NPTEL

NPTEL ONLINE CERTIFICATION COURSE

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

Module 3:
Environmental issues and Management
Lecture 5: Atmospheric pollution Contd.

Friends in this fifth lecture we will continue with the atmospheric pollution models, what we have been discussing in the last lecture. It is lecture 5 and module 3 where we are focusing on environmental issues and management under the HSE course at IIT Madras.

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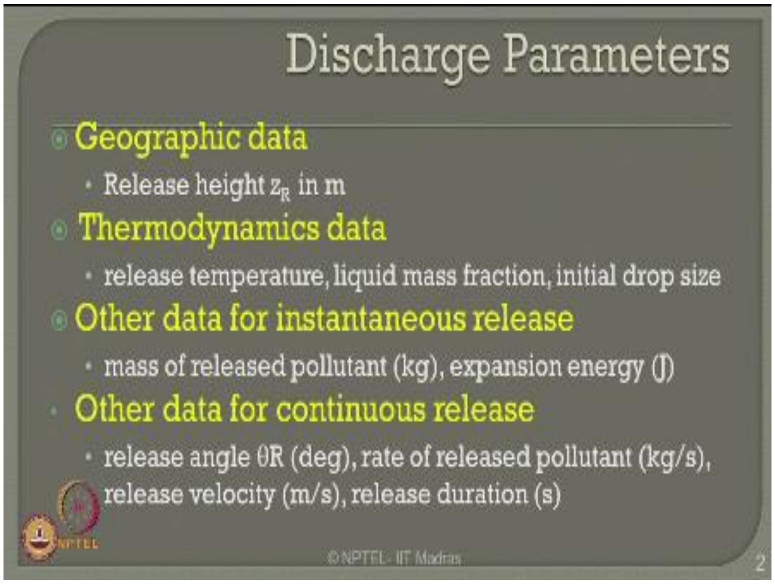

Before we understand the tough and plume release models which can cause atmospheric pollution because of the discharge it occurs from the pollutants which can be disposed in air. Let us quickly see what are those discharge parameters which are responsible to compute these models. One should require a geographic data we have to estimate what you call release height indicators Z_R which is generally given in meters.

The next data are setup data what you must require is the thermodynamics data which we talk about what is the release temperature, the liquid mass fraction which is getting released or discharge and what is the initial drop size in terms of thermodynamics. The other data for instantaneous release and also required like what will be the mass of the released pollutant in terms of kg, the expansion energy in terms of joules for instantaneous release. Other data required for continuous release could be the release angle, the rate of released pollutant and the release velocity and its duration.

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As we saw in the last lecture release actually is modeled essentially as a circular cross section where R_x and R_y are kept to be equal, this becomes flatten into an ellipse as the cloud of explosion or the plume or puff settles in the ground at what we call it a touching down point. At the touching down point the momentum is however conserve and therefore the cross-section becomes a truncated ellipse. It remains as truncated ellipse until the bottom edge rises further above the ground as we saw in the model.

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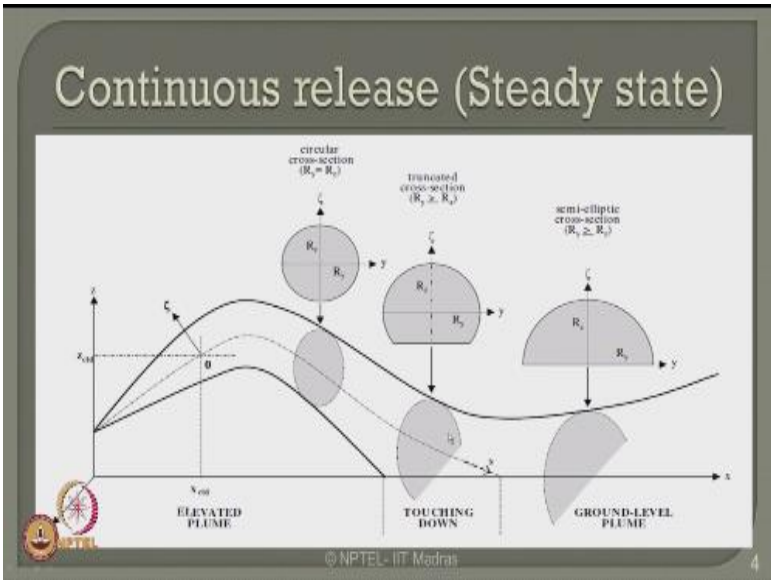

Now you can see here in terms of continuous release model which is a plume model which is set as a steady state model can see from the release point the center line of the plume model, so it is initially assumed as a circular cross section where R_z +R_y are taken to be equal where R_z is along the z axis vertical and R_y is along the axis normal to the propagation of the plume model. It initially becomes circular when it touches the ground what we call the touching down section or a zone it is truncated because the momentum is conserved therefore R_y expands compare that of R_z and we call this as a truncated cross section.

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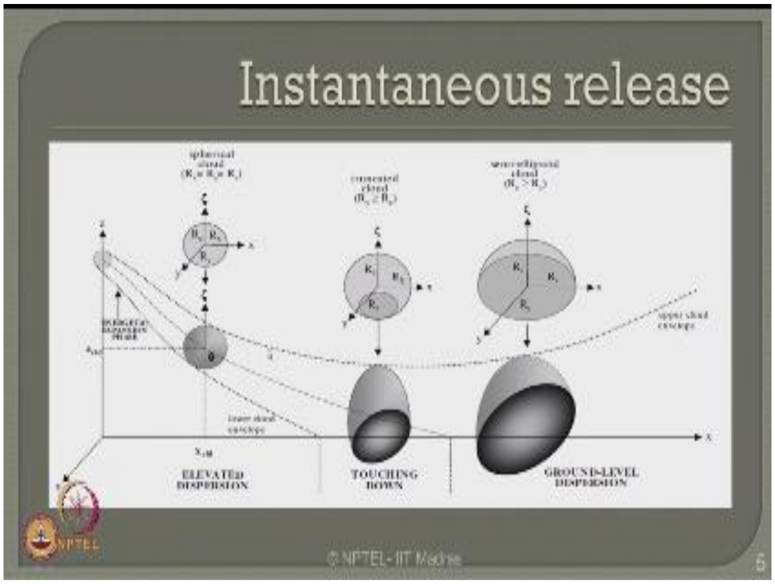

This is too however friends in the case of an instantaneous release model what we call is a tough model. So when a tough release happens at a specific height the centerline of the tough is what you see here initially again is considered to be a spherical cloud where are R_y R_x and R_z are consider to be equal, in that case as it as the puff model touches the ground at the touching down point the momentum is conserved and how height becomes a truncated cloud which becomes a semi ellipsoid until it raises further to form an upper cloud envelope.

Friends please understand this is the area the darker one, the darker one which actually becomes a cloud coverage for the tough model cost on the ground and this becomes actually the dispersion in the atmospheric pollution for a puff release model.

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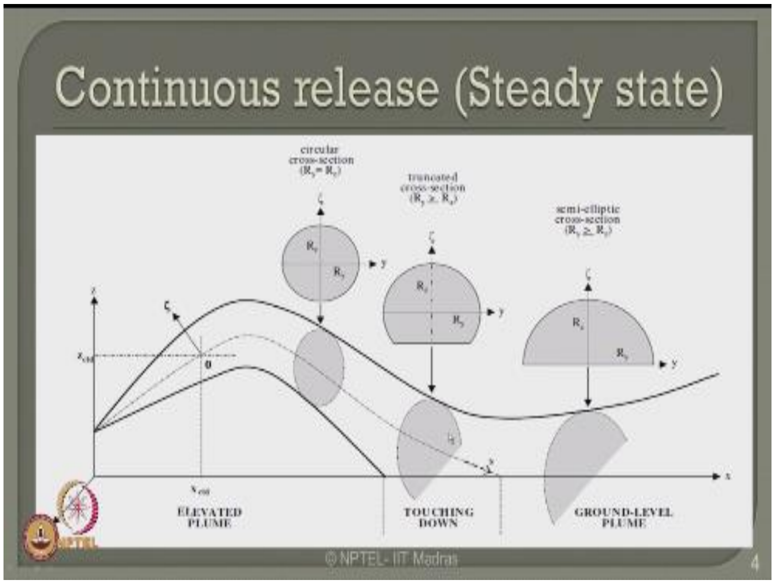

Similarly for a plume release model this is the area which becomes a plume cloud which forms above the ground at the touching down point as you see here until the plume touches and further releases off from the ground.

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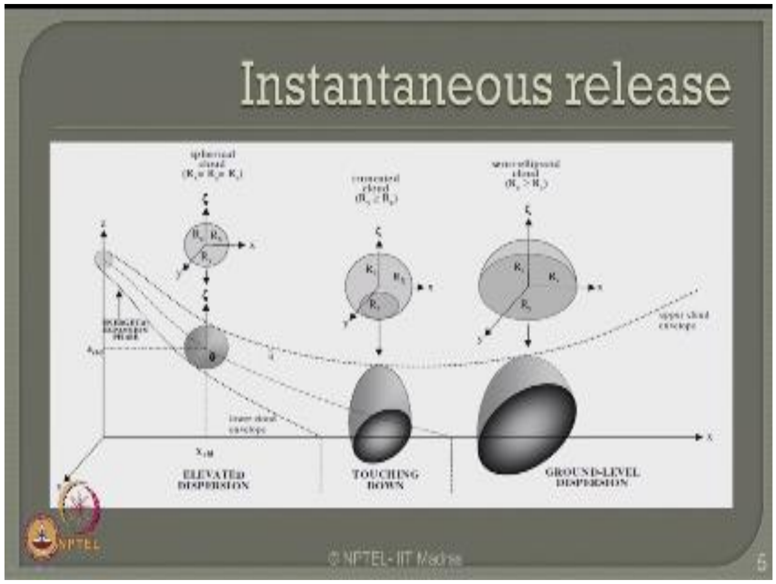

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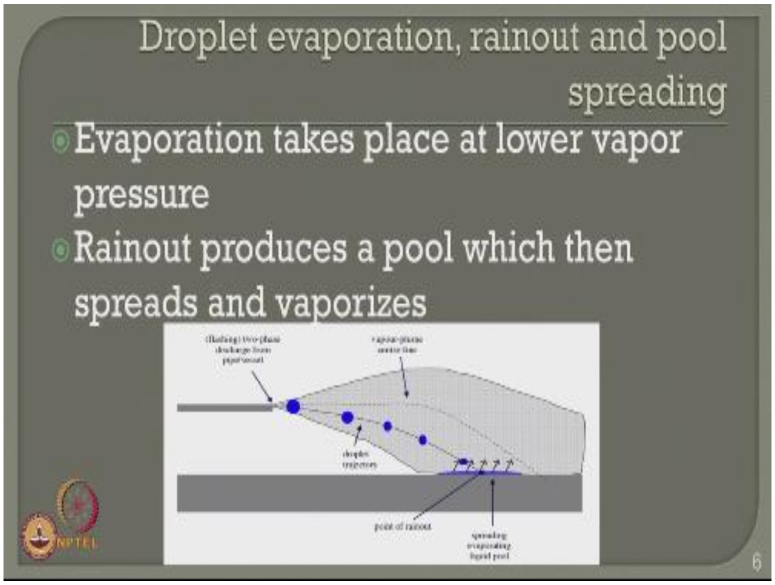

We can also try to understand what would be the effects of droplet evaporation, rainout process and pool spreading in such cases. When I have a flashing happens which is a two-phase discharge either from a pipe or from a vessel. Evaporation takes place at lower vapor pressure and initially which is a circular one where I am marking the, the droplet trajectory as you see here in the blue one when it touches the ground it becomes a point of vein out and this becomes a vapor plume center line and this becomes a droplet trajectory.

When the droplet trajectory touches the ground what we call the touchdown point, this spreads off and results in what we call evaporating liquid pool, from the liquid pool we all know that it will vaporize further which results in what we call a rainout process. So when you have all in discharge which occurs from a pipe or a vessel which essentially a two-phase discharge it forms in two parts, one is the droplet which results in evaporation as well as spreading of a liquid pool.

The rainout therefore is produced from a pool which then splits and vaporizes for a larger area above the surface of ground.

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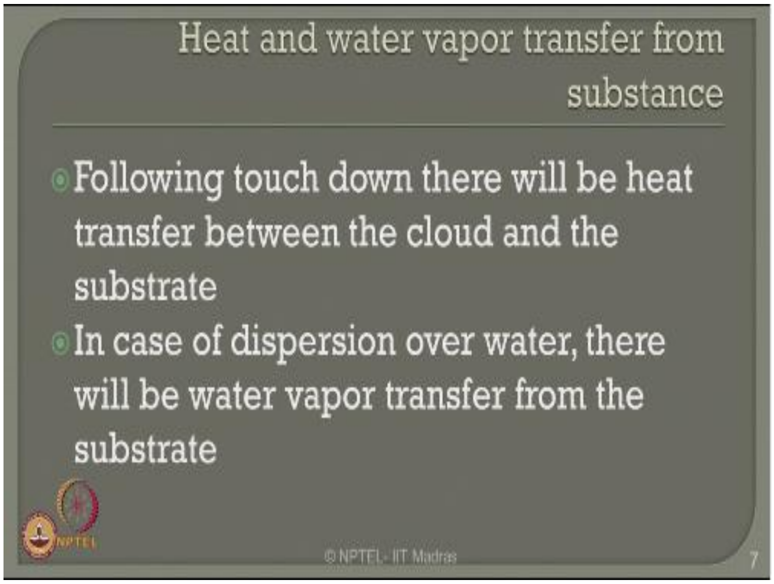

When we talk about heat and water vapor transfer from the substance. Following the test one point there will be heat transfer between the cloud in the substrate. In case of dispersion over water there will be water vapor transfer from the substrate.

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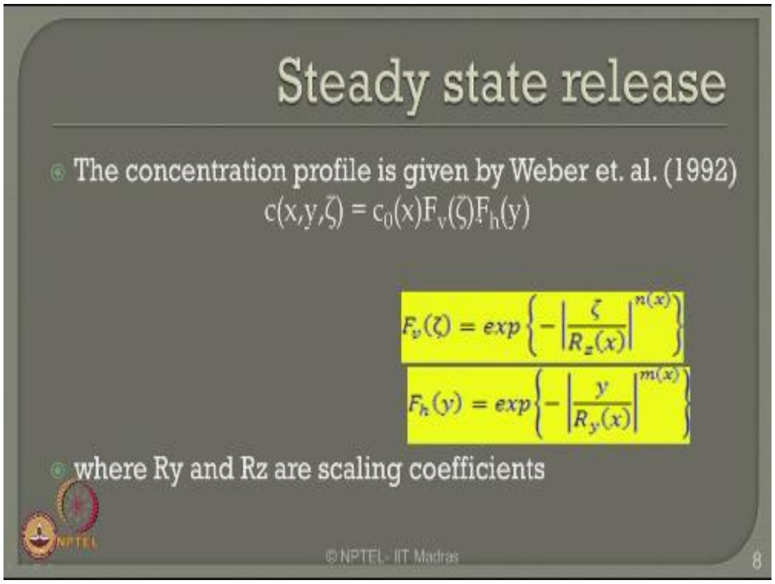

When we talk about the steady state release then the concentration profile is given by the following equation. Where the concentration in terms of x,y and z coordinates are given by the equation as you see in the slide here, whereas F_v and F_h are subsequently exponential expressions I see from here where in this expression R_y and R_z are the scaling coefficients which are relatively applied along the y and z axis respectively in this equation.

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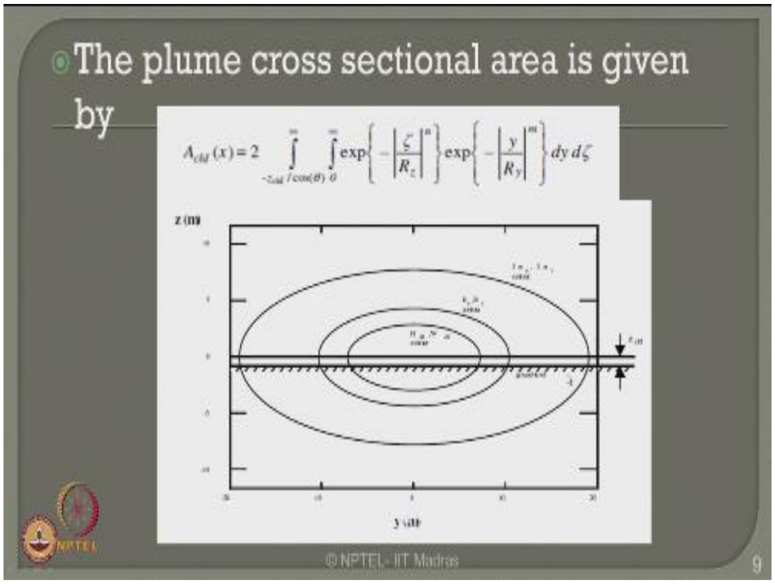

The plane cross-section of course is given by an equation as see in the slide now where the plume cross section area of the cloud is given by a double integral which is have a double exponential as you see in the function here and when you try to plot this it becomes an elliptical formation in terms of Y as we all know when the circular cross-section being released as a plume model when it touches the ground it becomes an ellipse because there is a momentum conserved in the area of release of the plume model.

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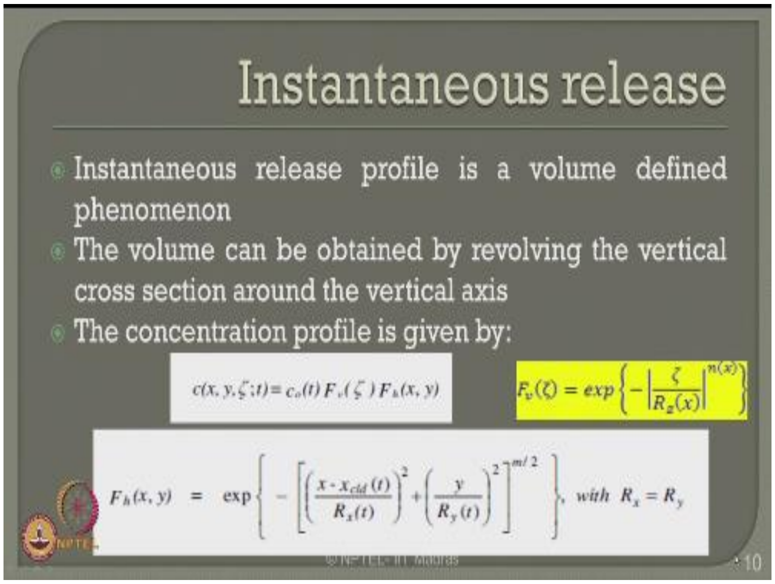

However when I talk about a puff model which is an instantaneous release of gas or vapor into the environment the instantaneous release profile is actually a volume defined phenomenon. The volume can be obtained by revolving the vertical cross-section around the vertical axis and the concentration profile is now given by this equation as a function of X Y Z as well as time whereas F_v and F_h are given respectively by the equations as you see here on the slide where R_x and R_y are considered to be equal in the situation for an instantaneous release models.

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Having understood how to compute the area of cross section of a plume model the dispersion relationships of a puff model in terms of x y and z coordinates as you see in the previous slides, one is interested to know what would be the core idea of release mitigation plans which essentially arise from these kind of release models into atmosphere.

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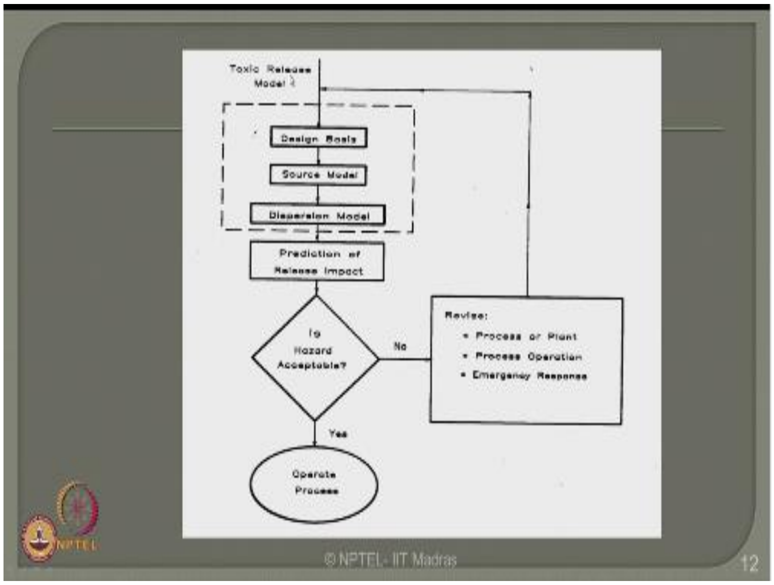

When you have got a toxic release model which can be considered on three models, one is it can be designed business model, it can be a source data model or it can be a dispersion model as we saw in the previous slides. Once we come out with any effective model which can capable of expressing the toxic release in the environment then the prediction release impact is to be done based on the dispersion or source model or the design basis model what you select for your analysis. Once the prediction of the least impact is done check that value whether is it hazard acceptable limit for an oil gas industry.

If it is not acceptable then revise either the process or the plant layout or the process operation or plan for more emergency response systems in the given process, then again feed this back to a toxic release model and check any one of the model is an outcome and again compare the result of the release impact arise from this revised model with that of hazard acceptable limit to the industry.

If it is yes, then operate the process if it is not then keep on revising either one of them until the acceptable limit is reached in terms of hazard acceptance level for the release impacts caused by the dispersion models of the toxic release in the industry.

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When I talk about release mitigation, there are many methods and plants by which these release mitigations are generally practiced in oil and gas industries. The foremost one is what we call inherent safety. We all understand that there are two methods by which safety can be implemented, one is the pre-accident scenario what is the post accident scenario. Inherent safety is actually a design process built in itself so that a pre accident scenario becomes more preventive the other than corrective measure.

Inherent safety can be focused on reducing the inventory available in the stock in the plant site itself it can also have what we call chemical substitution. If you have hazardous chemicals in the plant and operation one can try to find out whether these hazardous substances can be chemically equally substituted back with some other less hazardous material, can also try to find out whether there can be attenuation possible in the process.

On the other hand the release model which comes from the process can also be controlled in such a manner that the process intensification for further distance can be reduced to a greater extent all these come under single braces of inherent safety. The second aspect to release mitigation can be focused on the design process itself, one can look for physical integrity of seals and construction, one can also try to revise the process integrity in its terms of its layout, one can make the emergency control response guidelines or the systems more effective in terms of the design and its functionality, one can also attain to focus on the containment of spills.

We have already saw in the previous lectures earlier that how an oil spill can be contained using different kinds of booms. So on the other hand one can also look at release mitigation mechanisms in terms of the design itself. The third system of course is the managing release mitigation processes, one can come out with good policies and procedures which can be adopted by the industry and which can be practice with industry in a very stringent regulatory model.

One can also give enough training for vapor release studies to the people so that one can try to understand what would be the effect of dispersion cloud caused either by the plume model or with the puff model in the atmospheric release model systems as we saw in the previous slides. One should conduct periodic audits and inspections safety audits extra to keep on revisiting the mitigation plans managed and planned by the industry whether efficiently they have been addressed in terms of its practice.

Friends it is also important that one should go for periodic testing of the equipments in terms of its performance and efficiency. Routine maintenance of course is a mandatory process and step involved in managing release mitigation processes. It is very important that change a management system will always make enough and efficient changes in the whole methodology of safety practices and security of course is foremost important because security alertness can always expect the management to revisit the process in terms of its safety and of course focus on release mitigation plans more effectively.

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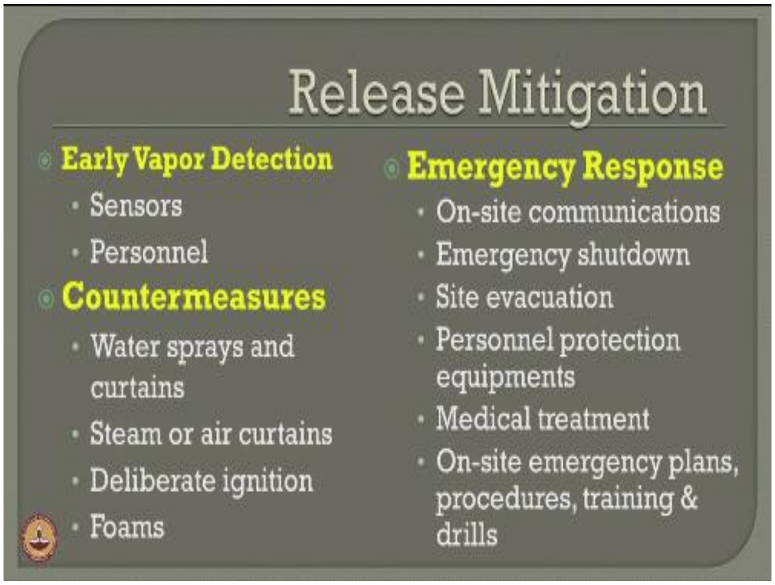

Further one can also look at early vapor detection schemes like providing senses and personal devices, so that one can look at the detection of any vapor release as early as before they are dispersed in environment. One can also look at countermeasures like water sprays and curtains, installing steam or air curtains in the process sector. Look at deliberate ignition or look at foams which can be used for mitigating or controlling the disburse of the release in the environment.

Of course we looked at the emergency response it is important that one can improvise on effective onset communications, one should also plan for and be ready with emergency shutdown processes in a given system and one should have a very clear sight evacuation plan so that personnel safety becomes more important. One should get train with personnel protection equipments, one should have first aid and detail medical treatment facilities available on site in case of any emergency occurrences in such releases it is very important that one should plan for onset emergency plans, procedures and import good training and do conduct periodic emergency drills in terms of people working in plant for efficient implementation of mitigation procedures in a given industry.

All these points which has been discussed in this two slides are become mandatory and very important under the guidance of oil industry and safety directorate which is being practiced very stringently in oil and gas industries.

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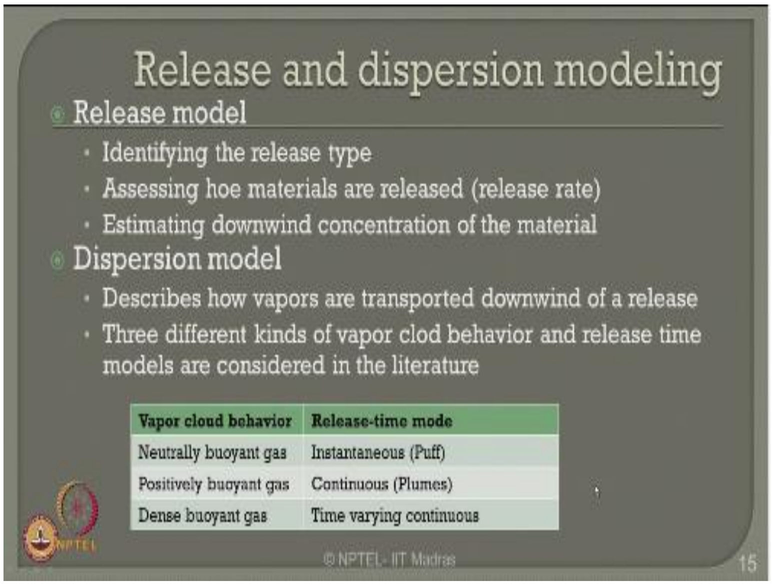

Let us quickly revisit some of the basic concepts again on reliefs and dispersion models. Release model essentially demands you to identify the release type it can assess how materials are released in terms of release rate. We can estimate the downward, downwind concentration of the material, however the dispersion models essentially focus on how vapors are transported downwind of a release three kinds of vapor clouds can behave in the same manner and release time models are considered in the literature.

One can have a neutrally buoyant gas positively buoyant gas and dense burn gas however the release time nodes can be different. For neutrally buoyant gas one can follow instantaneous release model what we call puff models in the literature. Whereas for positively buoyant gas one can follow the continued series models a steady-state release models what we call as plume release models in the literature. For dense buoyant gas one can go for a time varying continuous models which can use as an alternate extension of the plume models in the literature.

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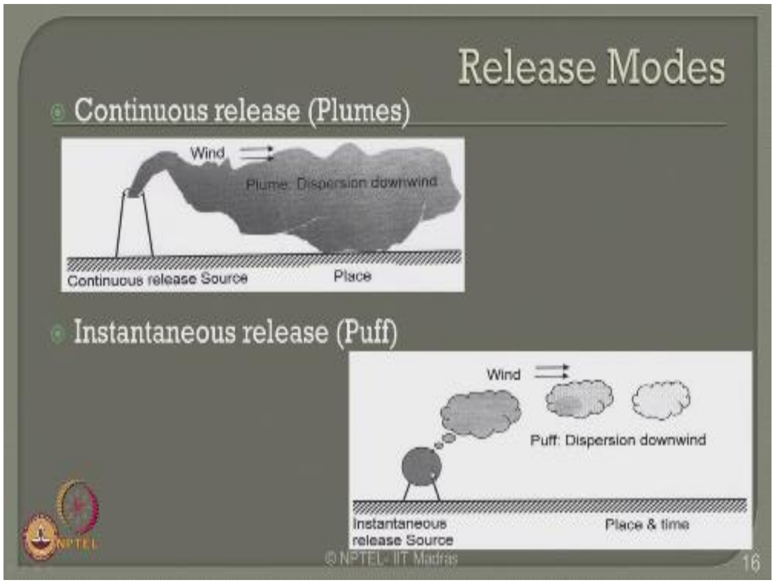

To look at the different release modes one can say the continuous release model will get dispersed off in the downwind direction and we call this as a plume release model in the dispersion downward wind. Whereas the instantaneous release source we call them as a puff release model where they do not come down touch with buoyant so easily they keep on disposing depending upon the stability of the wind class and the speed of the wind depending upon the place and time of release.

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Now one can also remember and recollect what are the factors which can affect dispersion release models. Most importantly we all agree that the dispersion will become effective and widespread essentially based on what is a wind velocity at a specific location. It also depends upon atmospheric stability class which I will discuss in this slide next one. One can also see that the ground conditions are the interferences or obstructions cost on the ground surface will also affect the dispersion models very significantly.

Is very important that at what height of release is happening above the ground as it is higher and higher the dispersion models will have a different strategy to get dispersed in the atmosphere. It also depends upon what is the initial momentum which is present in the released material.

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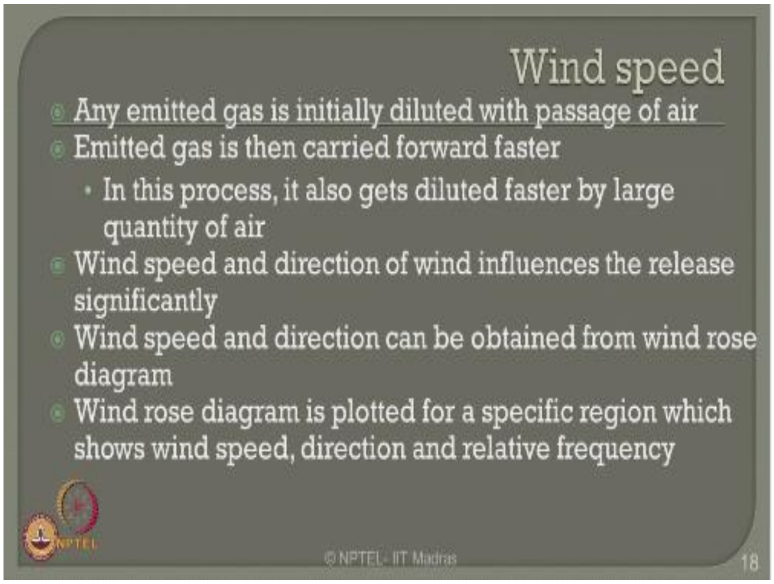

If we talk about wind speed which is one of the foremost data which governs the effectiveness of the dispersion models what you study which can result in atmospheric pollution. Any emitted gas friends is initially diluted with of course passage of air. The emitted gas is then carried forward faster because of the wind velocity present in any system. In this process it also gets diluted faster the large quantity of air getting added to it. Therefore wind speed and direction of wind influences the release significantly in any dispersion release moles.

The wind speed and direction can be obtained readily from what we call as a wind rose diagram. Wind rose diagram actually is a plot which is done for a specific region this shows the wind speed in the region the direction of wind velocity and relate to frequency at which the wind is blowing.

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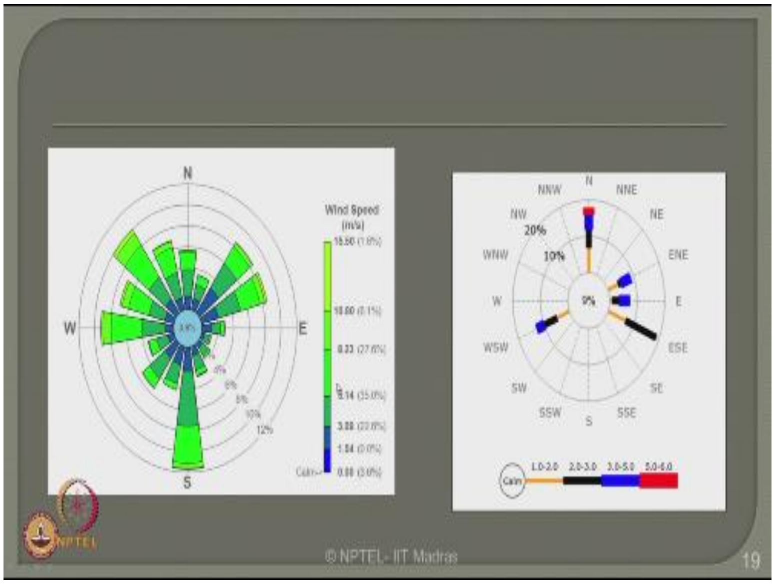

You can see two typical wind rose diagrams plotted on the screen now, the left hand side and the right hand side are more or less same however we will see the right hand side has got more detail in terms of its division. So essentially wind rose diagram which is a circular plot which has got north, east, south and west division and they can be further subdivided into the categories as you see on the segment. Please understand north is spotted at 0 or 360 and east is plotted at 90˚ therefore the plot has got a clockwise procedure of up gradation 0, 90, 180 at south and 270 at west and 360 at north or 0 at north.

Here is one and the same here that north, east, south and west are plotted now one can see here there are concentric circles which you see which in both the cases, that are constantly circles starting from the inner one and keep on proceeding towards outer, each constant if circle determines and represents specific frequency of the wind and you can see a legend plotted here which shows on the right hand side where the green one or the darker one shows the wind velocity at a specific percentage or specific meter per second.

Whereas the blue one is practically 0 what we call as a calm wind which is occurring at the center in both the cases the legends indicate the wind velocity in terms of meter per second.

However, it start from the calm place of 9% and it precedes further in this case to as high as 20% whereas in this case as high as about 15.5 %.

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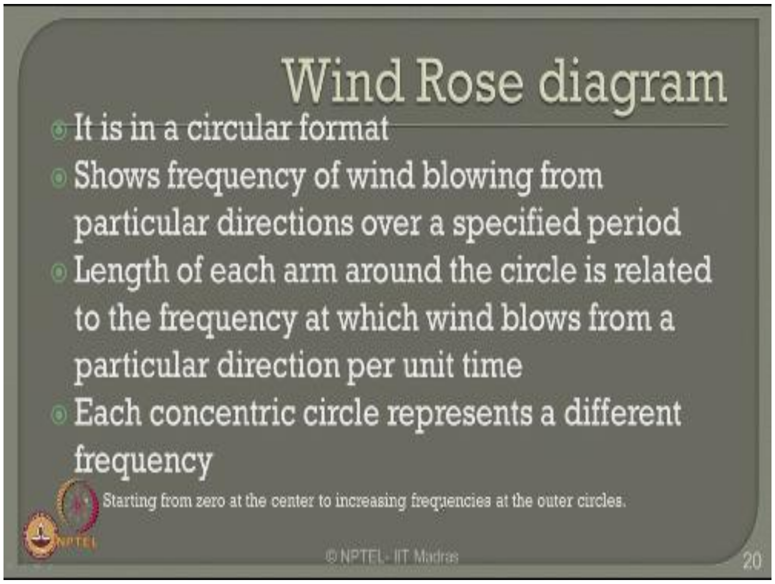

The wind rose diagram is in a circular format in general it shows frequency the wind blowing from a particular direction over a specific period. Length of each arm in a given circle is related to the frequency at which the wind blows from a particular direction per unit time. Each concentric circle as a set beginning it represents a different frequency it starts from 0 at the center which is a calm state to an increasing frequency as moves towards the outer circles.

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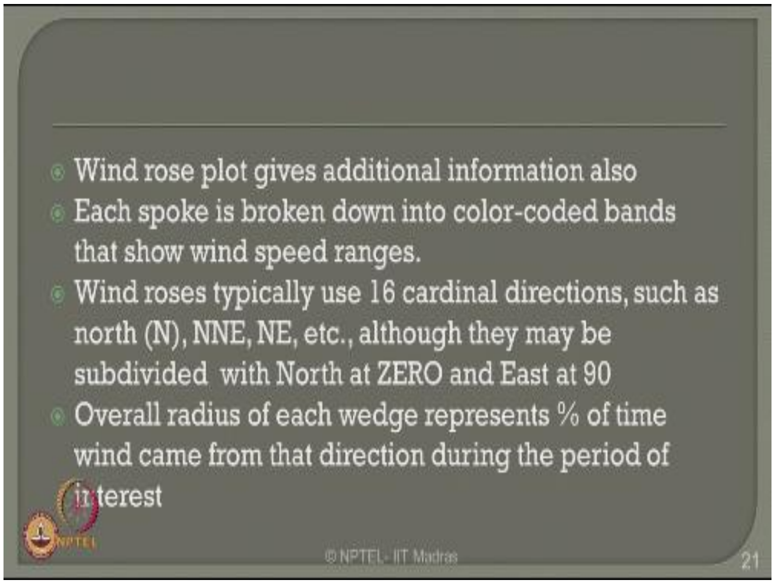

Wind rose plots also give you additional information as well let us see what are they. Each spoke is broken down into color-coded bands this shows wind speed ranges. Wind roses typically use 16 cardinal directions such as north, north-north east, north east extra. Although they may be subdivided with north at 0 and East at 90 and so on in a clockwise manner. Overall radius of each wedge represents the percentage of time wind came from that direction during the period of interest.

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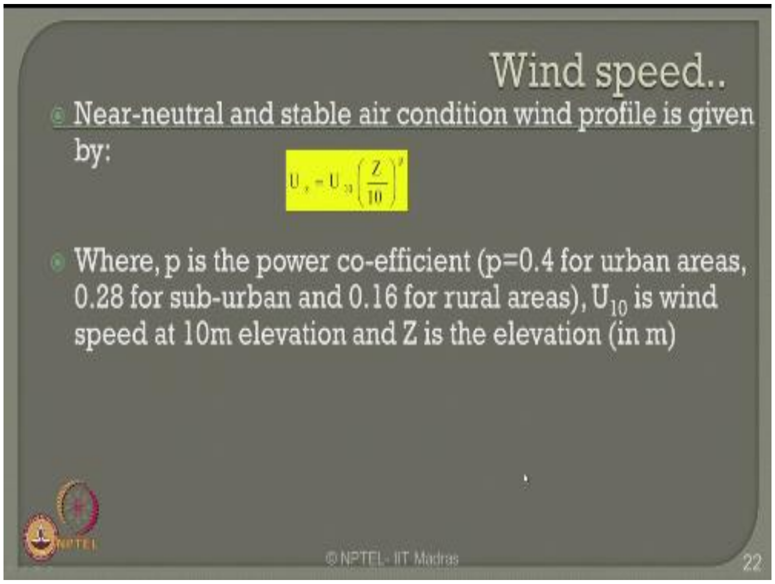

Now where is an equation available in the literature for computing the wind speed which is given in the screen now? Near neutral and stable air condition wind profile is given by this equation where Z is the height at which we are calculating the wind speed in meters, whereas U_{10} is what we call the basic reference wind speed which is the wind speed at 10m elevation above the ground, whereas Z is the point where you want to compute the wind speed and of course p is a power coefficient depending upon the location or geographic selection of the area, p is actually considers 0.4 for urban areas and 0.28 for suburban and 0.16 for rural areas.

As I told you in the beginning interference of buildings and trees present in the area will affect the wind speed velocity therefore, the p value is taking care of those inferences cost on the wind flow direction as well as velocity in the given equation.

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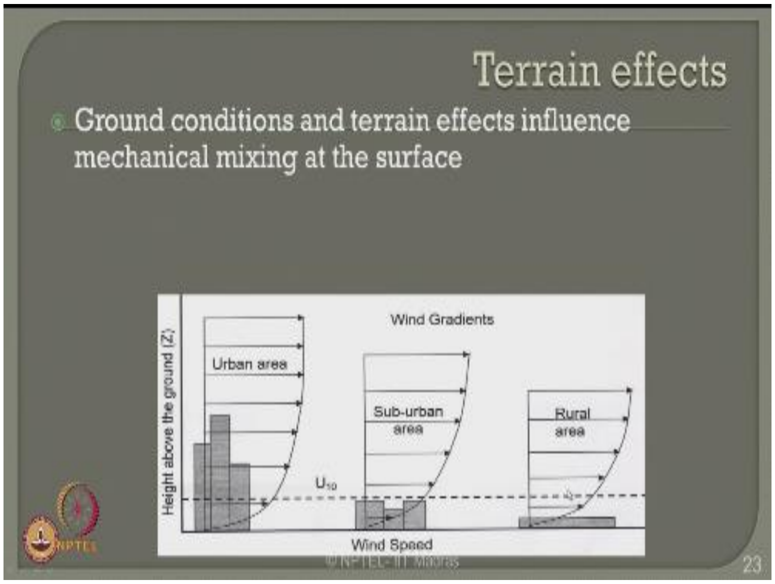

One can also see how the terrain effects significantly the wind speed or the wind gradient. The ground conditions alter significantly wind gradient if you have got abstractions more or there are no abstraction then you will see that the rays of the wind velocity above the ground which we call as Z will increase depending upon the interferences cost on the wind speed in gremial projection direction.

Of course U_{10} is the wind speed at 10m height from the ground, whereas if you really wanted to find out the wind velocity of the speed at any Z value which is measured on the y axis in this curve you will see that the interference caused by the buildings or trees present in different levels like urban, suburban and rural area will affect the wind velocity in terms of its disturbances caused by this terrain significantly. However, the interferences caused by this terrain is taken care of in this equation.

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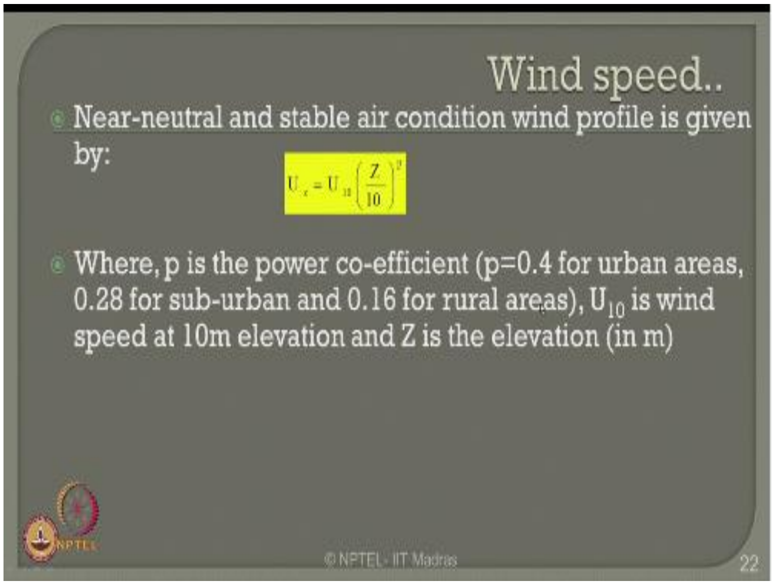

By a factor which is taken by p where the Pp factor is different for different segments as you see in the slide here.

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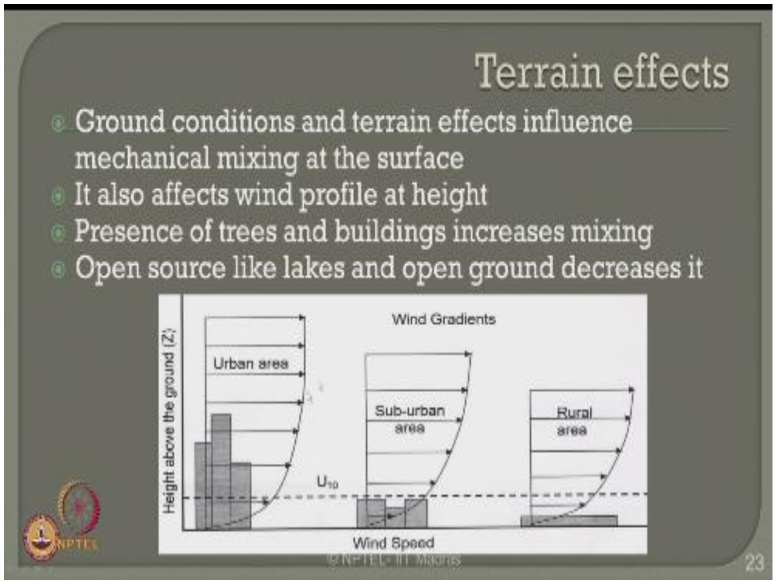

Therefore, the terrain interferences not only affects the wind velocity but also a wind profile along its height you can see here this is constant on less variation up toU_{10} and then it varies in a different manner and it affects how far it is varying depending upon inferences caused by the urban or suburban or rural area in terms of buildings or trees extra, which is influencing the wind effect in terms of its terrain. So the presence of trees, buildings increases what we call mixing, therefore the wind velocity profile alters significantly.

Of course the presence of open sources like lake and open ground decreases the mixing, therefore it is lower for rural areas and for higher for urban areas.

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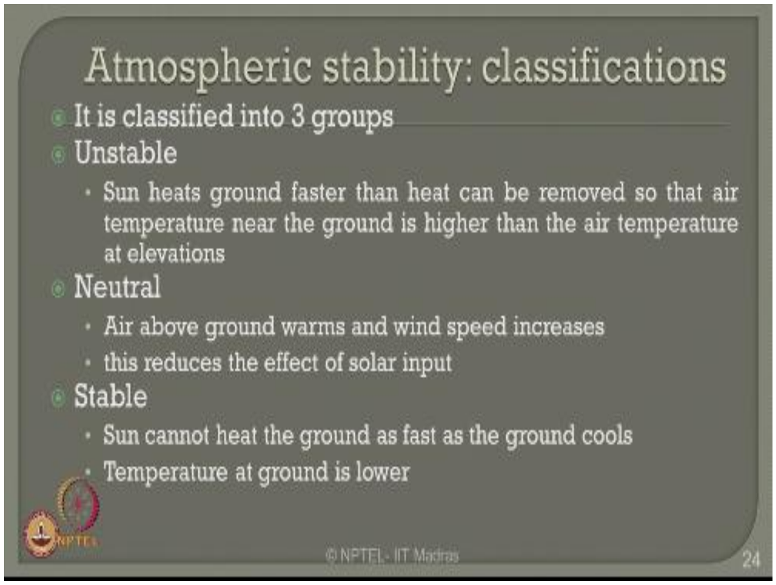

As we said wind velocity or wind dispersion also depends upon the atmosphere stability which is classified as three groups, one is called unstable, neutral and stable class. Unstable is an area or regime where sun heats the ground faster than heat can be removed so that air temperature near the ground is higher than that of the air temperature at higher elevations. We call this particular classification as an unstable atmospheric stability. If I air above the ground warms up and wind speed increases this will reduce the effect of solar input therefore, we call this particular stability class as neutral stability class.

However, when sun cannot heat the ground as fast as the ground gets cooled up then the temperature ground is much lower we call this as a stable class in atmospheric stability classification.

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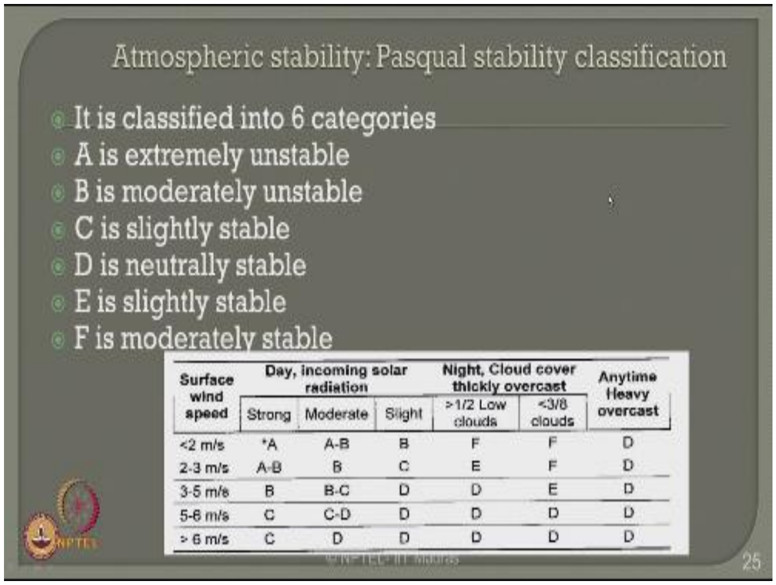

They are also alternative classified depending upon past Pasqual stability declassification as you see in the table which is normal literature varying from A to that of B which is in six categories, A is called extremely unstable whereas B is moderately unstable, C is slightly stable, D is neutrally stable, E becomes slightly stable whereas F is moderately stable depending upon a surface wind speed which varies from 2 meter per second to that of higher as 6 meter per second one can always try to find out what will be the day night and any time over cost depending upon where is the Pasqual stability class. So friends one can classify that much stability either based on.

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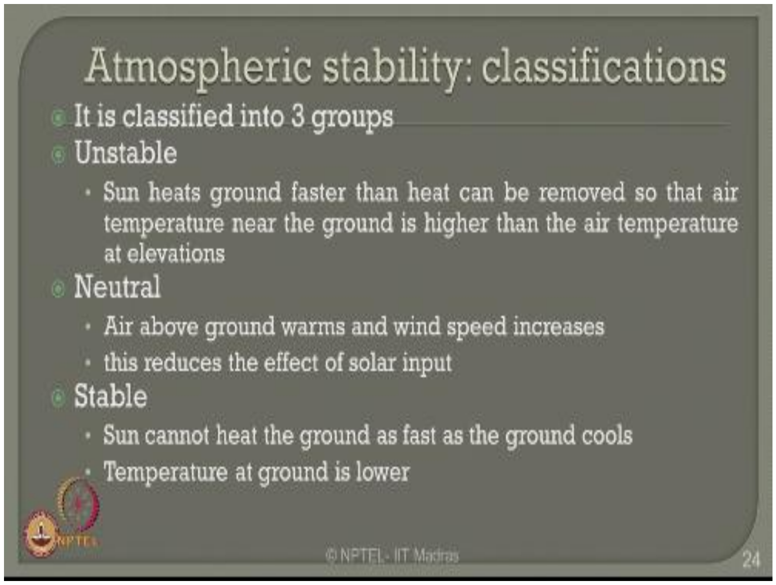

The categories or classifications as you see here as unstable, neutral or stable in general or to be very specific.

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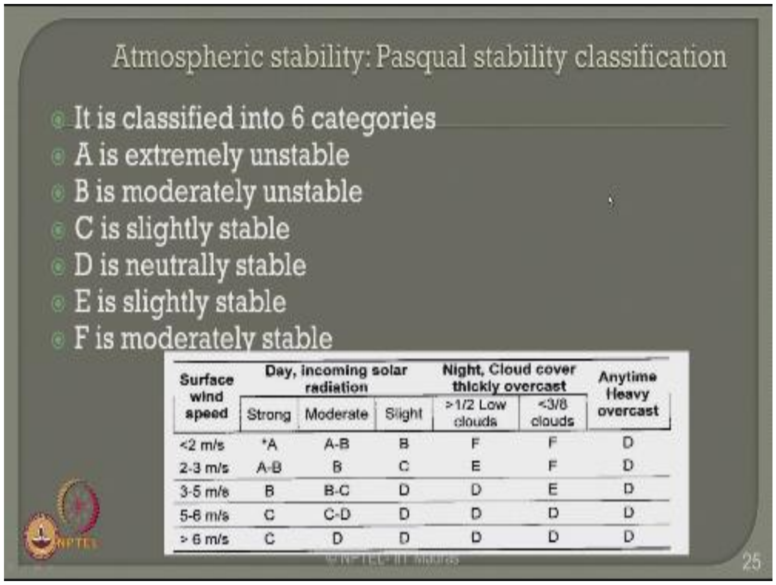

One can also classify them depending upon the surface wind speed and for day night in any time depending upon the classification given by Pascal stability as you see in the slide now.

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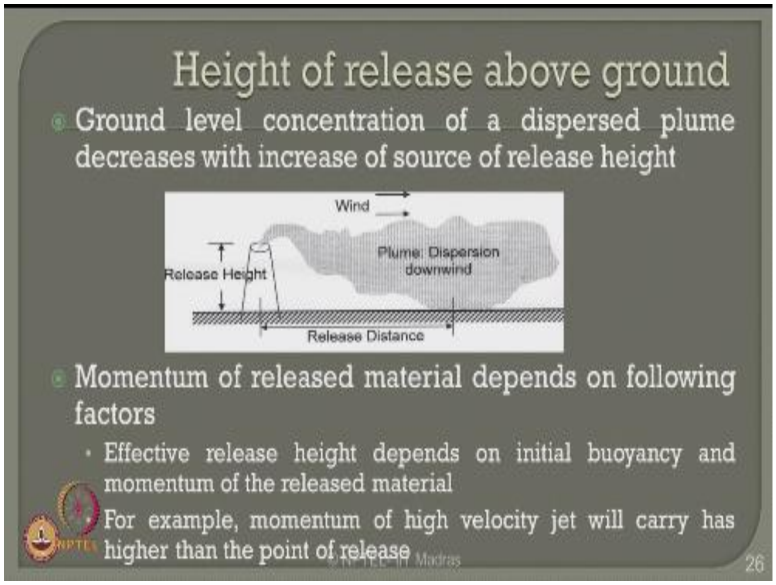

Now we all agree that the height of release above the ground is also one of the important factor which is influencing the dispersion model for both plume and puff, of course you see here is a plume model because the plume model has got a touchdown point which comes and touches the ground and then further it really is off or picks off. The point from where it is touching the ground form out of that source is what we call the release distance and the release height is influencing significantly the dispersion of the plume model in the windward direction.

The grounding level concentration therefore depends upon the dispersed plume as the dispersed plume decreases with increase in the source of the release height. So as the source release height is higher and higher the ground concentration of the dispersed plume will get narrowed down in the touchstone area of a given model. It also depends on the momentum released material, the momentum of course depends on effective release height which depends ultimately on initial buoyancy and momentum of the released material.

For example, the momentum of the high velocity jet will carry higher effects than that of the point of release.

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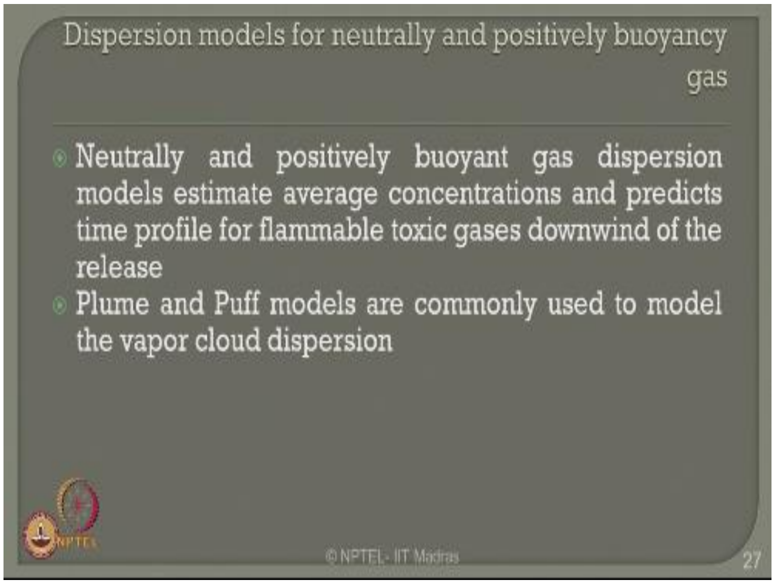

The dispersion models for neutrally and positively buoyant gas can also be used in the same manner, because these models estimate average concentration and predicts time profile for a flammable toxic gases in the downward direction of that of the gas release. The plume and puff models are successfully recommend in the literature for using vapor cloud dispersion for positively buoyant gas and neutrally buoyant gas as well.

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So in this lecture we understood that how the plume and puff models can be released and can be understood in terms of atmospheric pollution. What are the governing equations which tells me what would be the dispersion area or the dispersion contained in terms of its volume for continuous release as well as neutral release respectively from the equations. What are the factors which actually govern the dispersion of these models in the atmospheric pollution? What are those effects physically and mathematically in terms of modeling and what is the use of wind rose diagram, how a typical wind rose diagram looks like and what are the contents which can be derived from a wind rose diagram. Thank you very much you.

(Refer Slide Time: 28:19)

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