal spread into the atmosphere. due to limited tendency to rise vertically

→ In order to avoid interferance with life in this case height of the stack is properly designed.

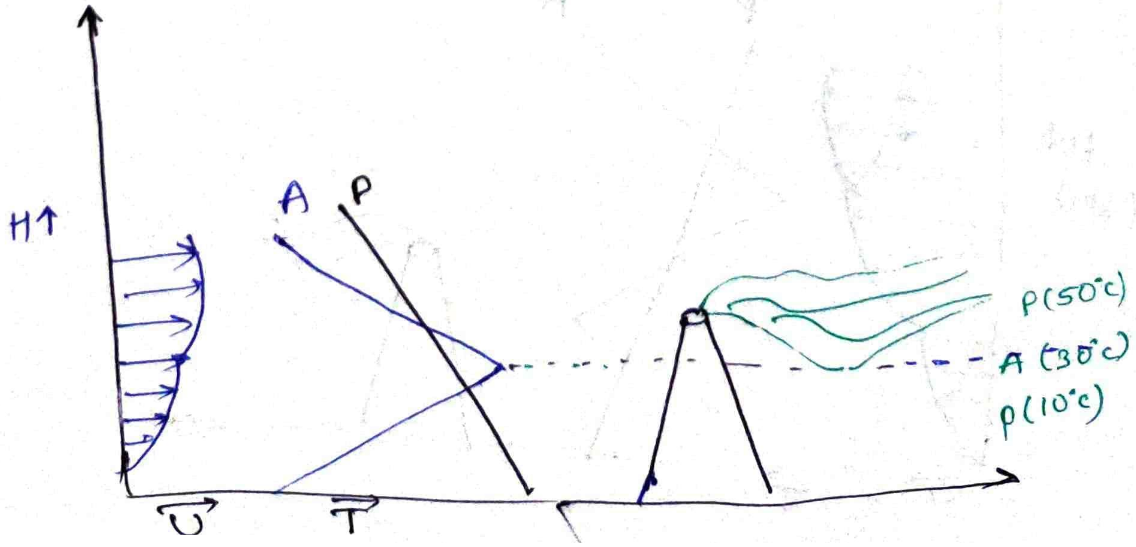


(v) Lofting Plume

→ This plume is found where exist a strong super adiabatic lapserate over a surface inversion.

→ This flume has minimum downward mixing due to the presence of inversion below it.

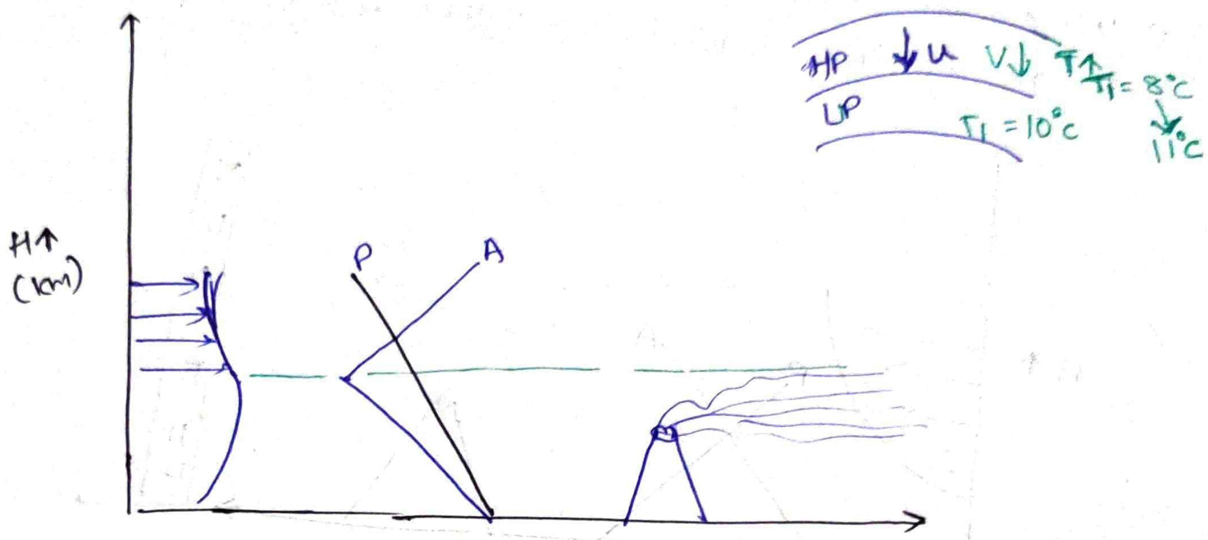
→ This plume is regarded as most ideal plume as it would have very less concentration of pollutants. over the ground



(vi) Fumigating Plume

→ When inversion layer occurs at a short distance above the top of stack & super adiabatic condition prevels below it, leads to the formation of fumigating plume.

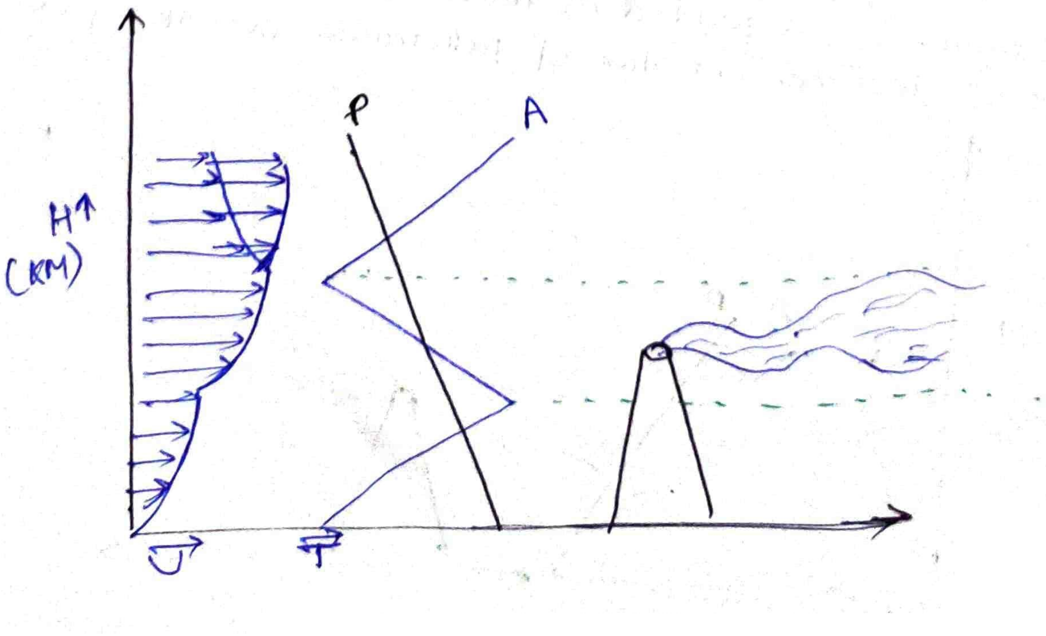
→ In such case the pollutant cannot escape above the top of the stack because of inversion layer over it, hence Continues to interface with the life in biosphere.



(vii) Trapping Plume

→ when inversion layer exist between above & below the super adiabatic environment it leads to formation of trapping plume.

→ It is considered a bad condition for dispersion, as the dispersion cannot go above a certain height.



Air Pollution Control

(i) Natural
(ii) Artificial

Nature self cleansing properties of Environment:-

(i) Dispersion

Dispersion of pollutants by winds reduces the concentration of air pollutants at one place but doesn't remove them as a whole.

(ii) Gravitational Settling

Large heavy particles from the ambient air settle down on building

(iii) Absorption. / washout.

Gaseous as well as particulate pollutants gets collected in rain and settle out with that moisture.

(iv) Rainout

Process involving precipitation above the cloud level.

(v) Adsorption:

Gaseous, liquid or solid pollutants are kept attached electrostatically by a surface.

(i) Gravitational settling chamber.

→ The emitted pollutants, when made to pass through a settling chamber, drop some of their large seize particles in the chamber (under stokes law)

→ The largest size of particle with 100% removal ~~se~~efficieny is given, by,

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

V_h = horizontal velocity of gas.
μ = viscosity of air.
H = Height of chamber.
L = length of chamber.
C = correction factor
ρ_p = density of particle removed.

→ It removes particle of size greater than $50\mu M$.
→ Its $\eta < 50\%$
→ It is simple to design maintain and has low pressure loss.
→ It requires large space and collection efficiency is also very low.
→ Only large sized particles are removed.

(vi) Centrifugal Collectors

(a) Cyclone collector
(b) Dynamic collector.

(a) Cyclone Collector.

→ 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 the bottom.

→ The efficiency of this unit depends upon the velocity, mass of the particle, radius of cyclone as centrifugal force depends on all these parameter.

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

M_p = Mass of particle.
v = Inlet gas velocity
R = Radius of cyclone.

→ It removes particle in range of 5-25 μm

→ Its efficiency is in range of 50-90%.

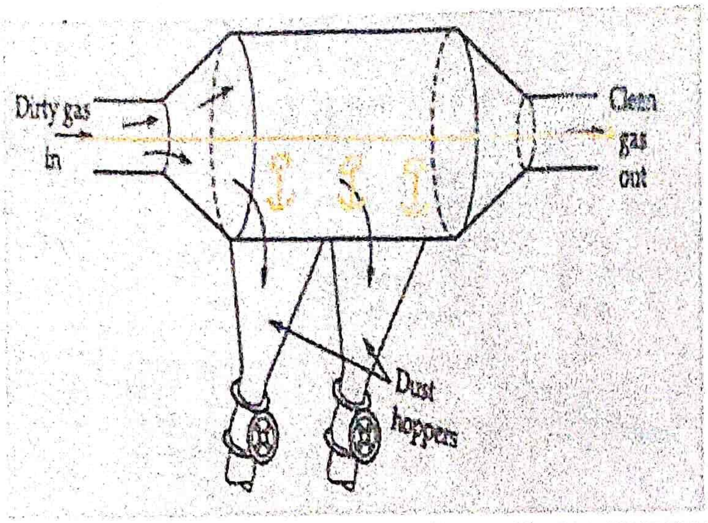
→ It is relatively inexpensive, simple to design require less floor area.

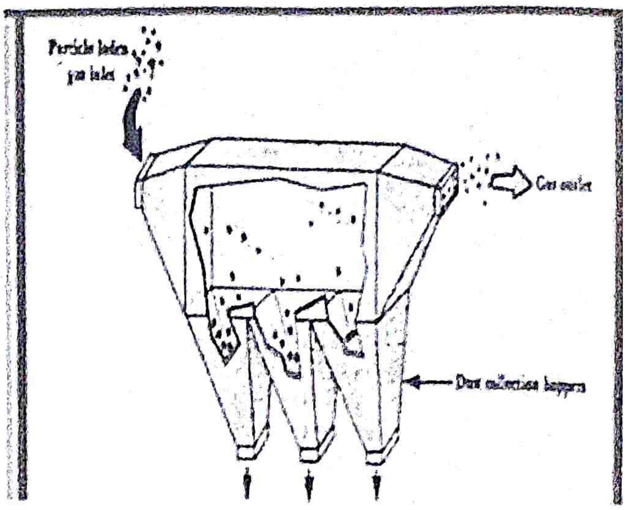
→ It insure dry & continuous of collected dust moreover it can handle large vol. of gases upto tem of 90°c.

→ It requires much head room, collector efficiency is low for smaller particle.

→ It is sensitive to variable dust loading & flow rate.

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 / collectors:

(a) spray tower	(b) wet cyclonic Scrubber.	(c) Venturi Scrubber.
$(d > 10\mu m)$	$(d > 2.5\mu m)$	$(d > 0.5\mu m)$
$\eta < 80\%$.	$\eta < 80\%$.	$\eta < 90\%$.

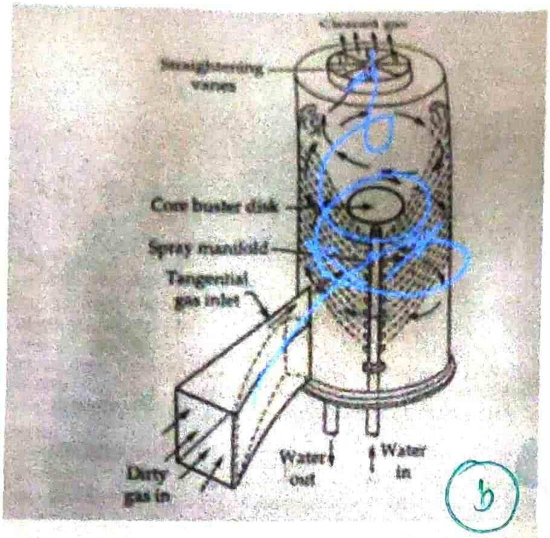
→ In these devices the flow gas is made to push up against a downfalling water, in which the particolate matter mixes up with water droplets, thus falls down and get removed.

→ Water solution, when replaced with other chemical solution like lime, K_2CrO_4, slurry of magnese oxide and MgO etc helps in removing gaseous pollutant along with particulate matter.

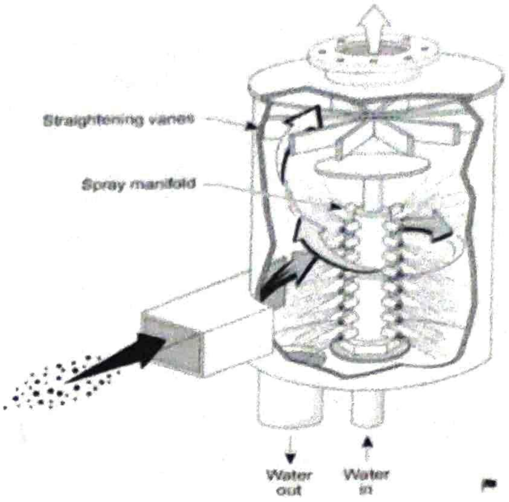
→ In this process corrosive gases can also be removed.

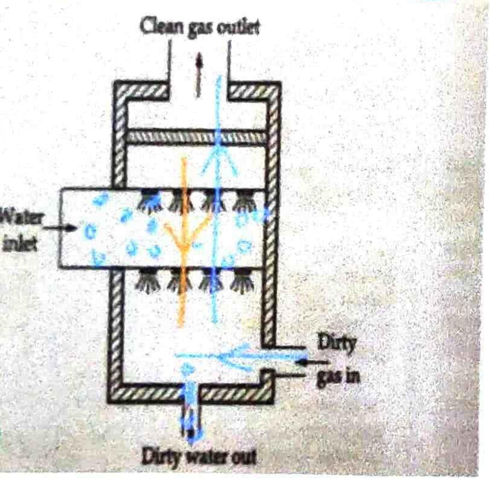
→ A lot of waste water is generated in this which requires disposal.

→ Maintenance cost is high.

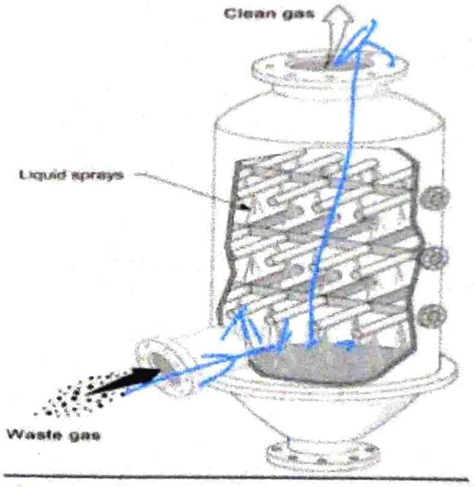


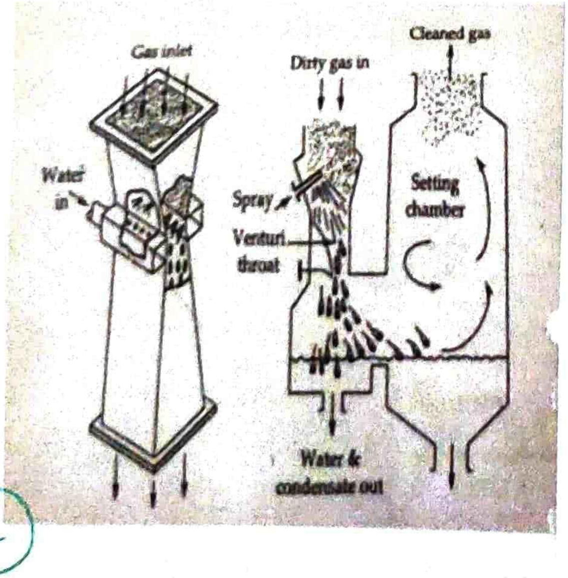
(b)





(a)





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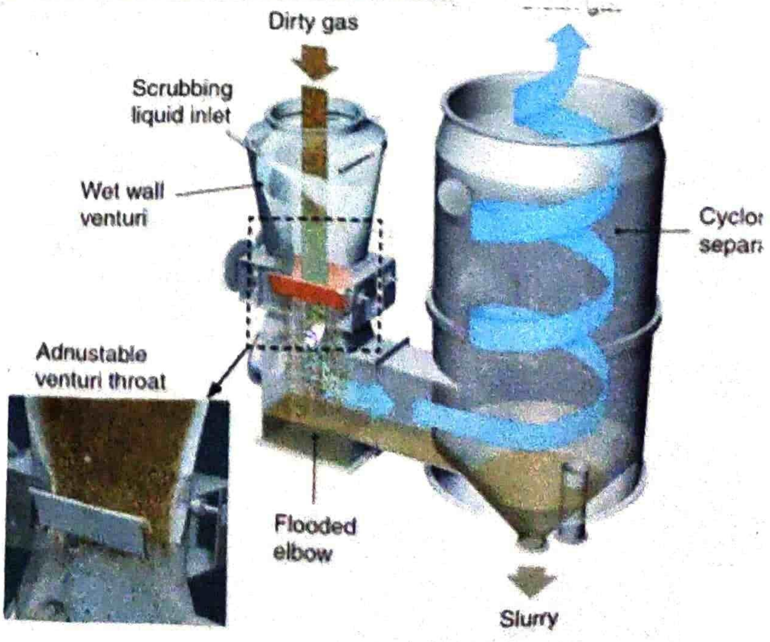


(iv) Electrostatic Precipitator:

→ In these unit flue gas is made to pass through a highly ionized zone where the particle get electrically charged and are separated from the gas, with the help of electrostatic forces in powerfull ectricfield

→ They are widely used in thermal power plant, pulp and paper industry.

→ It removes particles of size greater than $1 \mu m$.

→ It's efficiency in 95-99% and is given as follows.

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

Q_a = flow rate of air
A = collector plate area.
V = velocity of air

→ It can remove particles in wet or dry state

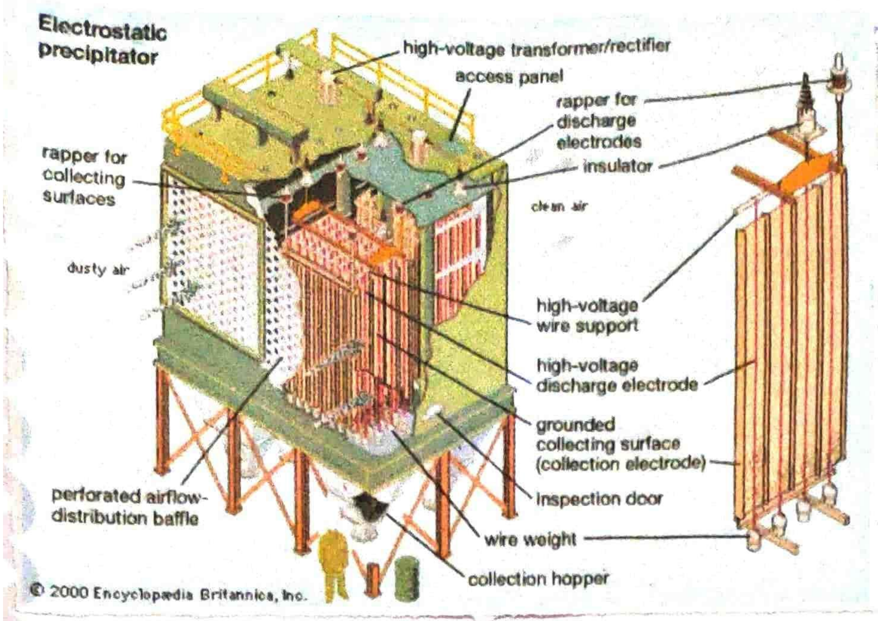
→ It offer very high effeciency.

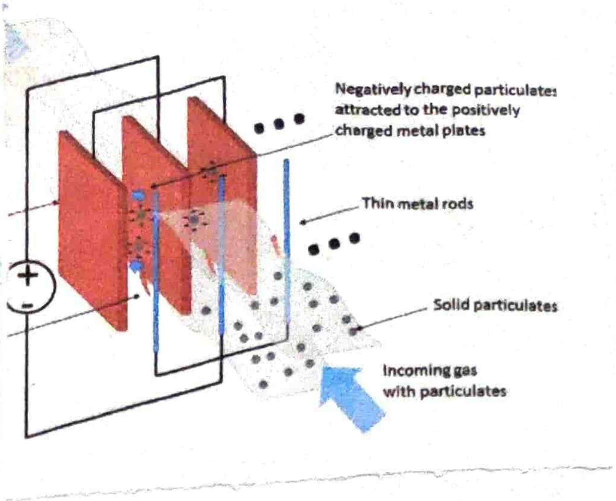
→ Its maintenance is nominal. & even small dust particles can also be removed.

→ It offers high initial cost.

→ It is sensitive to variable dust loading and flow rates.

→ It uses high voltage. hence power requirement is more.





(V) Fabric / Backfilter

- In such unit the flue gases are allowed to pass through a ~~back~~ bag filter which filters out the particulate matter and allows the gas to pass.

→ Small particles are retained on the fabric initially through interception and electrostatic attraction and later on when dust mat is formed it start getting retained over it more efficiently.

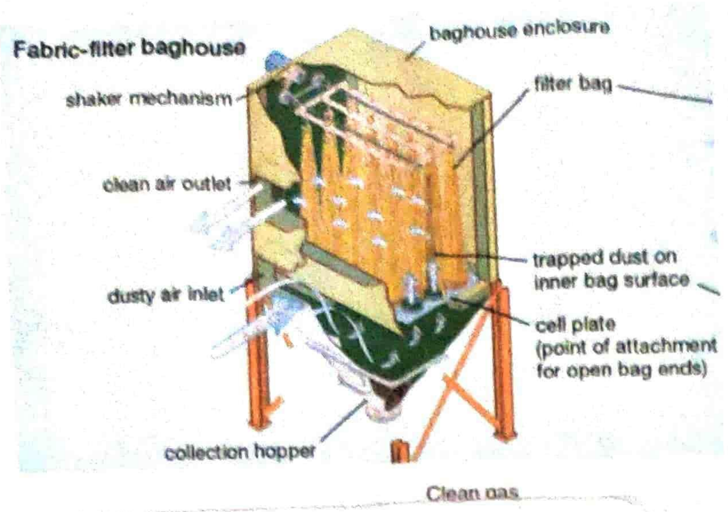
→ It removes the particle of size $< 1\,\mu m$.

→ Its $\eta > 99\%$.

→ It can remove particle in dry state

→ High temperature gases needed to be cooled down upto the range of 100-450°c before processing

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



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

(i) Electrostatic precipitator followed by Cyclonic Separator.
(ii) Settling $\overset{\text{Sem}}{\text{shember}}$ followed by bag filter.
(iii) Bag filter followed by ESP.
(iv) ESP followed by venturi scrubber.

Q It was decided to construct a fabric filter of 0.45 m diameter & 7.5 long for removal of Industrial stack gas containing particulates. The expected rate of inflow into the filter is 10 m³/s. If filtering velocity is 2 m/s compute the minimum no. of bags required for continuous of cleaning operation.

$$N = \frac{SA}{SA_I} \qquad SA = \frac{Q_A}{V_A} = \frac{10}{2} = 5\,m^2.$$

$$SA_I = \pi DH = 3.14 \times 0.45 \times 7.5$$
$$= 10.59\,m^2$$

$$N = \frac{5}{10.59} = 0.47 \sim 1 \text{ filter}$$

Q An electrostatic precipitator ~~of~~ with 5600m². of collector plate area is 96%. efficient in treating 185 m³/sec of flow gas from 200MW thermal power plant. It was found that in order to achieve 97% efficiency the collector plate area should be 6100m². In order to increase the efficiency to 99%. How much area of ESP collector plate is required.

96% — 5600 m²

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

$$96 = 100\left[1 - e^{-\frac{5600 \times V_1}{185}}\right]$$

$$97 = 100\left[1 - e^{-\frac{6100 V_2}{185}}\right]$$

$V_1 = 0.1061 m/s$ | $V_2 = 0.1061 m/s$

$$V_{avg} = \frac{V_1 + V_2}{2} = 0.106 \, m/s.$$

$$99 = 100\left[1 - e^{-\frac{A \times 0.1061}{185}}\right]$$

$A = 8014.64 m^2.$