NPTEL

NPTEL ONLINE CERTIFICATION COURSE

Health, Safety & Environmental Management in Offshore and Petroleum engineering (HSE)

Module 3:
Environmental issues and Management
Lecture 4: Atmospheric pollution

Friends welcome to the fourth lecture in the module three where we are focusing on environmental issues and management that arise from drilling operations in oil and gas industries in this lecture we will focus on atmospheric pollution which arises from the drilling activities that take place or the processing activities that take place offshore and onshore in terms of oil and gas production this is a lecture given in module three in the course of HSE management in offshore and petroleum engineering at NPTEL IIT Madras.

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Air pollution is one of a very serious concern whether it is related to the process industry which comes from offshore onshore or any chemical process industries we are all aware that air pollution is a very important constraint which is bothering environmental is all over the world friends pollutants that arise from offshore drilling have become a major concern of environmental impact because they result in various serious activities like greenhouse effect acid rain smog etc…

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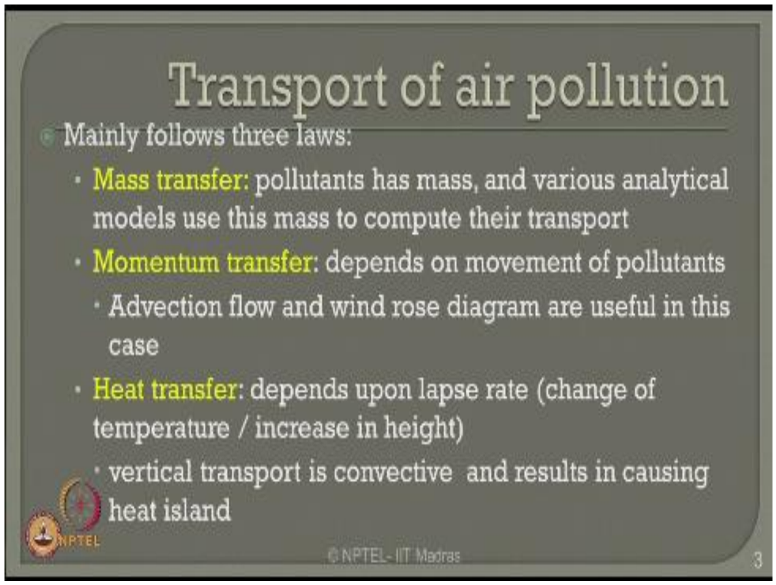

Now a question comes whatever pollution has been caused by the drilling flora activities in offshore how are they actually transported how the society or the neighboring area in the process industry is affected, so let us talk about transport of air pollution, transport of air pollution mainly follows three laws one is the mass transfer law, the second one is the momentum transfer law, the third one is the heat transfer law.

Mass transfer law adopts pollutants having a mass and various analytical models are available in the literature which uses this mass of pollution or pollutants to compute the transport distance in terms of height and horizontal distance the momentum transfer model depends on moment of pollutants it follows advection flow wind rose diagram is very useful in this specific case of calculating the transport of air pollution when you talk about momentum transfer method.

The third method available is a heat transfer method which depends upon the lapse rate the lapse is nothing but the change of temperature with respect to increase in height so it discusses the vertical transport and shows that the vertical transport of air pollution is conducting and results in causing what we call heat island.

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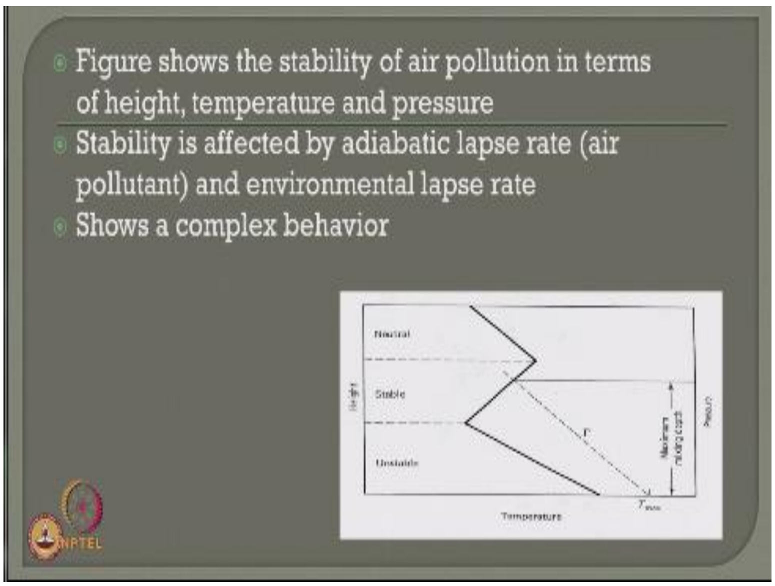

Look at the figure which is shown in this slide now this figure shows a stability of air pollution in terms of its height temperature and pressure now if you look at the x axis where temperature is plotted and look at both the y axis where one height is plotted and the other way pressure is plotted you can see that for a larger temperature for a lesser height in vertical distance the transport of air pollution becomes unstable as the temperature decreases and the height increases it is remaining stable for a specific height what we call the maximum mixing depth.

Now as the temperature further increases and the height increases you will see that they become neutral so from an unstable layer of height it gets into a neutral layer which causes the stable layer, so it is a function of temperature where as a temperature increases most of the area for low height is unstable but for a higher heights for lower temperature it is either stable or becoming neutral same story with that of the pressure as well.

So stability is essentially affected by the adiabatic lapse rate of the air polluted and the environmental lapse rate this shows a complex behavior therefore the stability class of height distribution or the maximum mixing depth value lies in between the unstable and the neutral layer.

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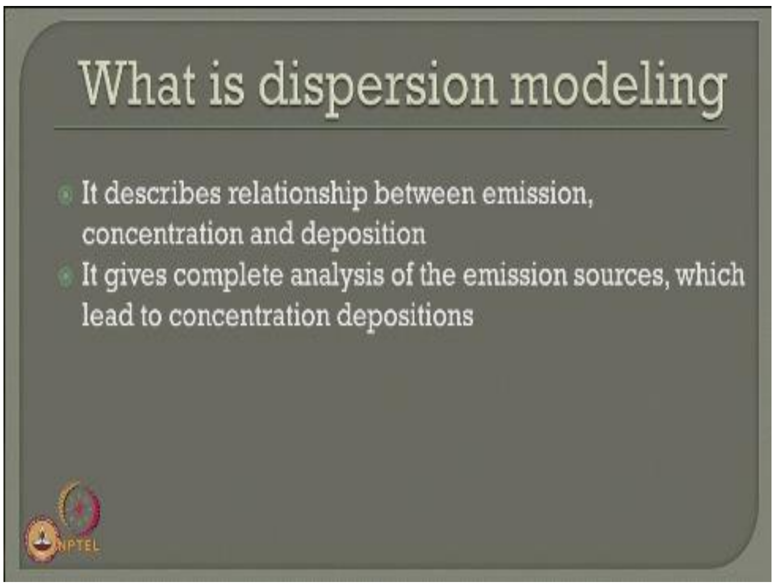

Now the fundamental question comes in mind is what is dispersion modeling dispersion modeling is a technique which describes the relationship between emission concentration and deposition of the pollutants it gives of course a complete analysis of the emission sources which lead to the concentration depositions.

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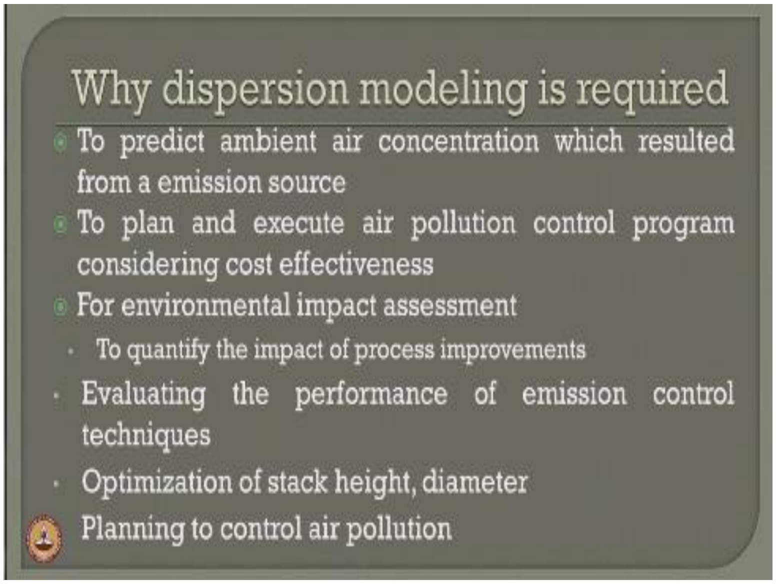

One can ask a question why this disposition modeling is required for studying air pollution models it is required because if you want to predict ambient air concentration which resulted from an emission source then one is interested looking at the dispersion models it is required to plan and execute air pollution control program which includes the cost effectiveness of the proposed programs for calculating or computing environmental impact assessment which is required to quantify the impact of process improvements dispersion models are required to evaluate the performance of emission control techniques it is also required to optimize the stack height the stack diameter of any process industry. It is of course used by enlarge in planning control air pollution.

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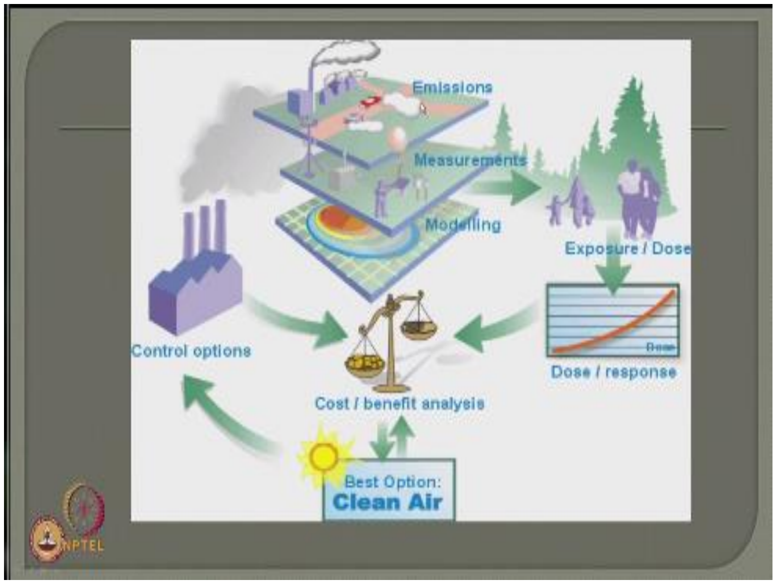

This is the very interesting cycle which discusses how the cost-benefit analysis is looped to the to that of various control options which can be seen from this figure let us say we have emissions related from any process industry there are methods analytical models which are used for either measuring them using experimental techniques or we mathematically modeling them using analytical ambient relationships they all result on how do we compute what is called exposure verse dosage a suspect and we can see from this plot very simple that as the dose keeps on increasing the adverse effect of response on the humankind or mankind is always on the exponential height.

Now one is interested no if you want to control this kind of dose response evaluation or the exposure to be limited to the mankind which arise from that of the emission occurring from the process industry then one should always see what would be the cost benefit or what is the cost investment towards controlling mission and what would be the derive benefit which is arrived from that of control programs so we call this indirectly in offshore industry as an as low as recently practical which is called as a large regions.

Once a cost-benefit analysis shows a positive result then one can go for control options and control options can be implemented and again your cost benefit analysis need to be done for the cost invested towards the control option and one should also see what is the cost investment from the control option and what is the benefit derived from the dose-response assessment so you maintain a balance between these two and then recommend of course better measurement and better control options for emission control.

However it is very interesting for us and we all accept that there is no alternative for the clean air which remains of course as a best option so a lot of natural ventilation is necessary to maintain your emission control program for a successful implementation.

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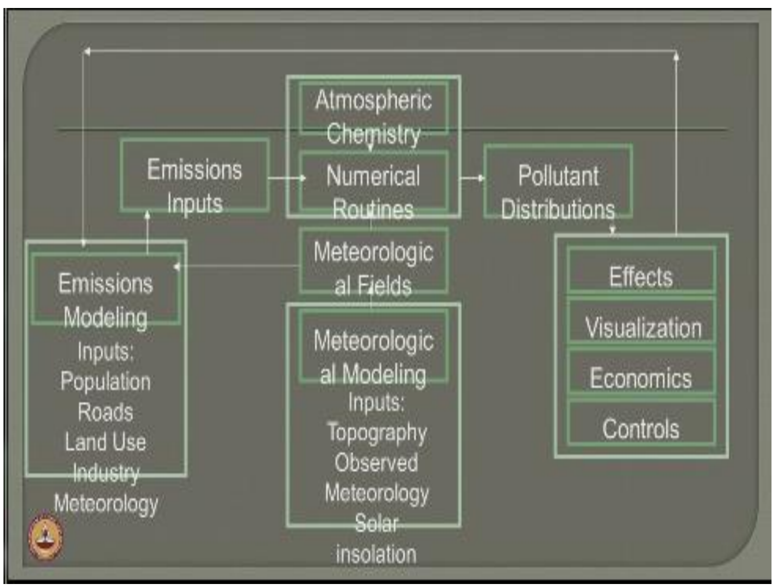

This is very interesting layout of different factors which is involved in emission control program let us talk about the pollutants where we talk about atmospheric chemistry which discusses the stability class of wind the temperature humidity etc... Which are all input for a numerical routines in a given program or a software of course numerical software requires the methodological data which comes from the topography the observed data the solar isolation etc…

Once we have the data effect in the numerical program the numerical program will also give me what would be the possible or the probable distribution of the pollutants in terms of it is vertical and horizontal disbursement distances so this will tell me what will be the consequences what will be the visual effect of these kind of pollution distributions what would be economic aspects are the cost-benefit which comes from this pollution etc…

And what would be the control programs which are effective to control or to minimize the causes which is arising from the pollutant which are disbursing in the environment of course the effects of this are fed back to understand or to modify the emission modeling's which of course has inputs like population in the segment what are the various roads and land-use activity what is the industrial topography and what is the meteorological data which arise from the modification cost by the industrial pollution this specific sector.

You can see that very interestingly these two of course are interlink because you see the industry meteorology can always affected or input by the topography of the ground or the layout of the plant or the city so you have this data interconnector to the emission modeling then you give emission inputs to the numerical model so it is a very interesting closed loop program where the data from the meteorological modeling which includes emission details are becoming input to the model which receives atmospheric chemistry from the meteorological data gives me output of course output is fed back again to cause the effects caused by the emission and there is a closed loop.

So as long as we do not get a very interesting cost-benefit and economics on the control programs of pollution distributions the program is not and cannot be successfully implemented.

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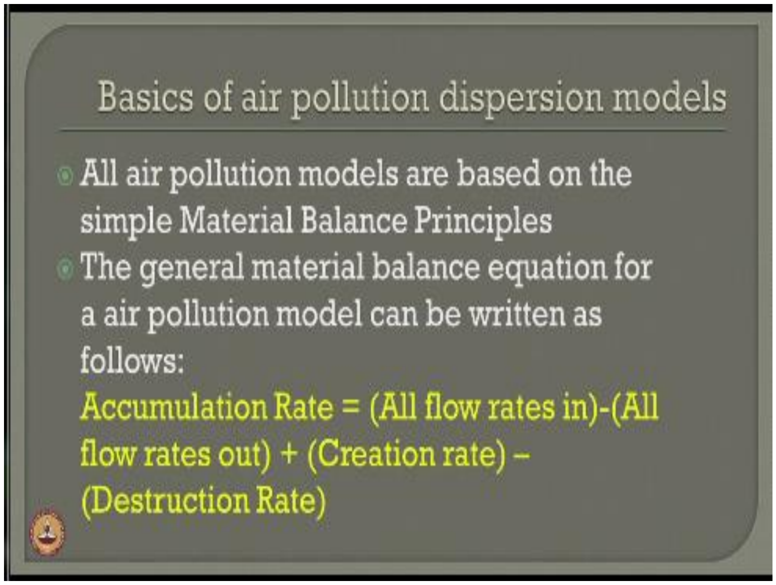

Let us quickly see what are the different basics of air pollution dispersion models all air pollution models are essentially based on simple material balance principles the general material balance equation for an air pollution can be given by the relationship as accumulation rate in the environment is nothing but the sum of all flow rates coming into the environment minus or flow rates getting out of the environment plus the creation rate minus the destruction rate so it is nothing but an algebraic sum of the inflow coming into the environment in terms of the flow rates coming from the pollutants the creation rate and the exit from the environment in terms of the flow rates and the destruction cost by the pollutants in the environment.

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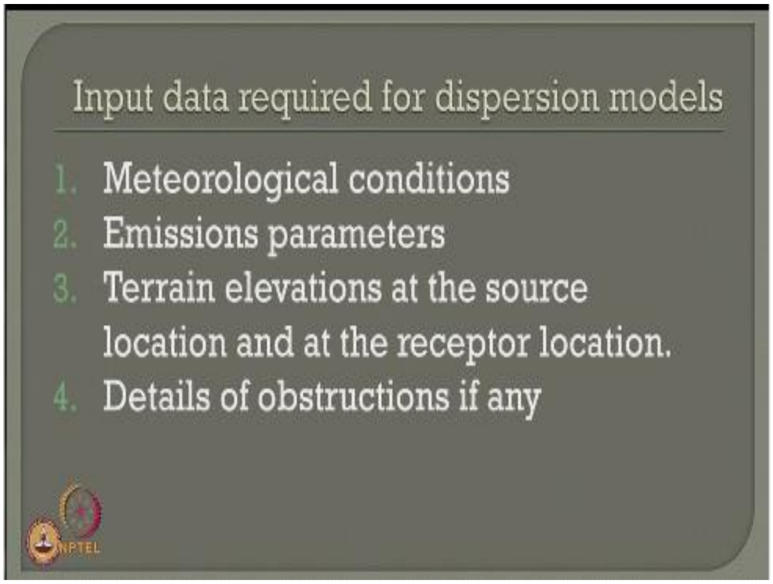

Now one can ask me a question what are all the input data required for computing dispersion models we must of course require the detail meteorological conditions available in specific location one should also have what are the different emission parameters that arise from industrial model one should also look at the terrain elevations because these elevation can cause what is called ground center concentration while working out the dispersion models one should also look at the source location and the receptor location geography and geometry. One should also have details of any obstructions in terms of toiletries taller buildings etc…

If you really wanted to calculate what will be the effect of the consequence arising from the pollution dispersion in the atmosphere.

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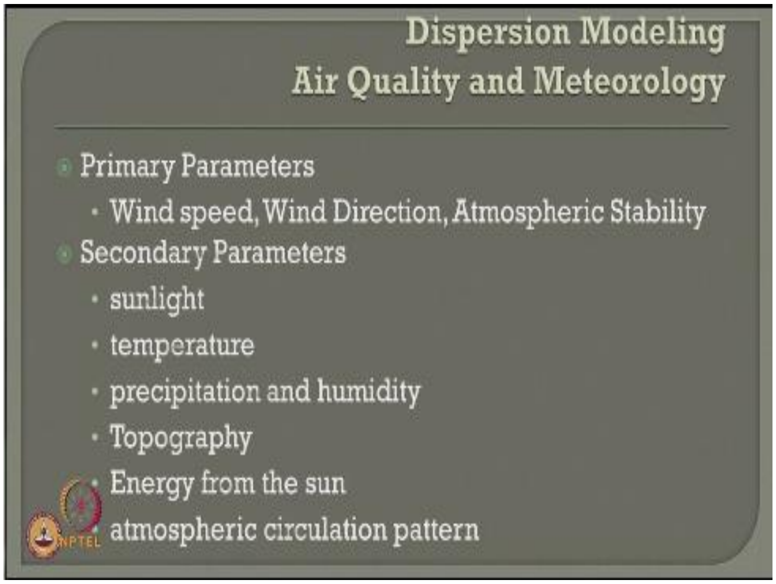

Let us talk about air quality and meteorology details in dispersion models the primary parameters which are required to do air quality management could be the wind speed the wind direction and atmospheric stability class which are locally applied to a specific location there are various secondary parameters which are also important to compute air quality management sunlight temperature precipitation and humidity in the local area the topography of the area energy received from the sunlight in terms of natural ventilation and of course one is interested to know the atmospheric circulation pattern which can be seen from the wind rose diagrams of a specific location.

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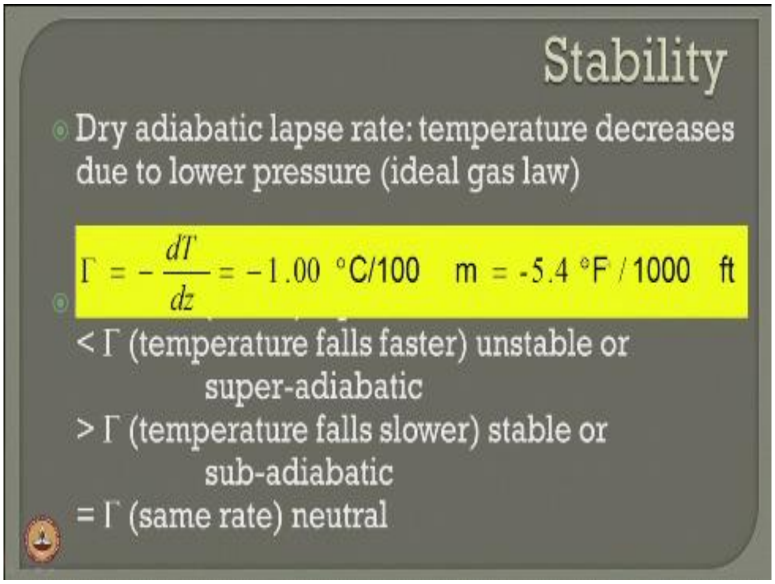

If you talk about stability class of environment the dry adiabatic lapse rate is one of the important factor which governs the stability class it shows that the temperature decreases generally due to lower pressure which follows an ideal gas law however ambient actual lapse rate depends on the factor γ where γ is given by the equation as in the slide now which is nothing but the differentials but to height which is minus 1 degree Celsius for every hundred meters or -π 5.4 degree Fahrenheit for every thousand feet.

So if the temperature falls if the temperature or the lapse rate is lesser than the γ value computed then it is understood that the temperature falls faster which results in what we call unstable class or it is a call super adiabatic condition if that adiabatic lapse rate is more than γ computer from this equation then one can infer that the temperature falls slower are it addresses a stable class which is called sub adiabatic condition on the other hand if the adiabatic lapse rate is exactly equal to the γ computer from this equation. Then one can say that it belongs to a neutral stability class.

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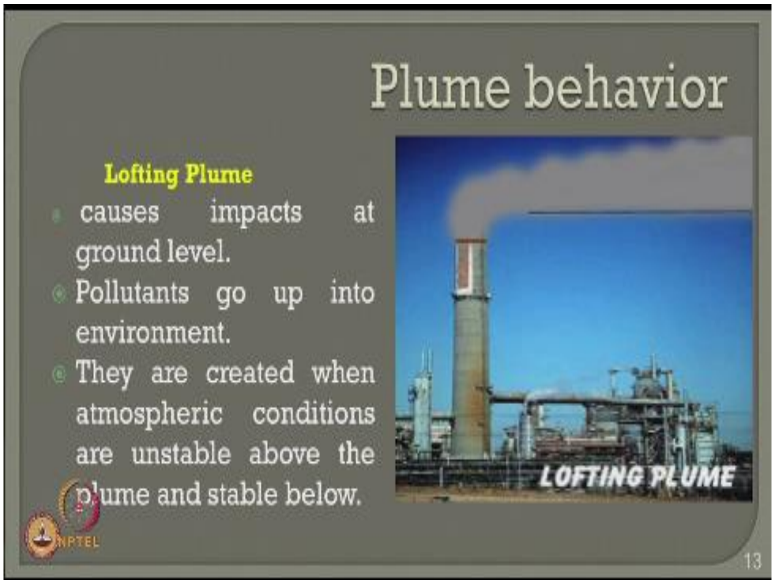

One important factor which arise from that of the emissions caused by the process industry in the environment is what we call plumes there are different kinds of plumes let us see one by one slowly what do we understand the a plume behavior the foremost plume which comes from a stack of a processing industry which is a refinery industry can be what we call the lofting plume lofting plume causes seviour impacts at the ground level pollutants actually go up into the environment they are created when the atmospheric conditions are unstable above the plume and stable below the plume.

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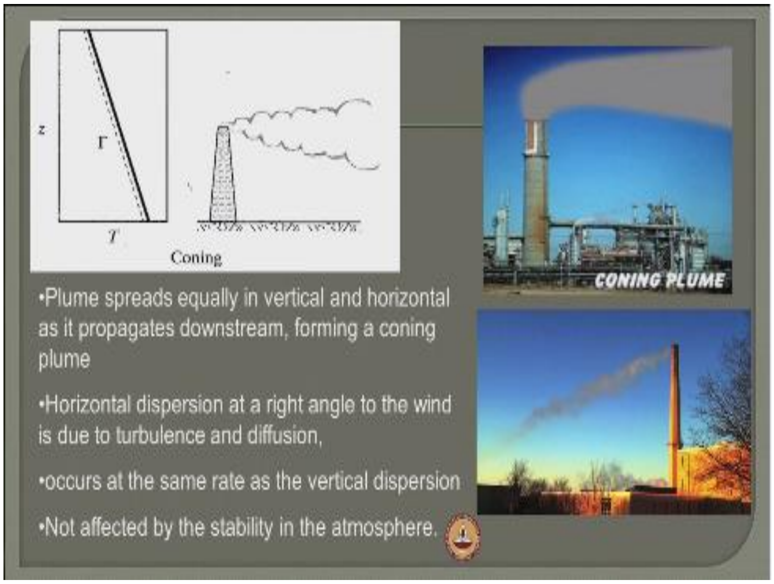

The second effect costs by the plume is called the coning plume the coning effect is very interesting to understand the plume spreads equally both in horizontal and vertical direction as it propagates downstream it forms a cone as you see in the photograph and the numerical model on the screen now the horizontal dispersion is actually happening at right angle to the wind direction which is due to the turbulence and diffusion it occurs at the same rate as that of the vertical dysplasia it is not affected by the stability in the atmosphere at all.

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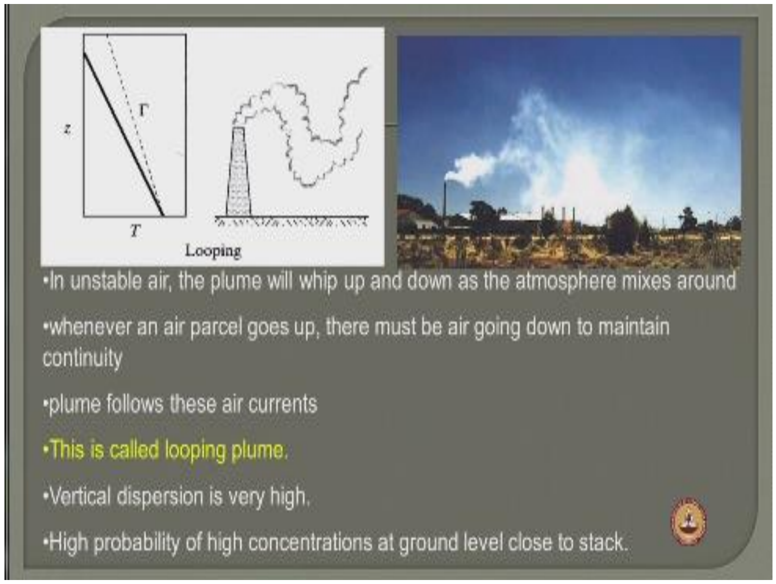

The third affect what we call is a looping plume in an unstable air the plume will whip up and down as the atmosphere mixes around when the air parcel goes up naturally there must be an air coming down to maintain continuity and the plume follows these air currents we can see here the plume which is coming from the stack followers an up and down movement this is what we call as looping plume this call is as a looping plume the vertical dispersion arising from the spoon is very high it has a high probability of more concentration at the ground level close to the stack.

You can see very interestingly here looping plume model which comes out from a stack of a Industry.

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The next type of plume behavior is identified as fanning behavior in the literature Fanning occurs when the wind speed is very high in a specific locality generally fanning occurs during the night time it results in a very high horizontal dispersion of the pollutant in the air the vertical dispersion of course is suppressed by the stable atmosphere so the pollution does not spread towards the ground this results in a very rare pollution concentration at the ground.

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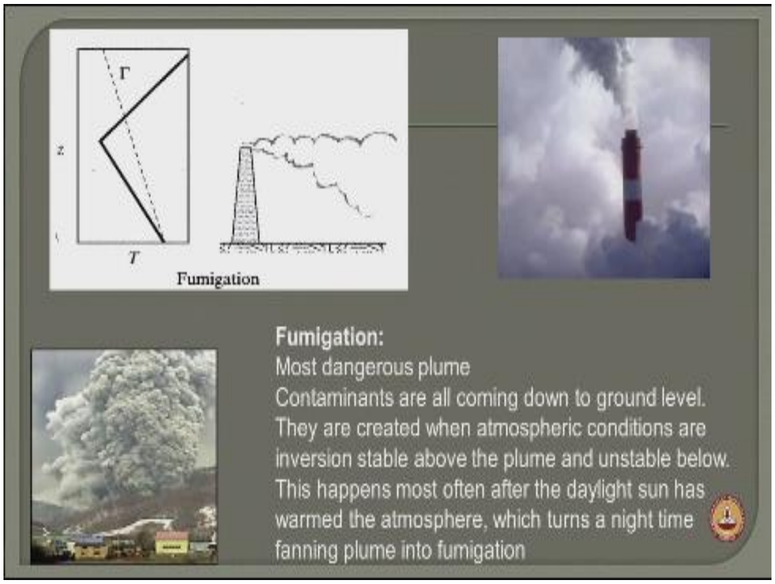

The next effect which comes from the air pollution arising from the stack of a process industry is what we call fumigation it is the most dangerous Plume the contaminants are all coming down to the ground level directly as you see in this photograph they are created when the atmospheric conditions are in motion stable above the plume and unstable below the plume this happens most often after the daylight sun has warmed up the atmosphere which turns a night time Fanning plume into fumigation.

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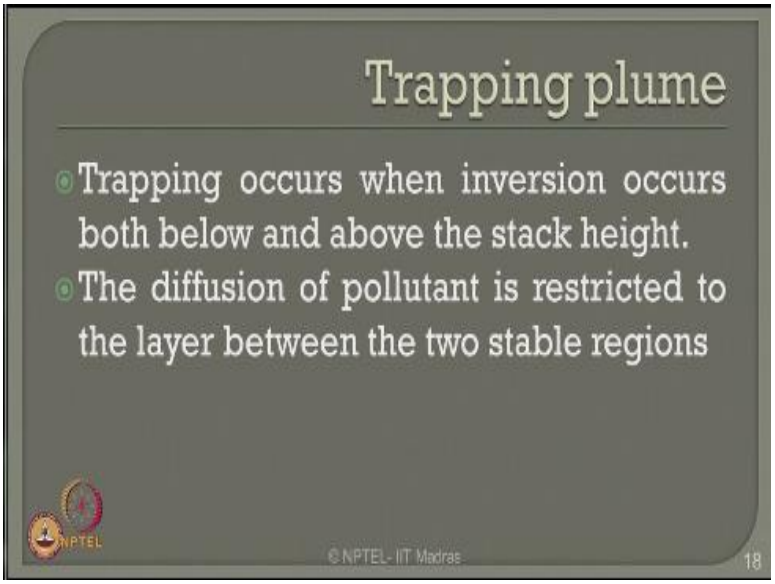

There is something called a tapping plume which is seen in the atmosphere trapping occurs when inversion occurs both below and above the stack height the diffusion of pollutant is restricted to the layer between the two stable regions in a given system.

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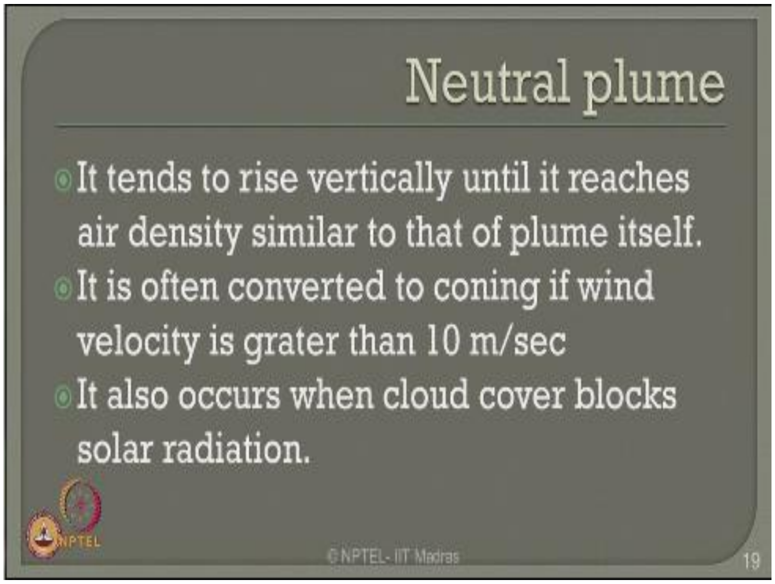

Say something called a neutral plume which tends to rise vertically until it reaches air density similar to that of plume itself it is often converted to a coning plume if the wind velocity is greater than 10 meter per second it also occurs when cloud covers blocks the solar radiation.

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One is interested to know it is air pollution model what is called MMD which stands for maximum mixing depth the dispersion of pollutants in lower atmosphere is generally aided by conducting and turbulent mixture the vertical extent of this mixing depends on the environmental lapse rate which is also affected by topographical features in a given location the depth of convective mixing layer in which vertical movement of pollutants is possible is what we call as maximum mixing depth I will give you the next slide how to compute this particular distance or the depth.

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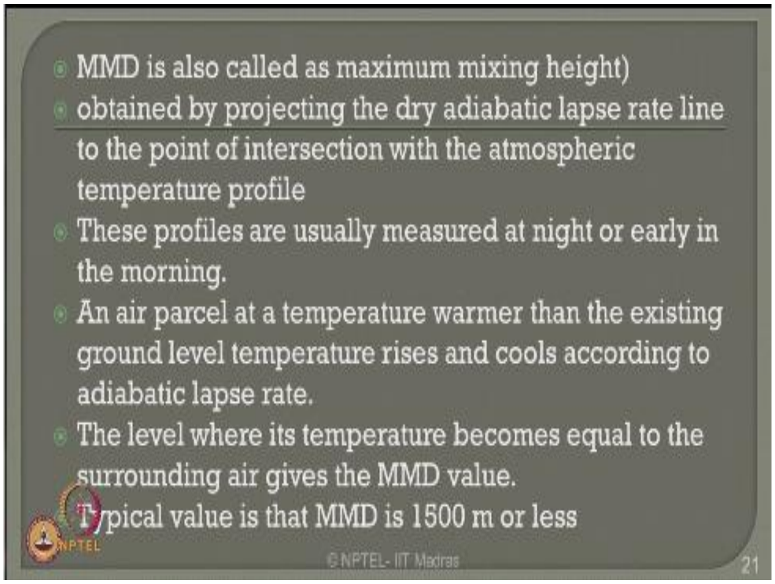

Maximum mixing depth is also called as maximum mixing height it is obtained the projecting the dry adiabatic lapse rate line to that of the point of intersection with atmospheric temperature profile these profiles are usually measured at night or early in the morning and air parcel at a temperature warmer than existing ground level temperature rises and then subsequently cools according to the adiabatic lapse rate the level where it is temperature becomes equal exactly to the surrounding air gives me the maximum mixing depth value.

The typical value of maximum mixing depth in the literature is about thousand five hundred meters or slightly lesser than this.

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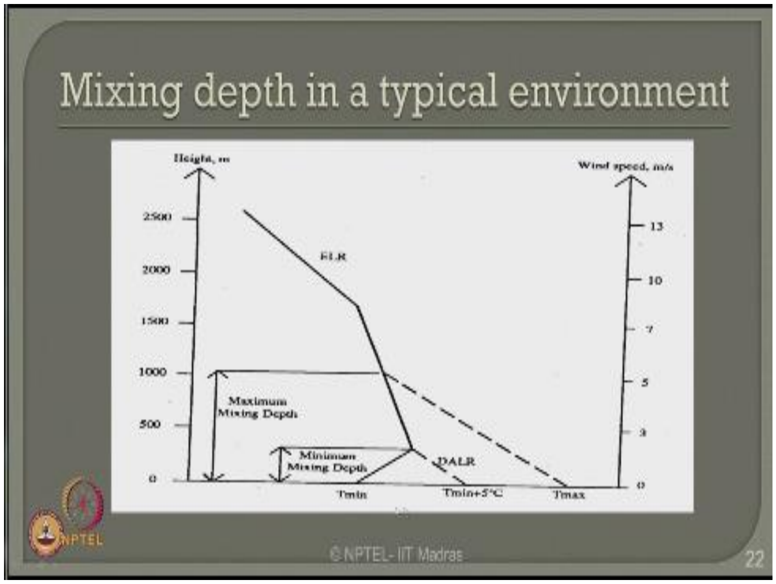

The mixing depth in a typical environment looks like this a mixing depth actually is a function of temperature height and wind speed one is interested to know what would be the influence of temperature on the maximum mixing depth in terms of height and in terms of mixing in the wind speed in meter per second so look at the temperature minimum it can cause a minimum mixing deep closely about that is a 300 to 400 meters where the wind speed is from 2 to 3 meter per second.

Even at a lower temperature as a temperature keeps on increasing to the maximum wind height or a temperature which is five degree centigrade plus the minimum temperature the maximum mixing depth increases to as high as thousand meters where the velocity of wind is at a rate of about five to six meter per second so the mixing depth depends on the temperature and of course the wind velocity and the stability class of the wind speed at a specific location.

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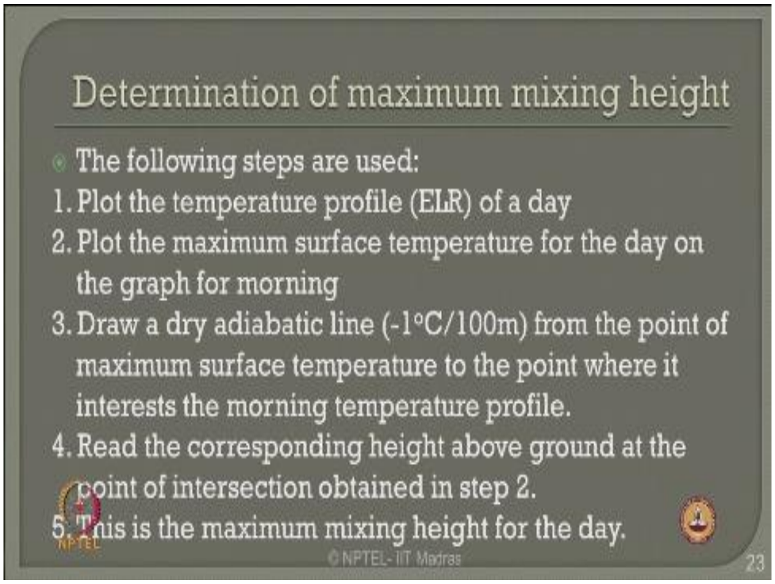

Now the question comes how to determine the maximum mixing height or the maximum mixing depth for a given site there are different steps involved in doing this calculation step number one plot the temperature profile of a day which we call ELR plot the maximum surface temperature for the day on the graph for the morning temperature draw a dry adiabatic line the dry adiabatic line governing is given by minus 1 degree centigrade for every hundred meter you have to draw this line from the point of maximum surface temperature to a point where it intersects the morning temperature profile read the corresponding height above the ground at a part of intersection obtained instep number two and that will give me the maximum mixing height for the specific day.

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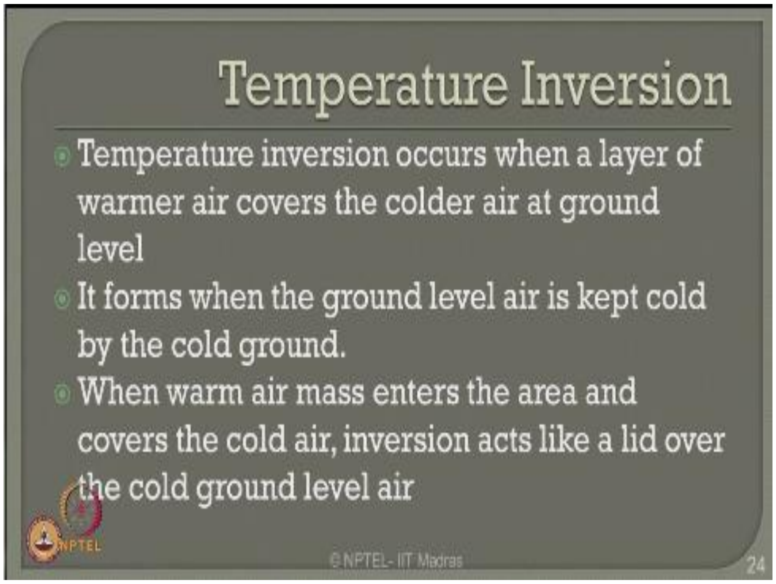

The temperature inversion is another serious problem which is actually a different philosophy in terms of air pollution temperature inversion occurs in the layer of worm air covers the colder air at a ground level it forms when the ground level air is kept colder by the colder ground when worm air mass enters the area and covers the cold air content inversion acts like a lid over a cold ground level air.

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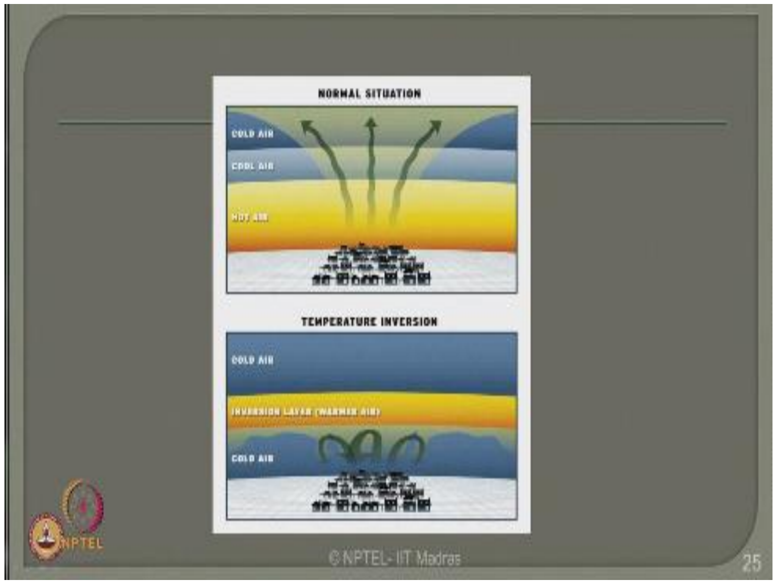

Look at this figure where in a normal situation generally hot air rises and the cooler is trapped between the coldest possible and the hot air and we all know as hot rise it is colder so a normal situation whereas for the temperature inversion occurs you will see that the colder it is re circulated and the inversion layer or the wormer layer trapped between the two cold layer therefore it does not escape through this is trapped and this what we call as temperature inversion.

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The temperature inversion can cause a very different environment to that of the species and an air class which actually covers a cloud layer of different temperature over a colder ground because of the heat retention in the colder area.

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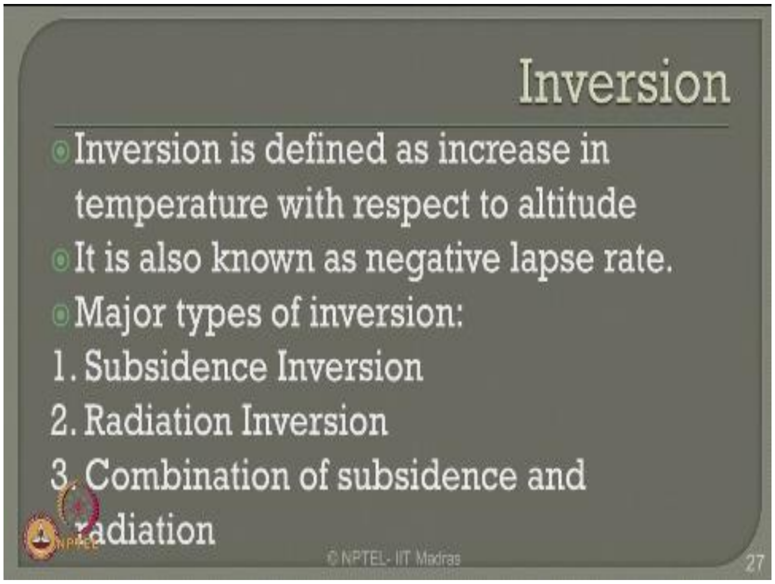

Inversion actually therefore is defined as an increase in temperature with respect to altitude it will also known as negative lapse rate in the literature there are major types of inversion which are seen in the literature as subsidence inversion radiation inversion and a combination of these two let us see one by one quickly and briefly.

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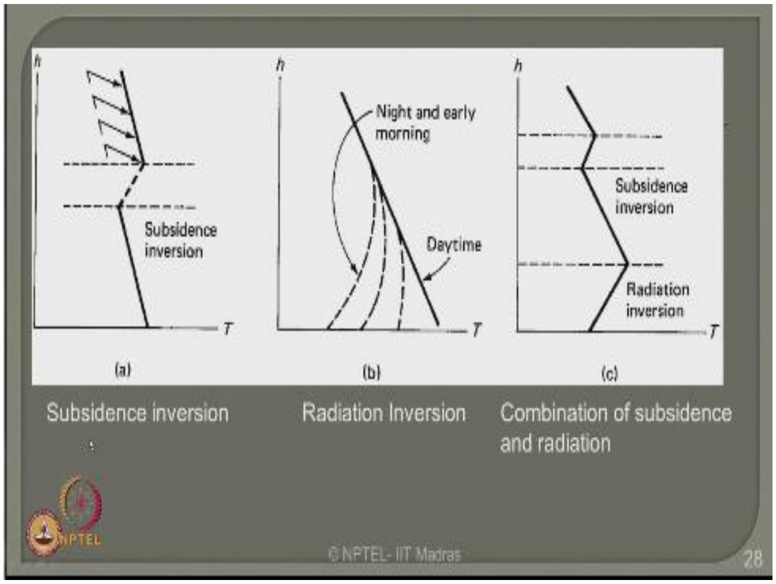

The subsidence inversion is actually occurring at a specific temperature which decreases with increase in height then increases marginally then further decreases with increase in height whereas the radiation inversion is having a constant value where the decrease in temperature causes increase in height but not as linear as it was in the case of subsidence inversion model so the change and drawn at the maximum point of these will give me a curve which we will talk about the temperature during the day time.

Whereas the combination of these two of course will be a complex model where it has got a linear and none any technology is arising from the of what you see in between the layer here as you see in the case of subsidence inversion.

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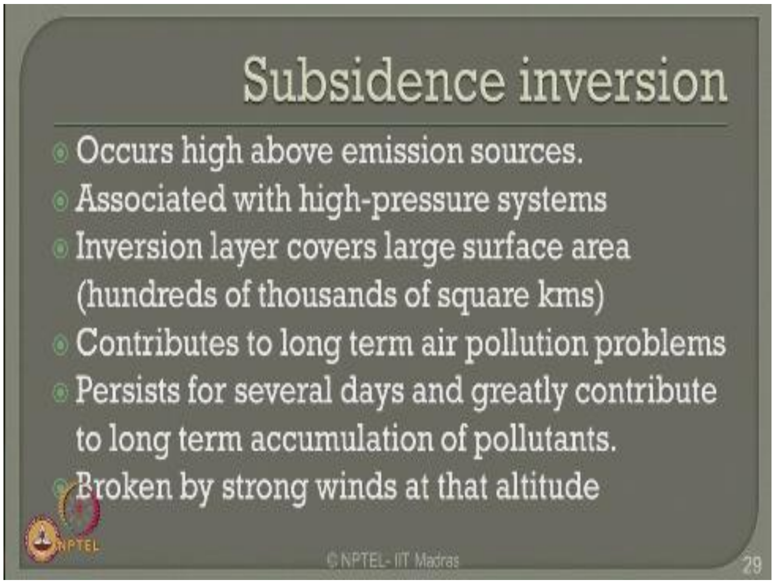

Subsidence inversion generally occurs high above the emission sources it is associated with high pressure systems the inversion layer covers large surface area especially this can be seen in literature as hundreds of thousands of square kilometers it contributes your long term air pollution problems that is a very serious difficulty as well subsidence inversion is concerned it persists for several days and can contribute to long-term accumulation of pollutants in the environment. Of course it is broken by strong winds at a very high altitude.

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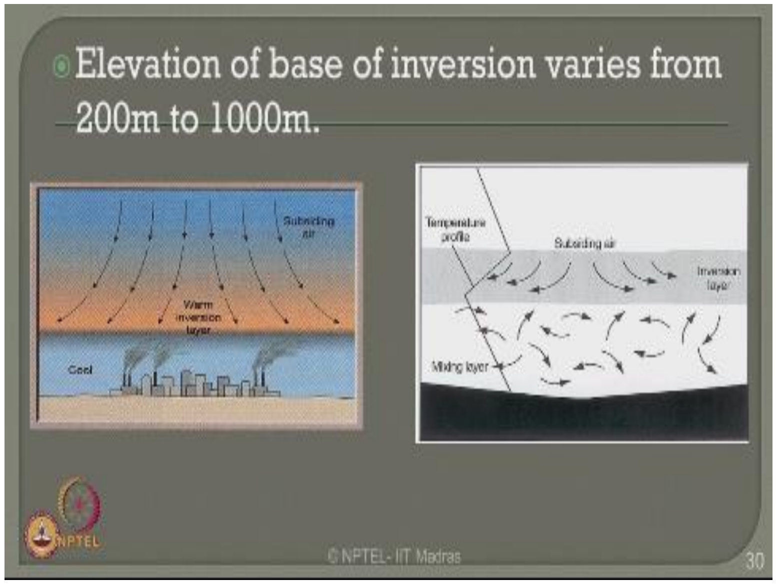

The elevation of the base of inversion takes place which varies from 200 meters to the that of thousand meters, so that is the inversion layer which can vary from a height of altitude about 200 to 1000 meters and it is trapped between the two layer as you see in this case and I will show you how the wind directions allow the pollution transport takes place in inversion layer so they are actually trapped between this the subsidizing air which gets mixed completely in the colder region.

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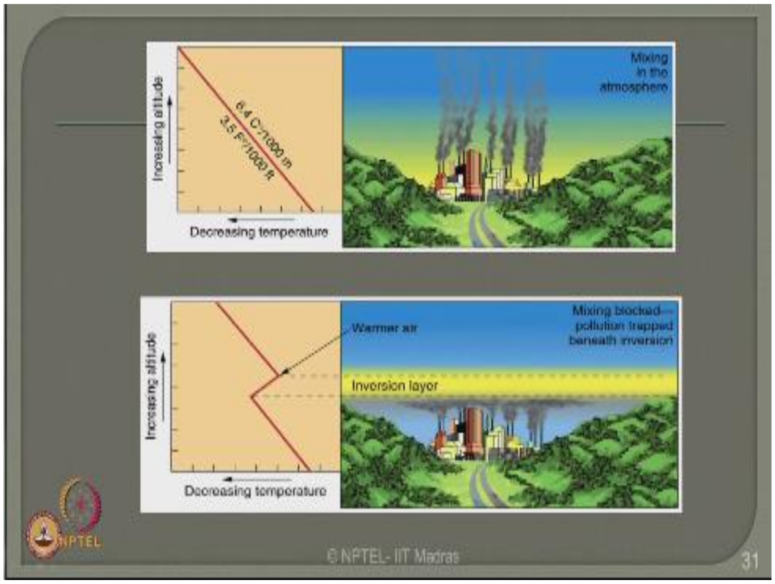

This figure shows that how the decreasing temperature results in increasing altitude as you see from the linear line here which is one of the important effect which is caused by the mixing in the atmosphere if the mixing can be locked during inversion layer you see this is where actually the decrease in temperature with increasing altitude get trapped and that becomes an inversion layer.

So the warmer air is located here whereas this becomes a colder one and there is a circle with cycle happening in this inversion layer which is actually called as a mixing blocked pollution trap beneath the inversion and this is where the pollution cannot be escaped out and it does not depend are result in vertical dispersion.

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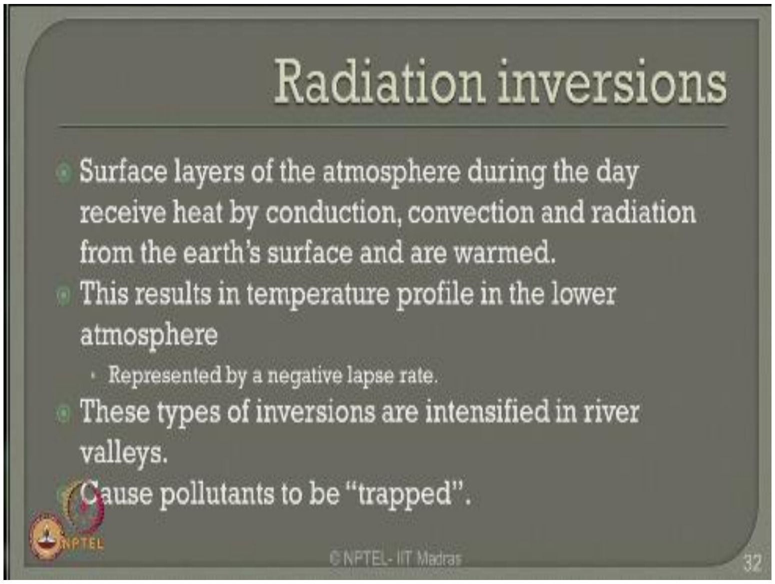

Now the radiation inversions caused by the air pollution when the surface layers are atmosphere during the day receives heat by conduction convection and radiation from the earth surface and are warm radiation innovations occur in the environment this results in temperature profile in the lower atmosphere which is represented by a negative lapse rate these types of inversions are intensified in river valleys in general it causes pollutants to be trapped between the inversion layers as we saw in the last slide.

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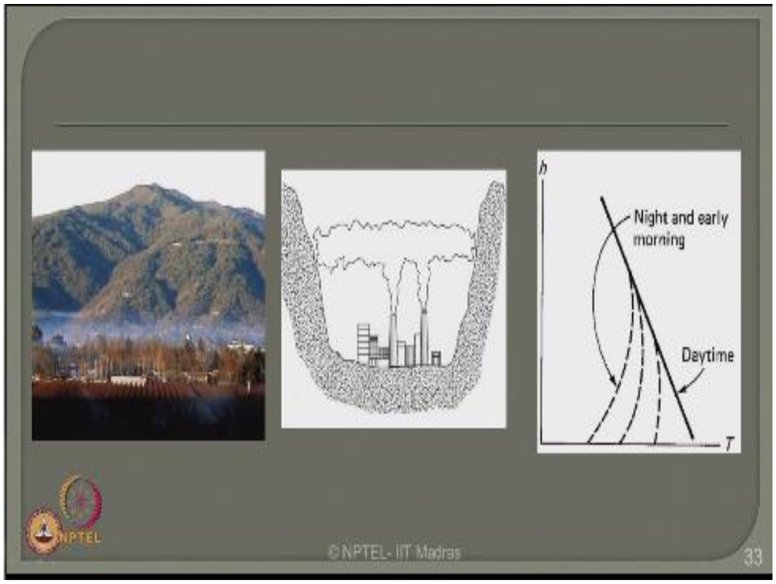

So you can see here the river valleys is very interesting that these pollutions actually trap they do not get escape and they cause serious damage to the environment as well as to the mankind because of the effects caused by this pollution in terms of its contamination this is a very interesting model which already discussed and they say clear photograph shows how this pollution is actually trapped between the segment's in a three-dimensional view in a valley.

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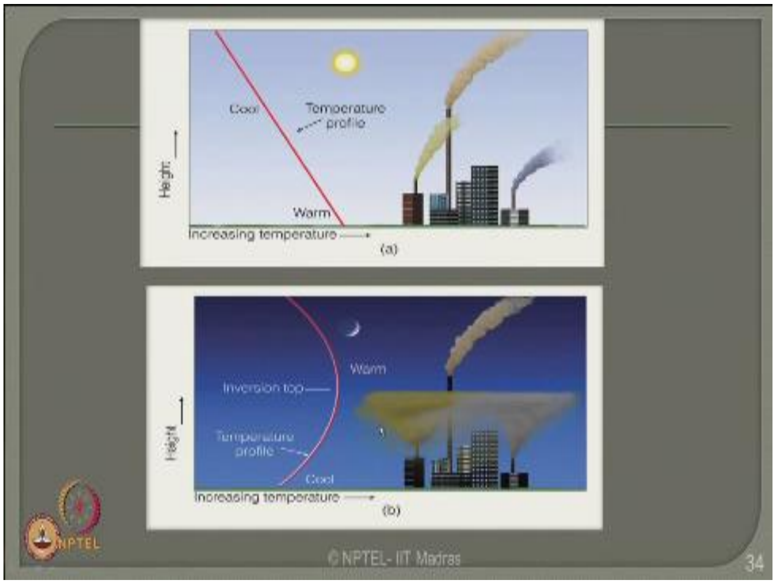

If you look at increase in temperature expect to height you can always see that there is a bondman require or located the closest segment in this as it goes up it becomes cool and the temperature profile shows that there is a decrease in temperature as you keep on increasing the height whereas in case of inversion it happens the other way where the temperature increases as increase the height and then it decreases as it height is increased.

So there is an inversion layer which happens which actually traps the pollution without allowing it further dispersing in the atmosphere and this is the effect which we call as clouding effect which causes lot of serious contaminations to air pollution near the stacks of the process industry.

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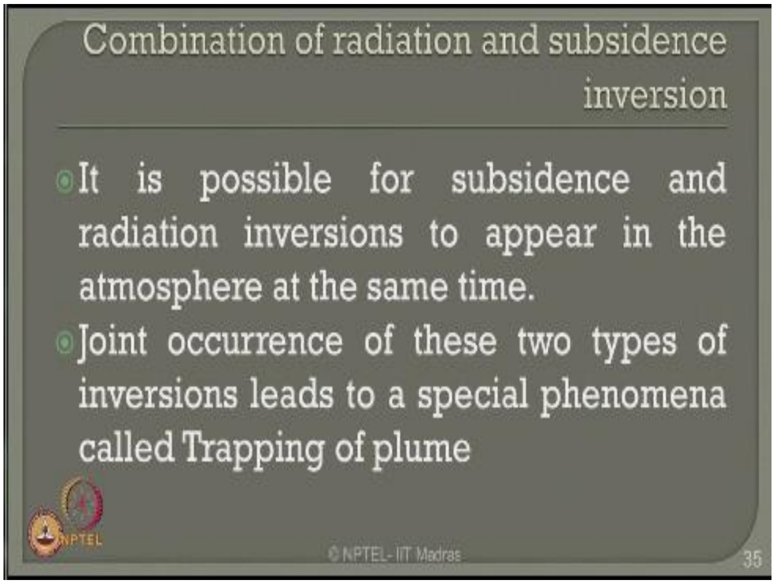

If you look at the combination of radiation subsidence inversions we subsequently happen in many cases it is possible for subsidence in radiation inversions to appear in the atmosphere simultaneously the joint occurrence of these two types of inversion actually leads to special phenomena called trapping of the plume.

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One can also looked at the unified dispersion model which can characterize this kind of dispersion releases in the atmosphere it is used for consequence and risk studies for two-phase pressurized release it calculates dispersion downward direction it calculates what is called touching down point in a given plume it is applicable to toxic and flammable release models in the atmospheric pollution studies after the touch stone point is reached in the ground it assumes a uniform surface roughness.

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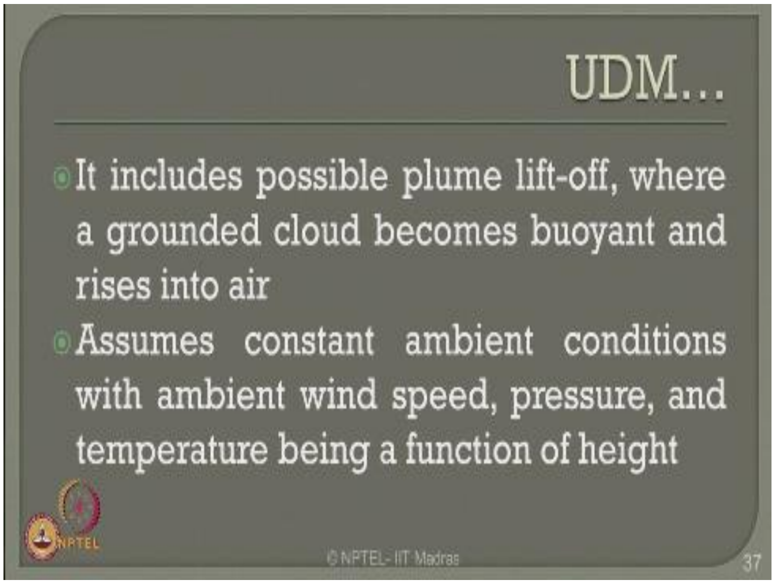

If you looked at the models it includes possible plume liftoff where a grounded cloud becomes buoyant and further rises into the atmosphere it assumes constant ambient condition with ambient wind speed pressure and temperature being a function of the height.

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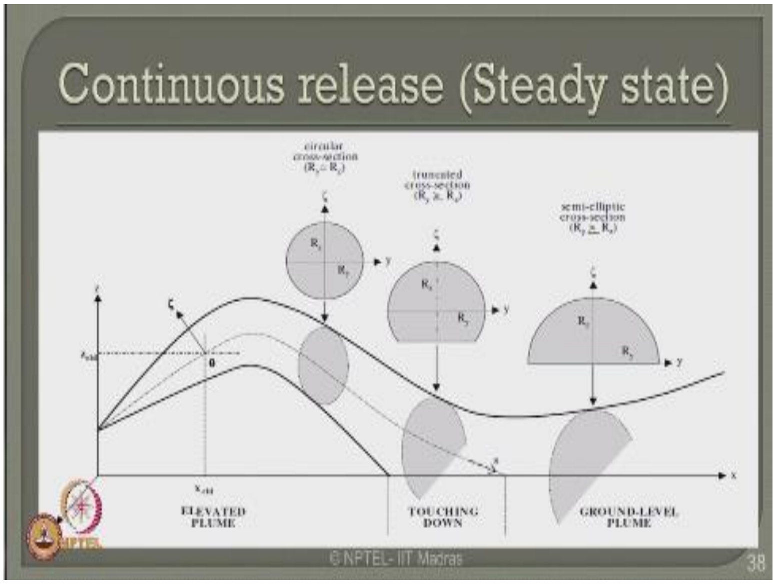

So if you look at the continuous release which is called a steady state release of Plume in the atmosphere so this is what we call as an altitude height of the cloud Z cloud and the angle Zeta from a point of theta from the X cloud is we because an elevator plume so initially the plume is elevated a specific point then the plum settles down and the point by the plume touches the ground is what we call the touching down point.

There is always a probability that the touching down point maybe at one location where X can be computed and depending upon the plume diameter and density you will see that it can be either a circular cross section where R, Y and R, Z , R, Y is measured in this axis and Z is measured in this axis can be equal forming a plume can be also a truncated cross section where R,Y is larger than R,Z R can become a semi elliptical where RY is significantly as an RZ I as seen in this case.

So in such situation this becomes the area the volume of concentration of the plume which affects environment which is actually the horizontal dispersion distance of the occurrence of the plume in terms of its X axis as well as Y and as well as the vertical dispersion in the atmosphere we call this kind of model as continuous release model or steady state model.

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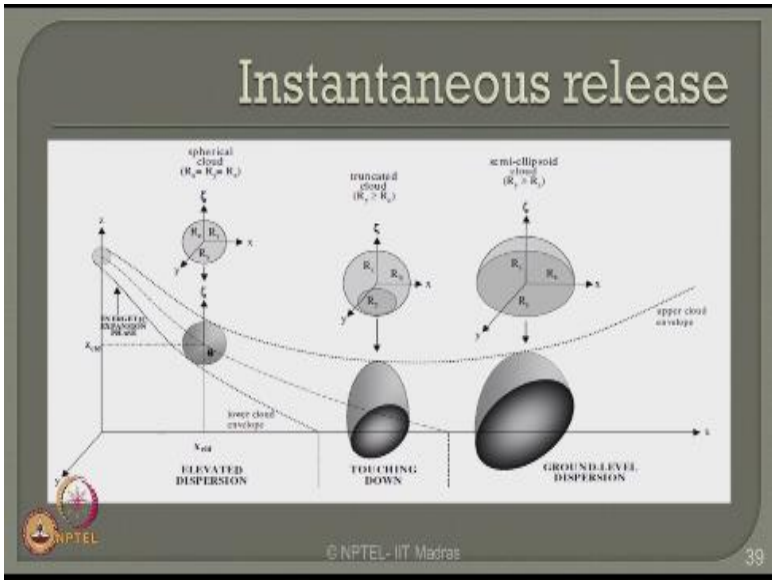

One can also look at instantaneous release of the model let us say have a plume at a specific location Z cloud which is indicated here which is released instantaneously and this can be plume which can travel along the x-axis of course along the Y and of course along the Z-axis but unfortunately as it keeps on traveling X you will see that that the touch stone point is reached and then it picks off and if further travels in horizontal ground level dispersion.

In such cases the distribution of this plume towards the ground level touch point becomes either truncated or semi ellipsoid unlike in case of ellipse or circular in the earlier case of steady state release.

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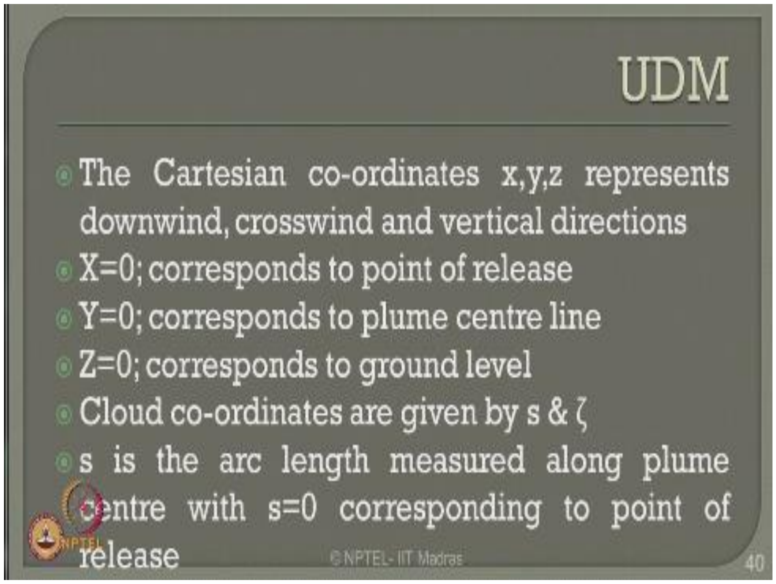

Therefore, the cartesian coordinates of x, y, z of this kind of plume distribution or dispersion along x y and z axis represents the downward the crosswind and the vertical directions respectively x is equal to 0 corresponds release of the plume y equals 0 corresponds to plume centerline and z equal 0 corresponds the ground level in all these figures what I showed you in the last couple of slides.

The cloud coordinate therefore are given by s and zeta where s is the arc length measured along the plume center with s is equal to 0 corresponding to a point of release of this plume from the point of release from the ground.

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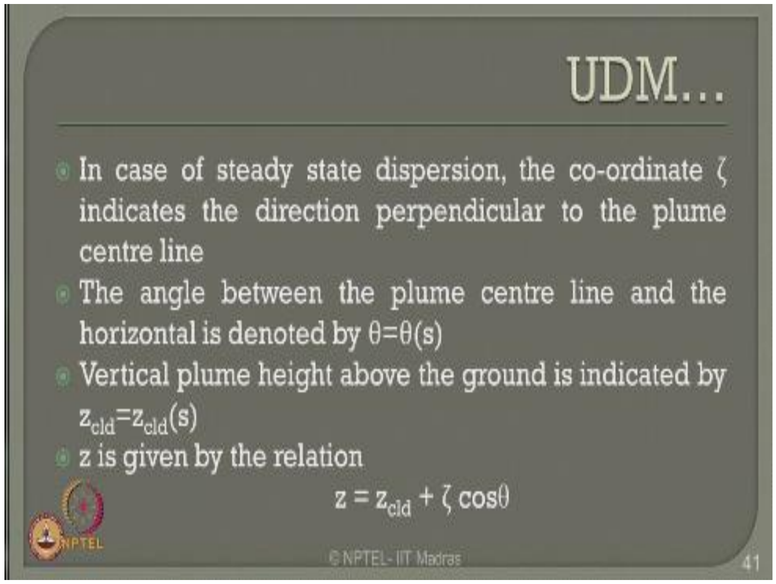

In case of steady state dispersion the coordinate Zeta indicates the direction of perpendicularity to the plume centerline the angle between the plume center line and the Horizonte is denoted by θ also called as θ s in literature the vertical plume height above the ground is indicated by Z cloud which is now given by a simple relationship that Z could + Zeta cosθ will give it a Z by any relation of the plume from the height in the vertical axis.

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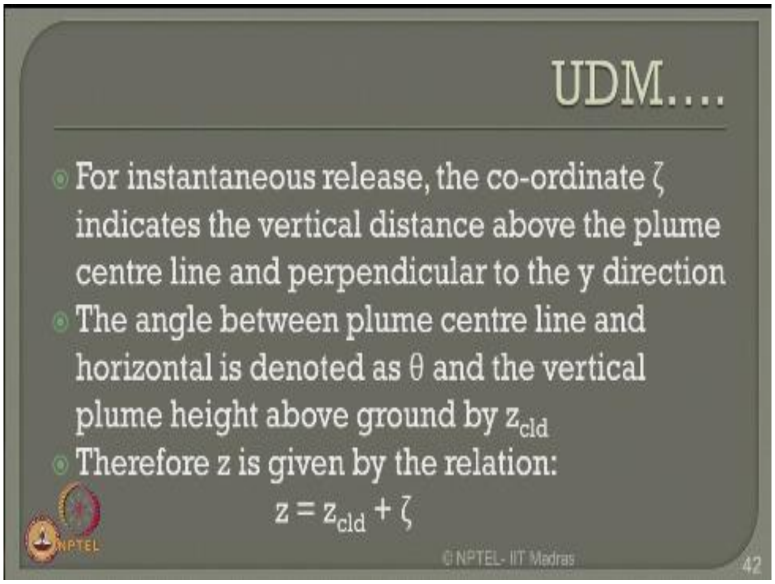

For instantaneous models the coordinate Zeta indicates the vertical distance above the plume center line and it is perpendicular to the Y direction the angle between the plume center line and horizontal is denoted as θ and the vertical plume height above the ground is given by Z cloud and therefore Z in this case is given by a simple relation where Z is given by Z cloud plus zeta.

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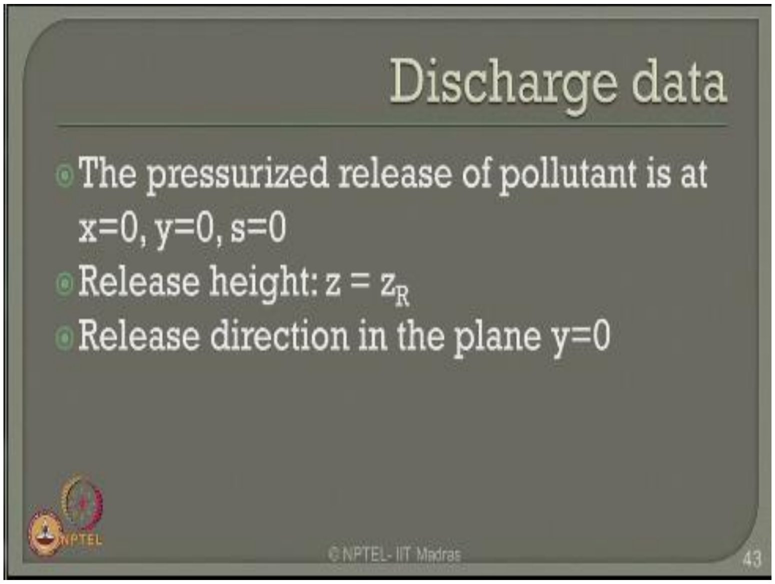

When we talk about the discharge data which is arising from the plume dispersion along x y and z axis respectively the pressure is release of pollutant in the atmosphere is specifically occurring at a specific location at x, y, s all the three set to zero the release height z is given by an equation which is equal to z_R where the release direction in the plane is given by a value where y is set to 0.

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We will talk about the release models more in detail which can give me the z_R value for various factors affecting the plume dispersion in the x y and z directions respectively so in this lecture friends we discussed about the atmospheric pollution caused by the dispersion occurring from the plume formation which occurs from a vertical stack of any process industry we have seen different models we have seen different kinds of plumes which occur we have also out how the touch turning point can be calculated and how the vertical cloud distance can be computed and you have very seriously understood what is called the inversion which suppresses the dispersion of this plume or the concentration air pollution in around the stack where the pollution or the pollutant is released into the atmosphere thank you very much.

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