Health, Safety and Environmental Management in Petroleum and offshore Engineering

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Module No. # 02

Lecture No. # 05

Dispersion models - atmospheric pollution

In the next lecture, we will discuss about different dispersion models which are used for estimating atmospheric pollution. This is lecture-5 on module-2 of HSE.

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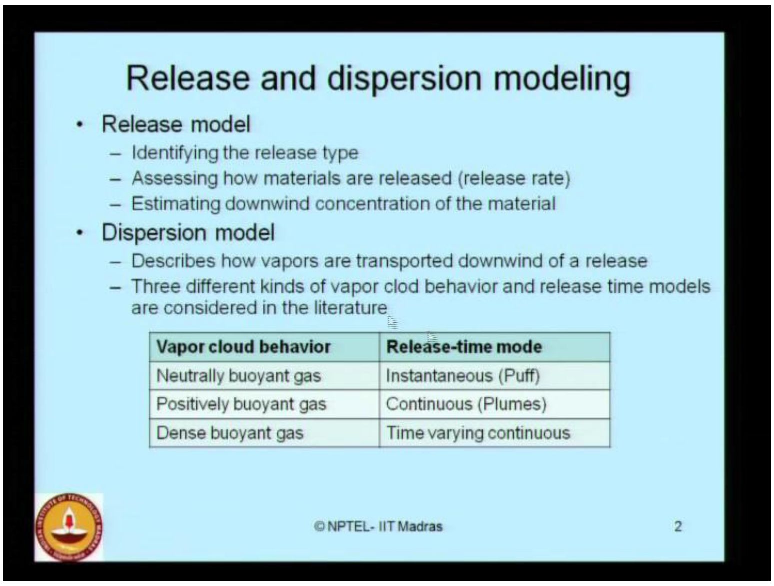

Let us look at the release and dispersion models which are available in the literature, for the release models, the following steps are generally done. Identify the release type, assess how materials are released; this is what we call as release rate, then estimate the downwind concentration of the material. If you look at the dispersion models, this describes how vapors are transported downwind of a release. Three kinds of vapor cloud behavior and release time models are considered in the literature. If you look at the vapor cloud behavior on the corresponding modes, how they have been done for a neutrally buoyant gas. We use what we call as a puff model; this takes care of instantaneous release. For a positively buoyant gas, we use what is call a plumes model which takes care of continuous release; for a dense buoyant gas, we use what is called time varying continuous models. So, there are generally three kinds of models available for dispersion, once the source is released.

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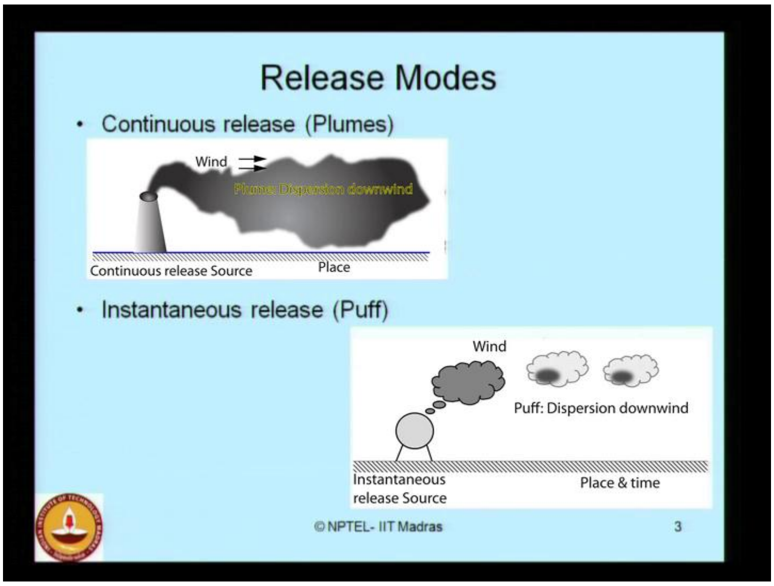

These are the pictures showing you the plume model and the puff model. The puff model as we discussed in the last slide is meant for instantaneous release from the source, there is the source where there is an instantaneous release, because of the downwind direction in this way the source or the released is getting dispersed of in the downwind side. So, this is what we call as instantaneous release model. In case of a continuous release, for example, you have got a release which coming from a source continuously in the downwind direction this keeps on dispersing on the downwind side in the larger and larger area, so to capture thus kind of dispersion we use what is call plumes model. We will discuss the mathematical equations and derivations for both the puffs models and the plumes models in the coming lectures. So, as I said the plumes models used for a continuous release, whereas the puff model is used for any instantaneous release.

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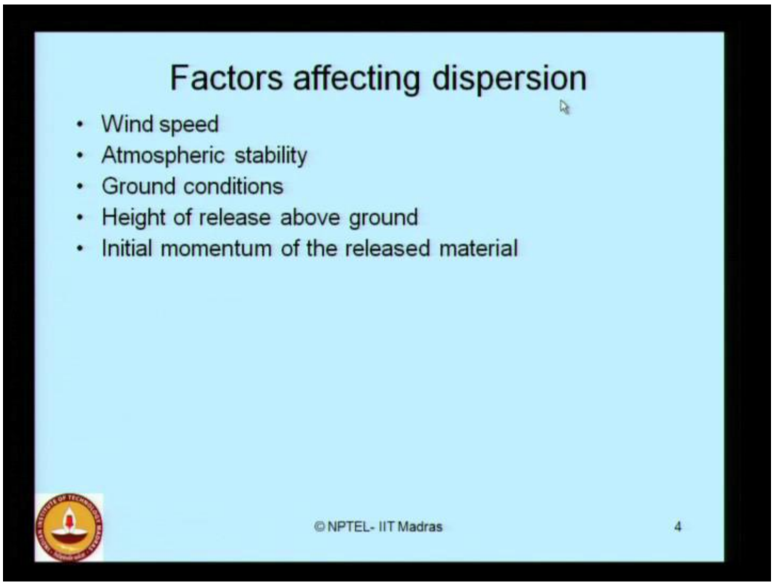

Let us ask a questions, what are the factors basically that affect dispersion? There are many factors which affect dispersion critically. The four most factor which affects dispersion is the wind velocity or the downwind speed. The next one is what is call atmospheric stability, we will discuss this in detail. The third one is what we call the terrain conditions; how is the surface area where the dispersion takes place? Is it a rough surface? Does it contain lot of open sea or open water body? Does it contain an open ground? Does it contain tall buildings? So, depending upon the ground condition a dispersion model is affected.

It also depends on where is your release point. What is the altitude of the release point from the ground? For example, you consider a release point as one of the tallest point in the chimney or you consider a release point something happening in accident in the ground in a building. Compare to the height of the building, which is practically 3 meters a chimney may be about 150 meters. So, the altitude of release of a smoke or any source of pollution which is going to disperse in at atmosphere, the altitude of this release is naturally different. So, it affects, it is one of the major factor the dispersion model.

Above all, the foremost important factor which we must consider is, of course, what is a initial momentum the released material has? If the initial momentum is very large then the dispersion is going to be stronger, and surface area of dispersion is going to be very high. If the initial momentum is very, very small and negligible, then the dispersion may not be effective. Even the dispersion is effective; the concentration of dispersion in the air will be highly diluted.

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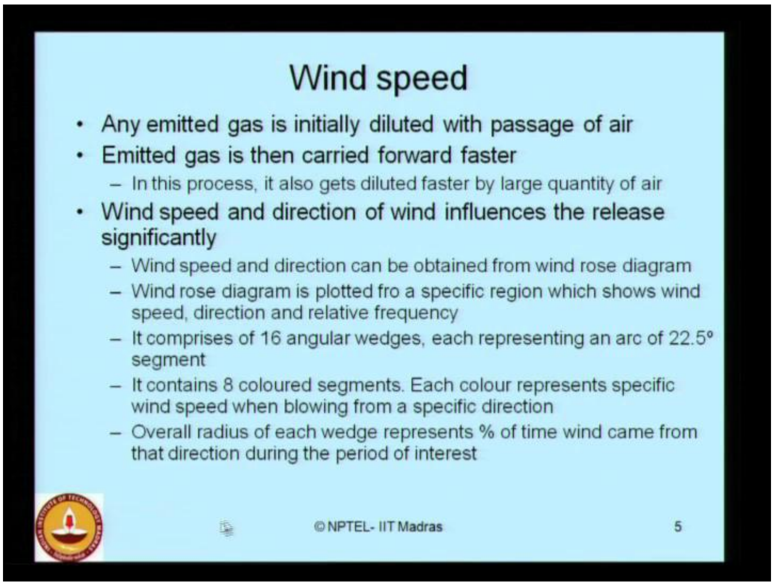

Let us look into these factors one by one in detail. If we consider the wind speed as one of the important factors which affects dispersion. Then lets us say, that any emitted gas is initially diluted with passage of air, this is simple fact. If you have got a gas which is emitted from a source, then as the source of the gas being released and gets in contact with atmosphere depending upon the passage of air or the distinct of passage of air from the source this emitted gas concentration gets diluted. The emitted gas is then carried forward – faster. Why do we say faster? Because, wind speed contributes to the carriage of this emitted gas in that downwind direction.

In this process one interesting thing happens is that the dilution factor gets further decreased, it means the emitted gas concentration further gets diluted, because of addition of large quantity of air at as it passes away. The wind speed and direction of wind influences the release significantly. The wind speed and direction can be obtained from what we call as a wind rose chart or a wind rose diagram. For information of the listeners and the learners of this program, let us try to explain very briefly, what do you understand by a wind rose diagram.

Wind rose diagram is plotted for specific region which shows wind speed, wind direction, and relative frequency. It comprises of 16 angular wedges, each representing an arc of 22.5 degree segment. It contains 8 coloured segments; each colour represents specific winds speed when blowing from a specific direction. Overall radius of each wedge represents percentage of time wind came from the direction during the period of interest.

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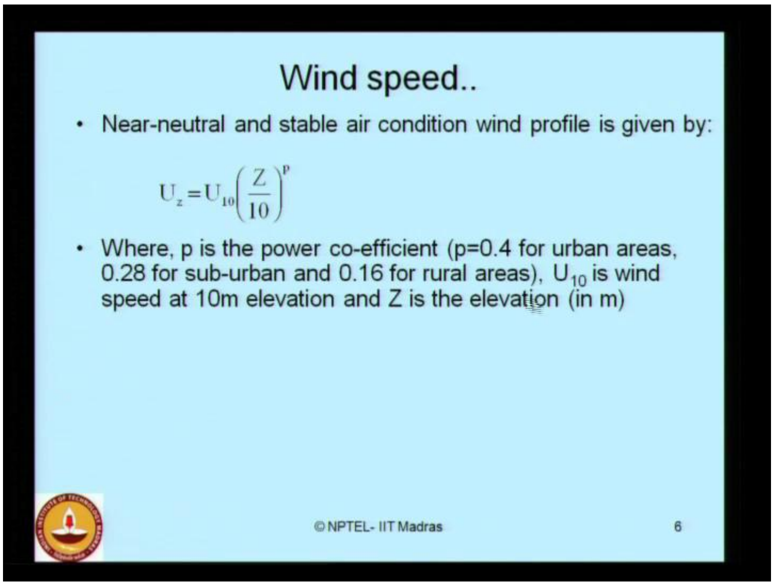

If we look at the wind speed computation, near-neutral and stable air condition wind profile is given by the following relationship: If we want to compute the wind speed at any altitude z in meters then the wind velocity at z point is given by U at 10 multiplied by Z by 10 of p. Where, p is the power coefficient; this is taken as 0.4 for urban areas, 0.28 for sub urban areas, and 0.16 for rural areas. Whereas, U 10 is the wind velocity at 10 meter elevation at a specific geographic location; where Z is the height of interest where you are computing the wind speed, which is given in meters.

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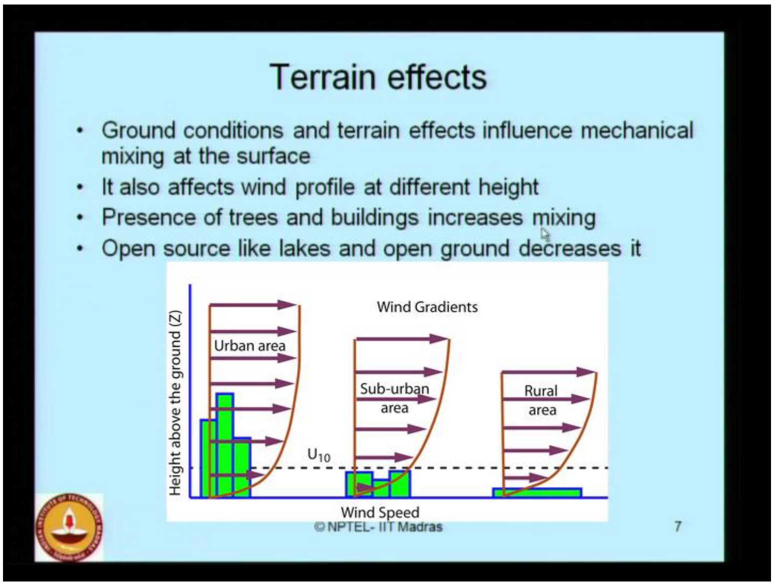

Let us look at the effect of terrain or the ground conditions on the wind speed. As I told you in the previous slide, the ground condition or the topography or the geographic locations of the ground where the dispersion model is estimated, also affects how the wind speed is being estimated. If we look at the so called wind gradient being plotted, wind speed verses height above the ground - Z in meters. In case of urban areas, in case of sub urban areas, and rural areas they distribute and they vary significantly.

This is the line which is showing you a constant wind speed, what we consider literature as U 10; U 10 is nothing but the wind velocity at an height of 10 meter from the reference data. A ground conditions and terrain influences the mechanical mixing at the surface where you are studying the dispersion model. It also affects a wind profile at different heights as shown in the figure. The presence of vegetation like trees, plants and tall buildings increases the mixing of these in the dispersion. Open sources like presence of any water body like lakes or open ground decreases the mixing. So, open lakes and open grounds decrease the concentration of the disposed content where as presence of trees and buildings increase the mixing of this with air much faster.

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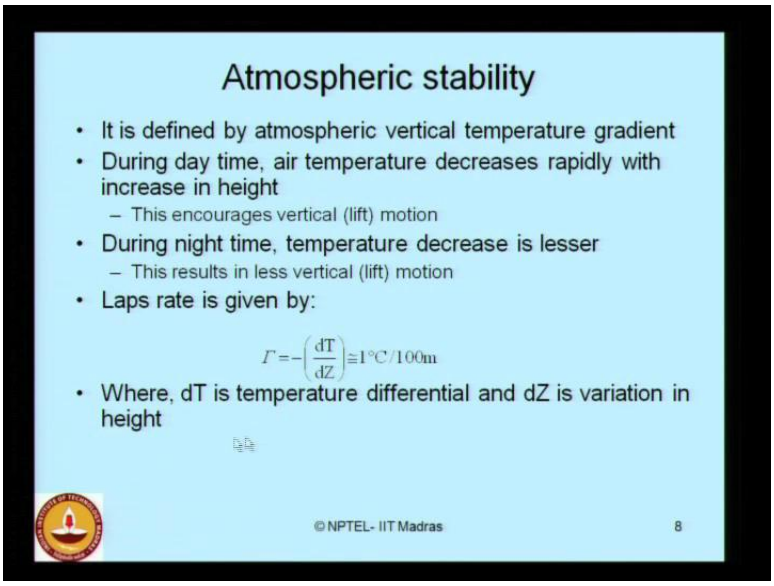

As I said atmospheric stability is one of the other parameter, which affects by dispersion model. What do we understand by an atmospheric stability? It is defined by atmospheric vertical temperature gradient. Ladies and gentlemen, it is interesting for you to know the during the day time, air temperature decreases rapidly with increase in height. So, in such cases there is strong encouragement of vertical lift motion, because air temperature decreases rapidly with increase in height. During night time, the temperature decrease happens, but it is far less; this results in less vertical motions. So, since we say the motion is happening in the vertical direction, a specific name is associated with this motion, this is what we call as lift motion.

Laps rate is given by a simple relationship as given by the equation here, gamma explains the laps rate which is given by dt by dz, which is approximately 1 degree Celsius per every 100 meters; dt in this expressions is what we call as temperature differential and d z is what we call variations in the height.

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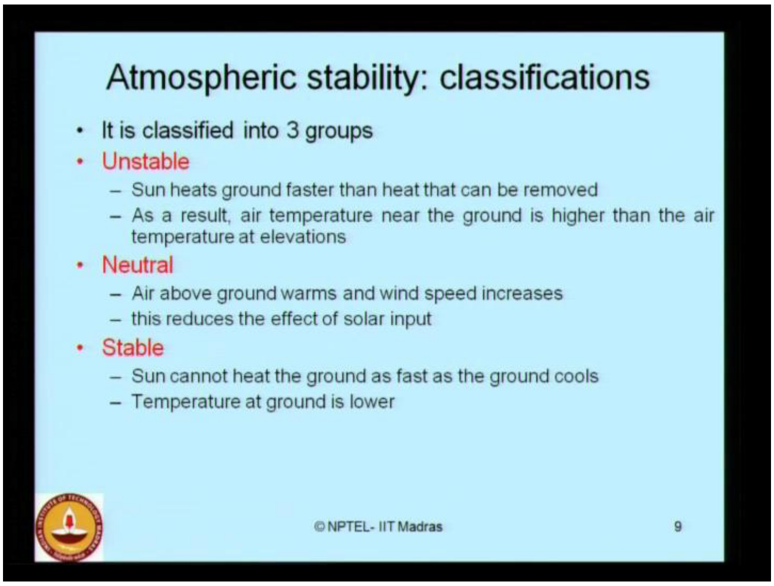

Atmospheric stability is also classified in the literature in three groups. Three groups are namely unstable, neutral, and stable. Unstable group is that group where the sun heats the ground faster than that heat can be recovered from the ground. As a result, air temperature near the ground is far higher than that the air temperature at different elevations; this is what we call as an unstable group of classification in atmospheric stability. The second group is what we called as neutral group of classification in atmospheric stability. Here air above the ground warms, and therefore, wind speed increases; this reduces the effect of solar input in atmospheric stability. The third and the last group what we have in defining the atmospheric classification is that, what we call it is a stable group. The stable group is those areas where the sun cannot heat the ground as fast as the ground gets cooled down; the temperature therefore near the ground is lower.

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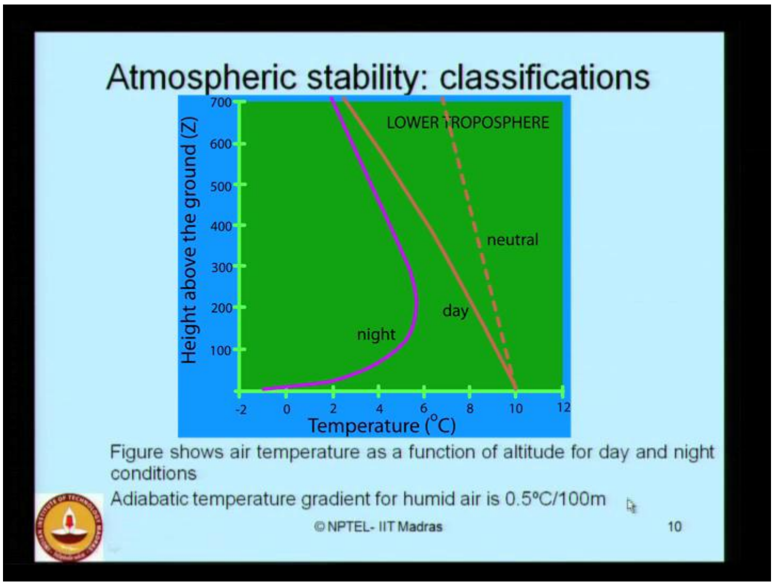

Ladies and gentlemen, this figure shows the air temperature, as a function of altitude for day and night conditions. Let us try to spend few minutes in understanding this plot, on the x axis, we have shown the temperature variation in degree Celsius; whereas on the y axis, we have shown height about the ground at z point in meters. So, during the night time, if you look at this curve, as the height above the ground level increases there is drop in temperature; whereas, surface area near the ground has obviously lower temperature compare to that of higher altitudes. Whereas, during the day time, there is a steep drop in temperature when there is increase in height. On the other hand, near the ground the temperature is relatively higher during the day time compare to that of during t he night time.

We also have something call a neutral layer, where the temperature near the ground layer is almost constant, closer to 10 degree Celsius. Whereas, as the height from the ground increases there is a drop in temperature, but that drop is not as steep as during the day time. The adiabatic temperature gradient for a humid air given in the literature is 0.5 degree Celsius for every 100 meter.

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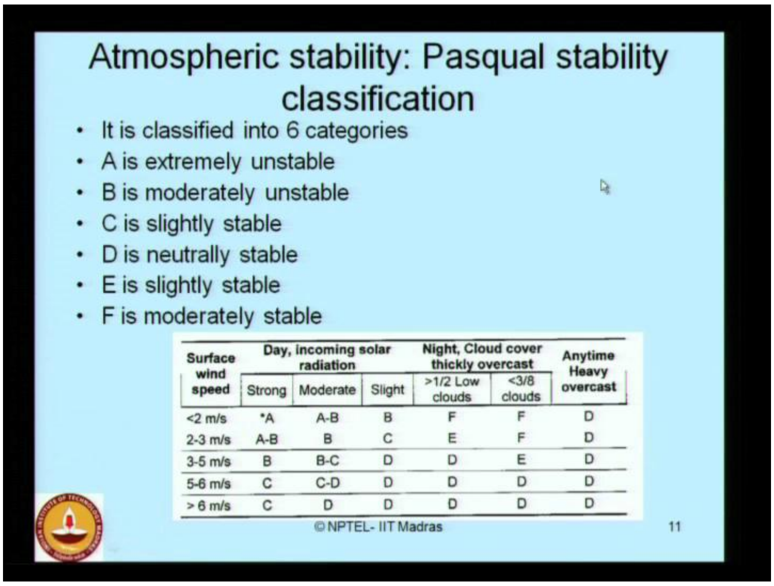

Atmospheric stability is also classified by Pasqual stability classification. This Pasqual stability classification is given in terms of alphabetic characteristics as six categories. For example, category-a says that it is extremely unstable; category-b says, it is moderately unstable; category–c says, it is slightly stable; category-d says, it is neutrally stable; category-e is assigned for slightly stable; category-f is assigned for moderately stable. If you look at the chart below, we have got surface wind speed varying from the value less than 2 meter per second to the value more than 6 meter per second.

If we look at the day and the night for classifications as strong, moderate, and slight, for example, for a surface wind speed of less than 2 meter per second. The Pasqual stability classification of atmospheric stability is considered as extremely unstable during the day time. On the other hand, if the same condition, if we look at the night, it is considered as moderately stable. So, from this Pasqual stability classification table for a given surface wind speed, whether it is a day or a night condition, you can easily say whether this condition of stability in terms of atmospheric stability is stable or unstable in a classification of six groups as we see here.

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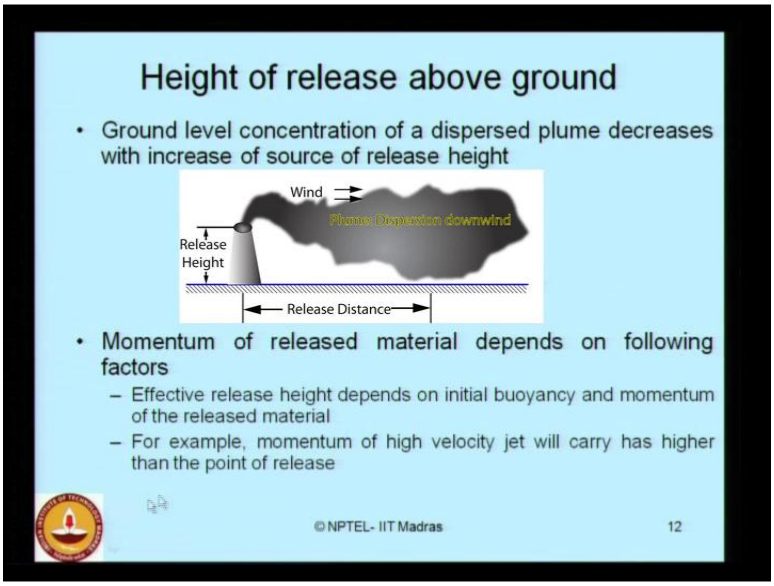

We also see that how the height of release above the ground also affects the ground level concentration of a dispersed plume. The ground level concentration of a dispersed plume decreases with increase of source of the release height, for example, if the source is closer to the ground then the concentration is larger; if the source is away or very much at on higher elevation from the ground then the plum concentration is decreased. You can see here as the source release height is away from the reference datum then the concentration of the plume is lesser. So, for in this case, it is having lesser concentration compare to that of dispersion concentration which is closer to the ground.

The momentum of released material as we discussed in a previous slide also affects, a dispersion models studies. The momentum depends on the following factors: effective release height depends on the initial buoyancy and the momentum of the released material, for example, the momentum of high velocity jet will carry higher than the point of release.

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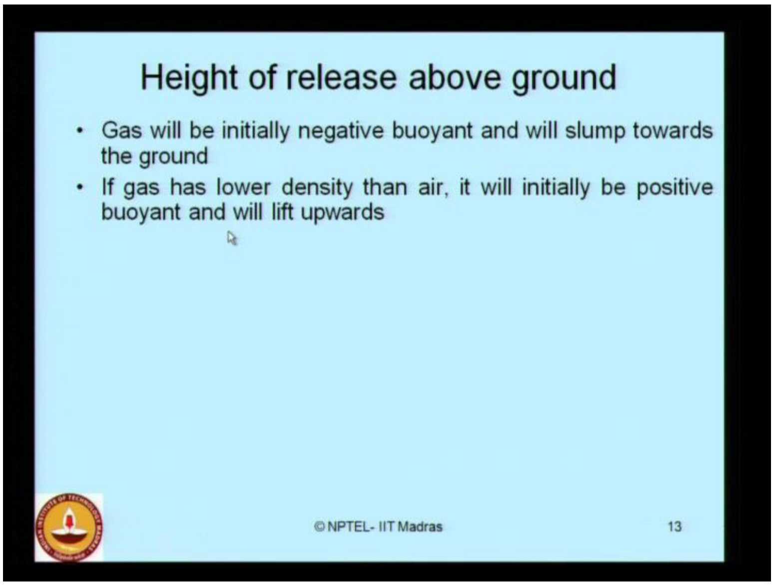

Height of release above the ground also matters in the dispersion models. Gas will be initially negative buoyant and will slump generally towards the ground. If the gas has lower density than that of air, it will initially be positive buoyant and will get lifted upwards.

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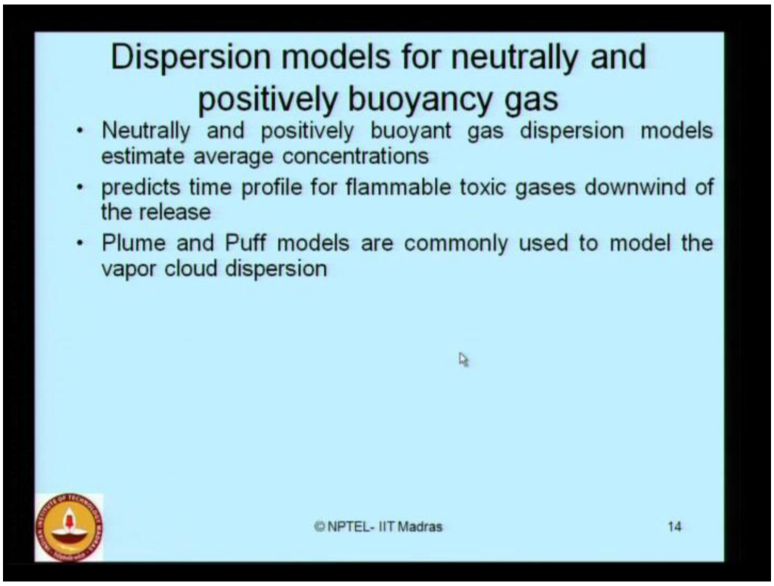

Dispersion models for neutrally and positively buoyant gas. Neutrally and positively buoyant gas dispersion models estimate average concentrations. They predict time profile for flammable toxic gases downwind of the release. The plume and puff models are commonly used to model the vapor cloud dispersion. In the next lecture, we will see in detail about these models.

Thank you.