Health, Safety and Environmental Management in Petroleum and offshore Engineering

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Module No. # 02

Lecture No. # 06

Dispersion models (continued)

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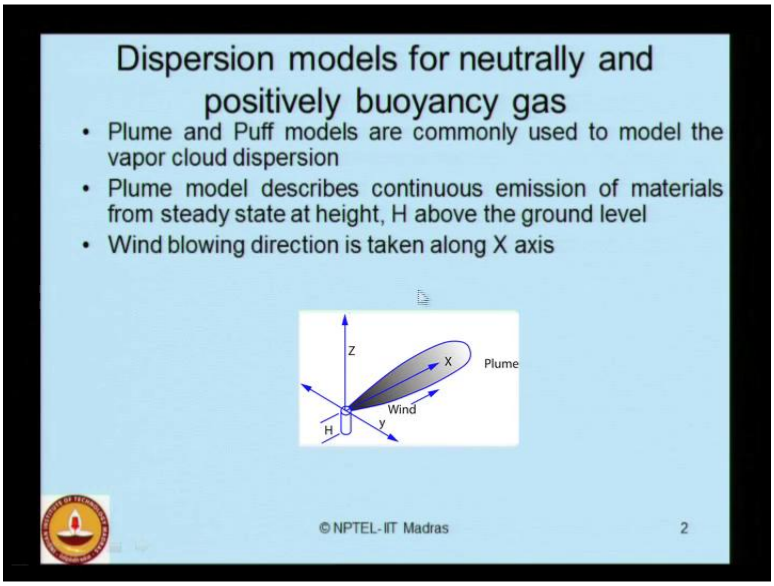

The sixth lecture is now focused on the continuation of the dispersion models what we discussed in lecture-5 in module-2. Dispersion models for neutrally and positively buoyant gas will be discussed. Now, the most commonly used models for this positively bouncy gas or plume model and puff models. They are commonly used to discuss the vapor cloud dispersion. Plume model describes continuous emission of materials from steady state at height, H above the ground level. Whereas, the wind blowing direction is taken along the X axis the coordinate system for the derivation is shown here. So, x is the wind blowing direction, y is the transcend direction to x, and z is the direction along which the height is measured. Let's say, this is my source at height H from the ground, I have emission of the material and the emission is continuous in such cases I discuss what is called a plume model.

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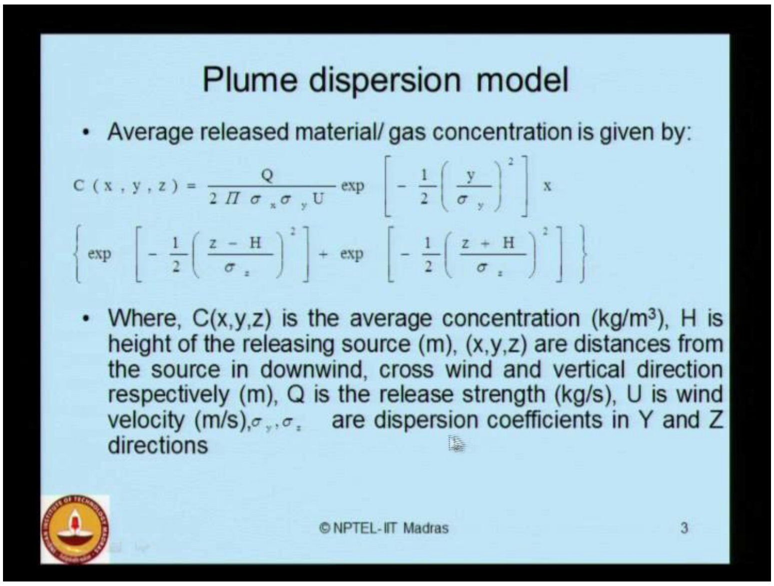

The plume model gives you the average released material per gas concentration. The following equation gives you the average release material in terms of x, y, z coordinate system, which is being explained in the last slide, which gives me the gas concentration. There are variables of Q, sigma x, sigma y, U, y etcetera. We will see them in detail here quickly. C(x, y, z) is the average concentration expressed in kg per cubic meter, H is the height of the releasing source which is given in meters, (x, y, z) are basically the distances from the source measured in the downwind direction, cross wind direction and vertical direction respectively.

So, downwind is along x, cross wind is along y and of course, the vertical direction is measured along the z axis, and the units for H is again given in meters. Q is what we call as released strength which is expressed in kg per second. U is wind velocity expressed in meters per second; sigma y, sigma z are basically called dispersion coefficients in y and z directions respectively.

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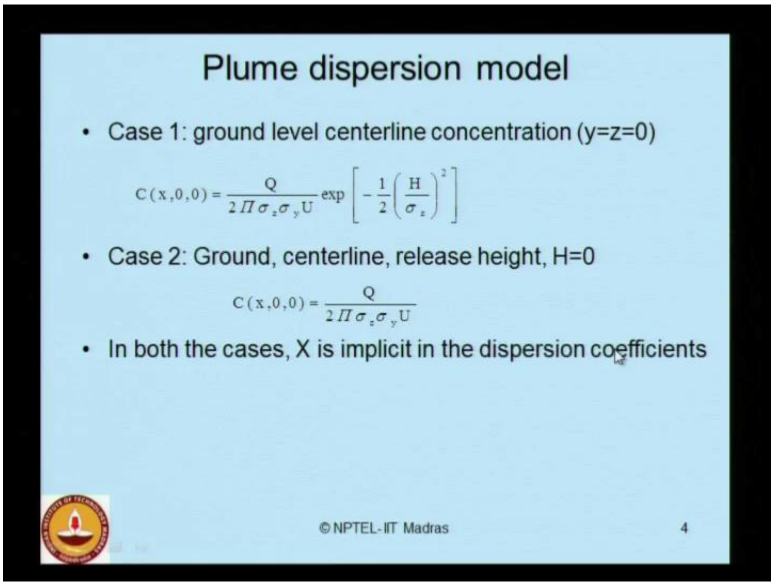

Let us look at different cases of the plume dispersion model. Case 1 is the ground level centerline concentration where y and z are taken as zero. So, if we substitute this variables and the corresponding dispersion coefficients in the previous expression then you get the concentration in terms of x alone, because we are taking about the ground level concentration. So, the cross wind and the vertical wind directions are taken as zero coefficients or zero displacements from the dispersion origin. So, of C f x will be given by this expression. Case 2 is for ground, centerline, release where height is also zero. So, this height term also goes away from this terminology, and substitute back in the principle equation you get again the concentration expression as given below. In both the cases x is implicit in the dispersion coefficients.

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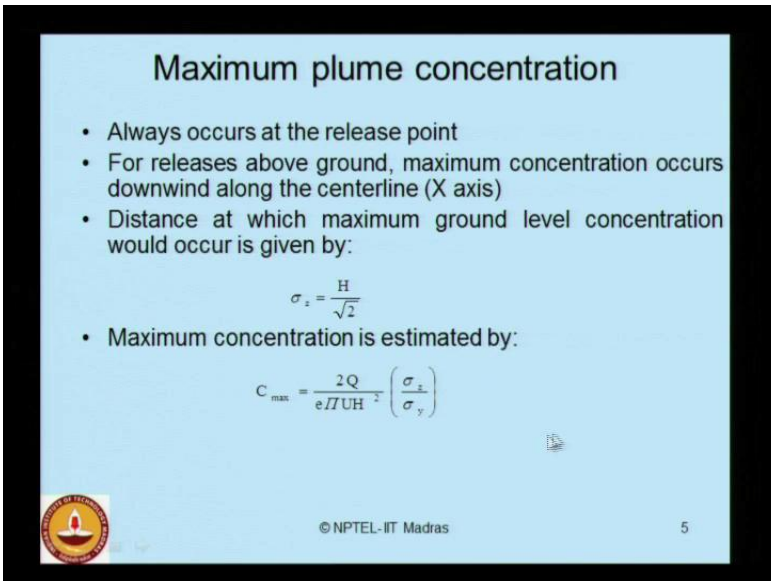

Now, one is interested to know what will be the maximum plume concentration. It always occurs obliviously at the release point, where the gas is being released at height H from the source measured from the ground. For releases above the ground, maximum concentration occurs downwind along the centre line X-axis. The distance at which the maximum ground level concentration would occur is given by this relationship, whereas the maximum concentration is estimated by the following relationship.

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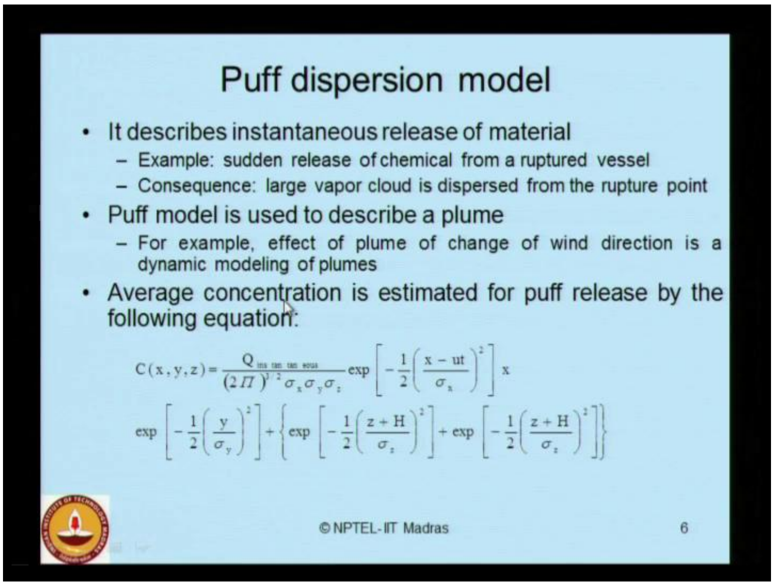

There is another alternative model available in the literature for gas dispersion. This is what we call as a puff dispersion model. Puff dispersion model is generally used for instantaneous release of material, whereas the earlier model which is called plume dispersion model is used for continuous release of material. If you have any gaseous or vapor release, which is instantaneous then we use what is called as a puff dispersion model. For example, there can be a sudden release of chemical from a ruptured vessels, the consequence could be a large vapor cloud is dispersed from the rupture point instantaneously. So, puff model is always used to describe a plume for example, if at a plume of change of wind direction is dynamic modeling of plumes. So in this case, average concentration is estimated for the puff release and given by the following equation, where we say here Q is instantaneous and C(x, y, z) x, y, z as the same meaning as that of the previous expression. C is again the average concentration expressed in kg per second is given by the following relationship.

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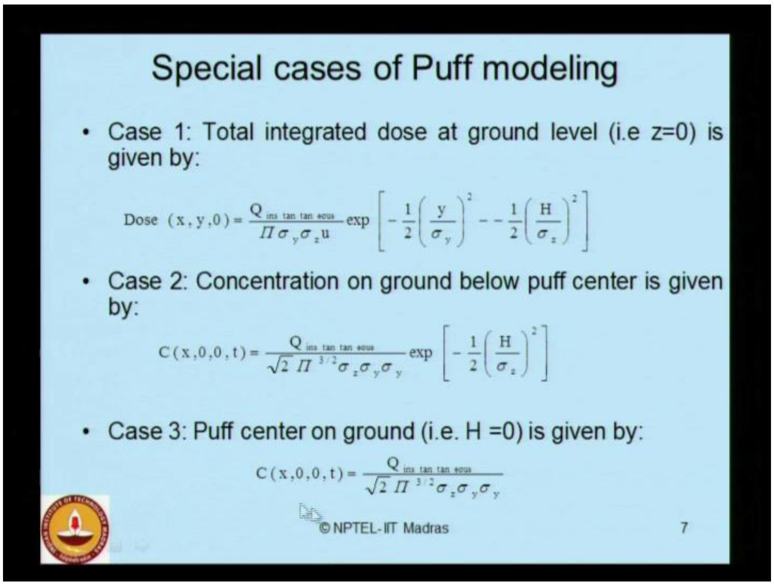

There are certain special cases of puff modeling where we say case 1 - the total integrated dose at ground level; that is considered z value as zero, which is given by the dose x, y and z ordinate is taken as zero. Q instantaneous substituted by this value will give you the doses at the ground level which the total doses of the dispersion. Case 2 can be concentration on the ground below what we called as a puff center at any instantaneous time t is given by this relationship. And case 3 could be puff center on the ground where H is taken as zero at any instantaneous time t is given by this relationship.

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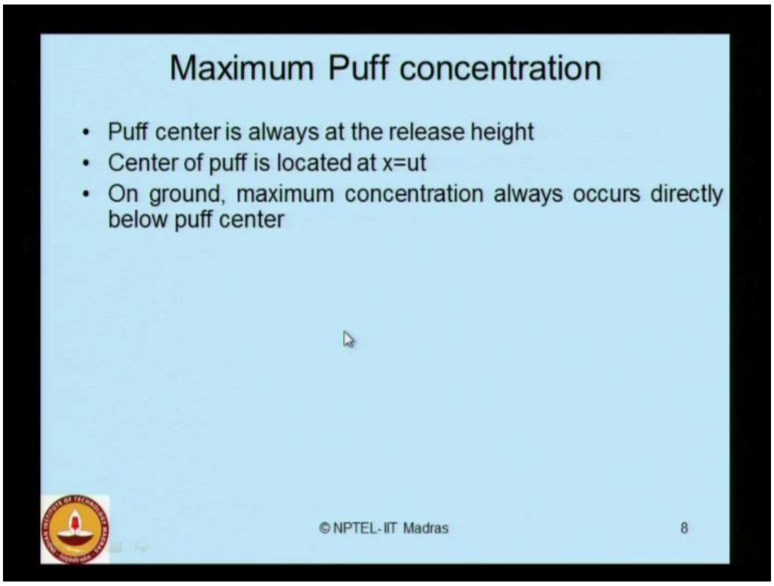

Now, one is also interested to know what would be the maximum puff concentration. Puff center is always at the release height wherever may be the release source, puff center is always located at the release height. Center of puff is located at x is equal to u t on ground, the maximum concentration always occurs directly below the puff center that is a projectile of the puff centre.

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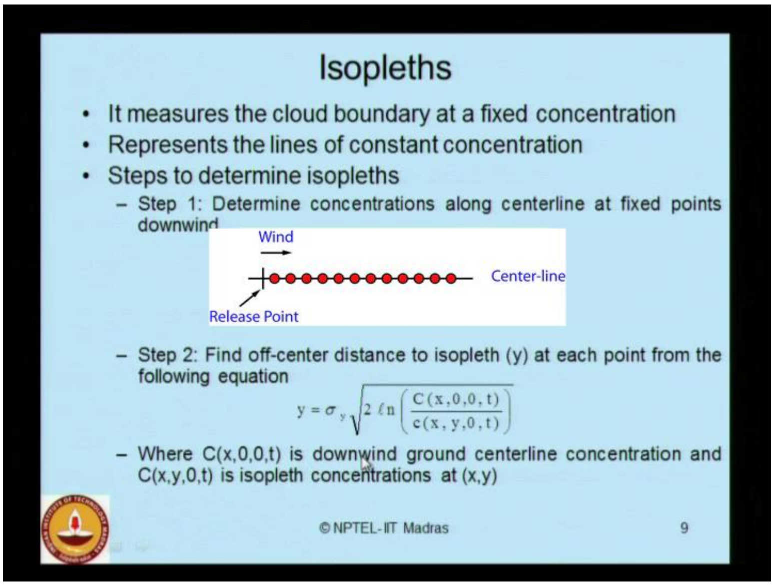

In the literature, we have some interesting terminology called isopleths. Let us ask a question, what do we understand by isopleths? Basically, isopleths measure the cloud boundary of any fixed concentration. So, if you have any gas or a vapor release fixed concentration, it disperses in atmosphere, what would be the cloud boundary of this dispersion in the atmosphere. This is explained by a term called isopleths. This represents the line of constant concentration, because we are fixed in the concentration; we are trying to estimate or set or remark the boundary of this vapor cloud. So, we call them as iso - iso stands for constant or a fixed concentration.

There are different steps to plot the cloud boundaries. Step number one: Determine the concentrations along the centre line at fixed points in the downward wind direction. For example, let us say, this is may release point, this may downwind direction, this may centerline, determine the concentration of the vapor cloud at different points along the centre line in the downwind direction, and you have got to locate these points as per your choice. In step number two: Find the off-centre distance is measured as y that is given by the following equation, which is given as sigma y of 2 log normal of the concentration what we estimated in the previous equation to the centerline concentration which we will have here at x and y.

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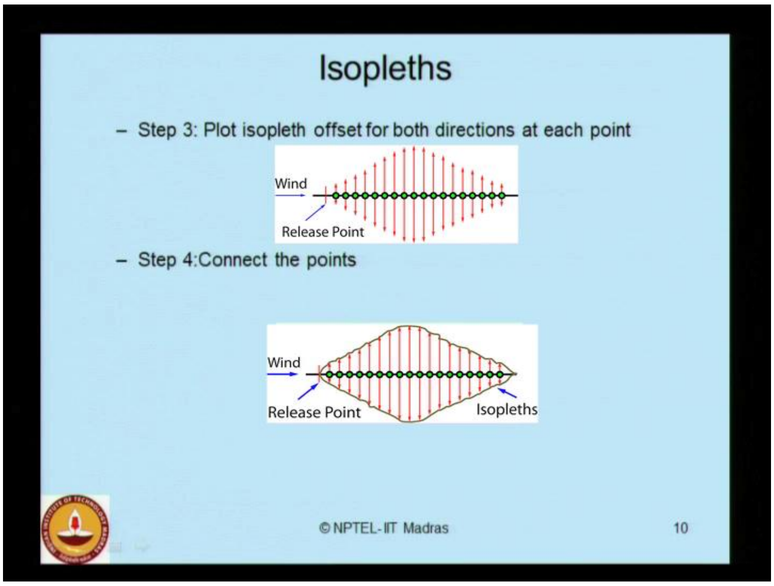

In step number three, using the values what you got in step number two, plot the isopleths offsets for both the directions at each point; that is you have got to plot for both the directions at each point while you have fixed already. This is the release source, this is the downwind direction these are the points of concentration, which you already know, we are trying to plot what will be the extent of the cloud boundary at every point of concentration. Then connect these points and the line joining these points is what we call as isopleths.

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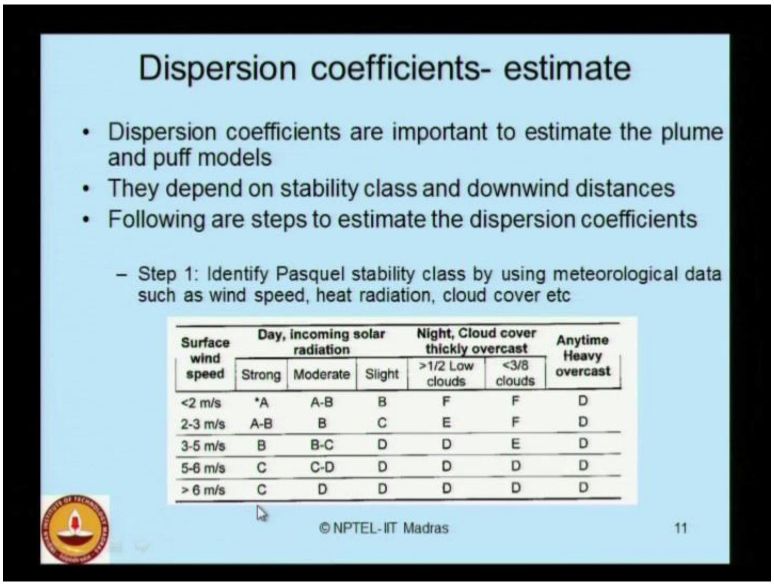

In plume and puff model, we had three categories of dispersion coefficients to be estimated, because if you do not know the values of these dispersion coefficients, it is difficult to estimate the concentration of the gaseous or the vapor release may be a continuous release or may be an instantaneous release. Now, how to estimate the dispersion coefficients, the dispersion coefficients are important to estimate for both the plume and puff models. They depend on the stability class and the windward distances. These are the two variables, which significantly influence the values of the dispersion coefficients.

There are different steps to intimate these coefficients. Step number one - identify Pasquel stability class by using the metrological data such as the wind speed, the heat radiation, the cloud cover etcetera. For example, if you know the surface wind speed, if we know the incoming solar radiation in day, and the cloud cover in the night, then in that case there are different categories of modifications in the day radiation and the night cloud classified as a strong, medium and slight. And you have been given the stability class in terms of A, B, C, D, E etcetera.

For different surface wind speeds less than two meter per second to greater than six meter per second, we have got different Pasquel stability class. So, for a given sight of known meteorological data which is known from the wind speed, heat radiation, cloud cover etcetera for a given side. You should first identify what is your Pasquel stability class.

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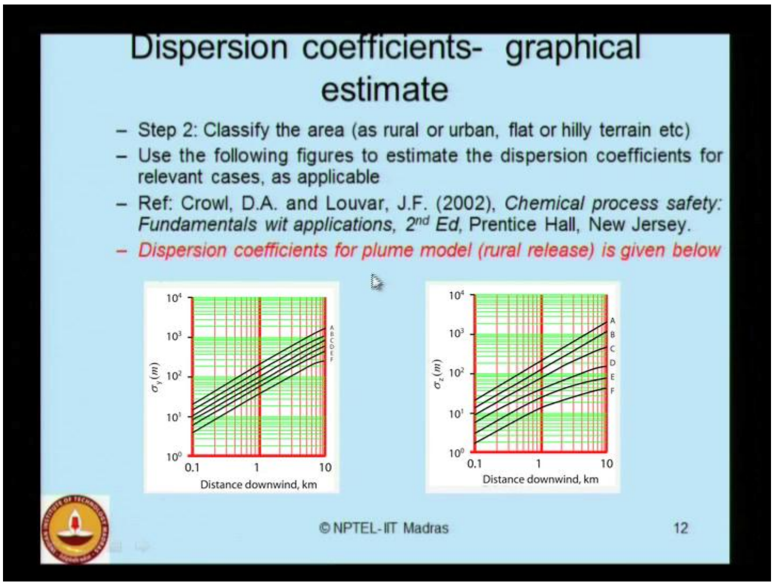

Now, obviously, ladies and gentlemen, you will like to know what would be the meaning of these alphabetic characteristics of A, B, C etcetera. The dispersion coefficients can be determined by two ways one is a graphical technique, other is by algebraic equations. So, before we explain what are those categories of A, B, C, D. Let us see, what do we do in the next step. Now you classify the area whether it is a rural area or an urban area, if it is a flat terrain or a hilly terrain, because the rural and urban category of the geographical status, the flatten, hilly terrain significantly affects the dispersion coefficients which will in turn affect the concentration of dispersion of the vapor cloud.

You can use the following figure to estimate the dispersion coefficients like sigma y and sigma z, Crowl and Louvar has discussed this figure in 2002. The dispersion coefficient shown below or for the plume model for a rural release. You can look here, if you know the downward distance in kilometers from the source, we can always find depending upon your Pasquel stability class A, B, C, D, E, F for a given downward distance in kilometers. You will know what is going to be where sigma z as a dispersion coefficient or what is going to be your sigma y in meters a dispersion coefficient. You may wonder, why the dispersion coefficients carry units? This is for the dimension stability in the given concentration of the vapor cloud in kg per second. So, you can estimate sigma y and sigma z, which can be used in the plume model for a rural release. Now for an urban release, you have these two figures, which will vary significantly from that of rural release.

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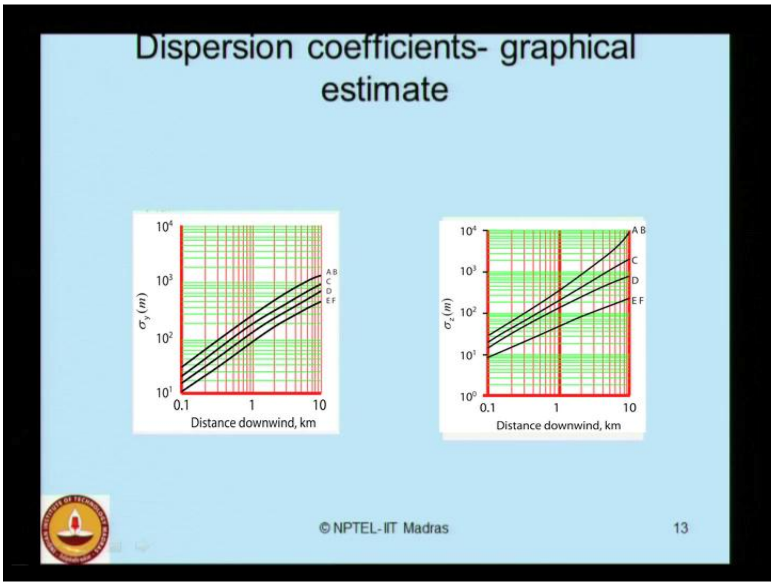

So, this is these figures of for the urban release if you know the downward distance in kilometers from the source of your release for identified Pasquel stability class from A to F, you should be able to obtain sigma y and sigma z which are called the dispersion coefficients, which are required to estimate the release concentration in k g per second for a plume model.

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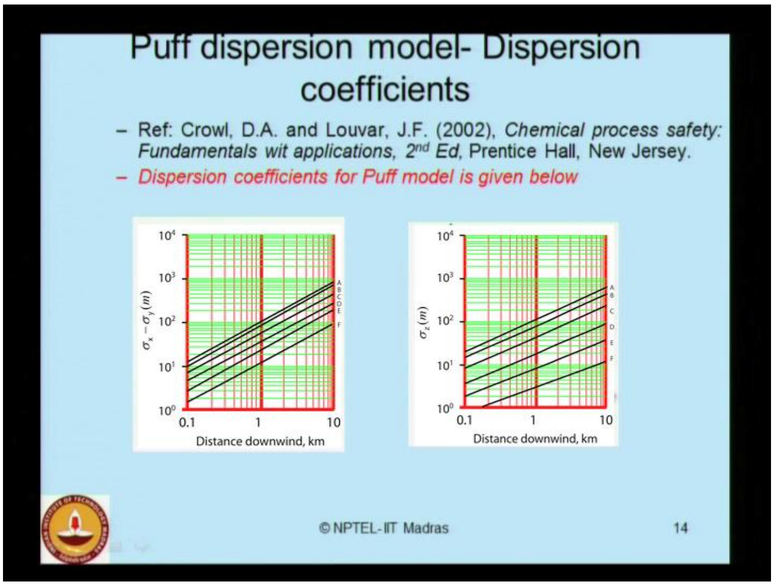

Similarly, for a puff model the dispersion coefficients can be obtained by the given two figures here. The downward distances is plotted in the x axis in kilometers whereas, y axis gives you sigma y x minus sigma y or sigma z in terms of A, B, C, D the Pasquel quos stability.

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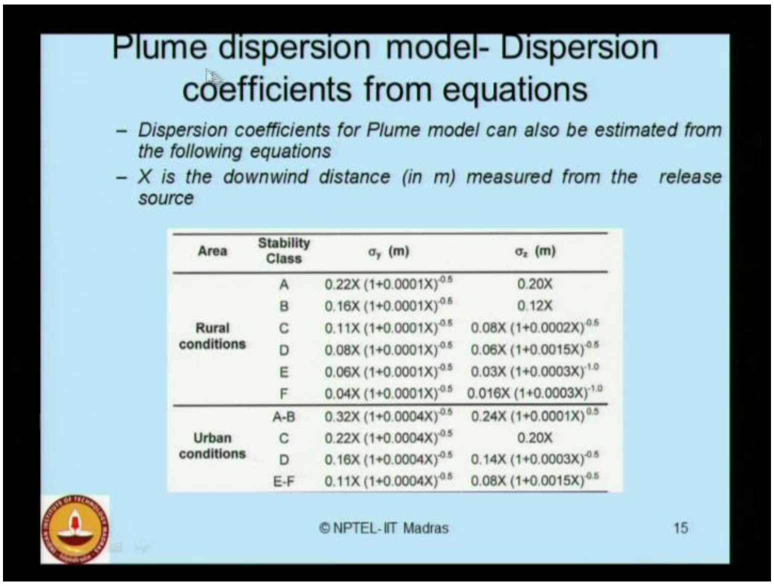

The dispersion coefficient can also be obtained for different stability class as shown here. For rural and urban condition for a plume model refer back to my previous lecture explaining what are the stability class A to F, for example, A is completely unstable and

F is totally stable. So, there is equation coefficient for plume model can also be estimated from the following equations. For example, if you know the Pasquel stability class depending upon the meteorologically data. For example, let us say your case is B and you have got a rural condition then to estimate sigma y use this equation to estimate sigma z use these equation, where x in these equations or the downward distance in meters measured from the released source.

So, ladies and gentlemen, you will be able to estimate the dispersion coefficients either from the graphs which has been shown in the previous slide or from the equations given for different class of areas like rural and urban conditions respectively for the plume model.

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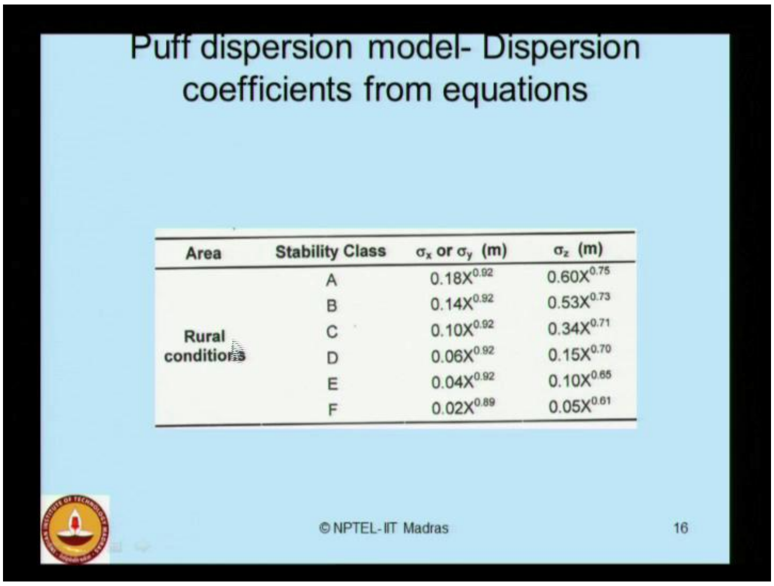

And for the puff model similarly if you know the condition of stability class Pasquel stability A to F, you can estimate sigma x or sigma y in terms of meters and sigma z for a specific class for rural conditions.

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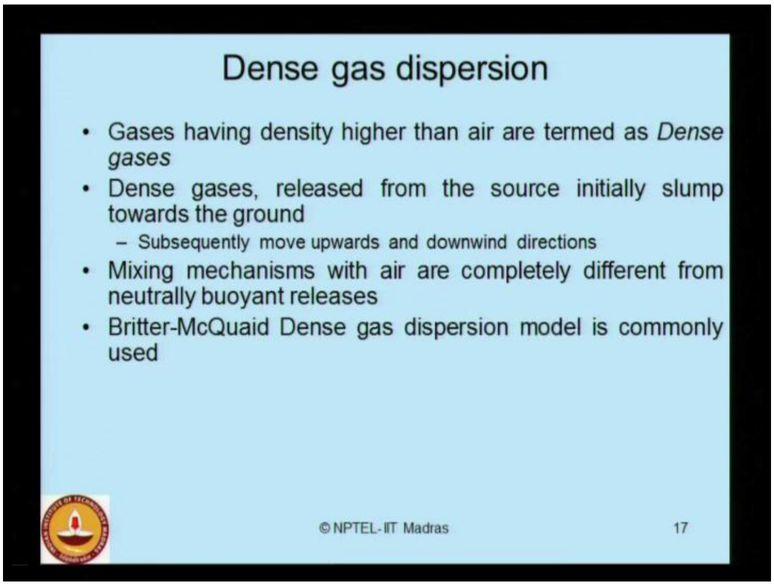

Now, let us ask a question, what do we understand by the terminology called dense gas dispersion? Gases having density higher than air are termed as dense gases. Dense gases, released from the source initially slump towards the ground this has been a literary observation made by very many experiments; subsequently they will move upwards and the downward directions. Mixing mechanisms of these kind of dense air are completely different from that of neutrally buoyant releases. The plume and puff models what we discussed in the previous present slides are meant for neutrally buoyant gas releases, which causes a vapor cloud the release may be instantaneous or the release may be continuous at an height H from the source from measured from the ground. Whereas, if you have got a dense gas getting dispersed in atmosphere then the mixing mechanisms of the dense gas or completely different from that of neutrally buoyant releases. Britter-McQuaid dense gas dispersion model is what we commonly see in the literature.

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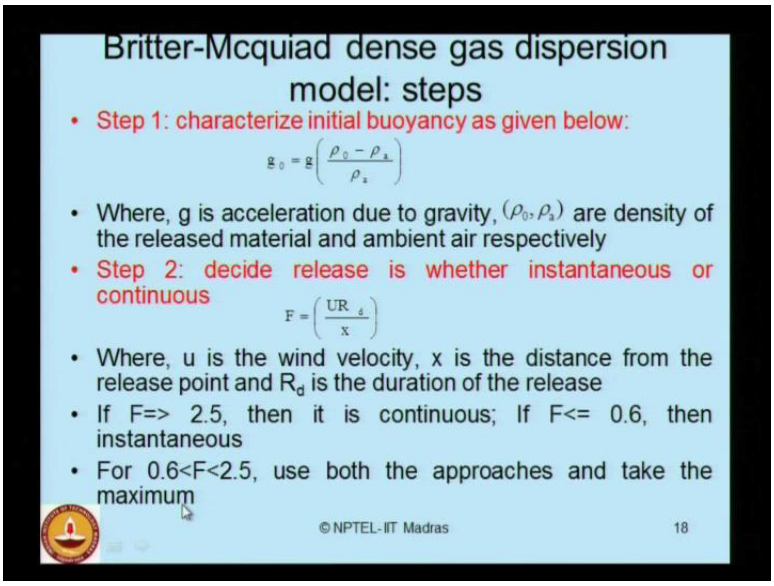

Now, we will discuss Britter-McQuaid dense gas dispersion models. There are different steps to estimate this. Step number one: characterize the initial buoyancy which is given by the following equation. In this equation, g is the acceleration due to gravity rho 0 and rho a are density of the released material and ambient air respectively, whereas the initial buoyancy will given by g naught. In step number two, decide the release is whether instantaneous or continuous, because you would like to know how the mixing going to take place if it is a dense gas. If the release is instantaneous, then the model is different; if the release is continuous for a specific time of about 10, 15 seconds say for example, then the mixing mechanism is different.

So, let us first decide whether the release is instantaneous or continuous, how do you decide that. The following equation will help you to decide, whether the release is instantaneous. In the above expression U is the wind velocity, x is the distance from the release point, and R d is the duration of the release. By substituting this equations, if you get f greater than or equal to 2.5 then it is taken as continuous. If the f value comes to be less than or equal to 0.6, then the release is instantaneous. Now for the value of f which is between 0.6 and 2.5 you can use both approaches that is the instantaneous release approach mixing, and the continuous release approach mixing, and try to find the maximum of these two and use it in your study.

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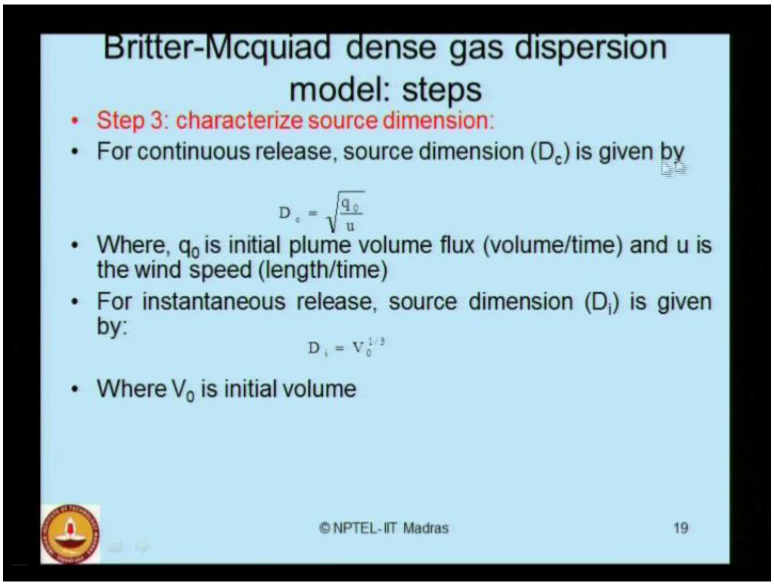

Step number three: Characterize the source dimension, which has got to be done for the problem. For continuous release the source dimension D c is given by the following equation, where, q 0 is initial plume volume flux which is nothing but the volume divided by the time. And u is the wind speed which is the again the units in length per time. For instantaneous release the source dimension D i is given by cubic root of v naught where v naught is the initial volume. Ladies and gentlemen, it is a very simple expression to understand D c stands for continuous and D i stands for instantaneous. So, you will know whether the release is instantaneous or continuous depending upon the f value from the previous equation. If you have a f value between 0.6 and 2.5, you have to follow both the models and get the maximum out of these two for your mathematical modeling.

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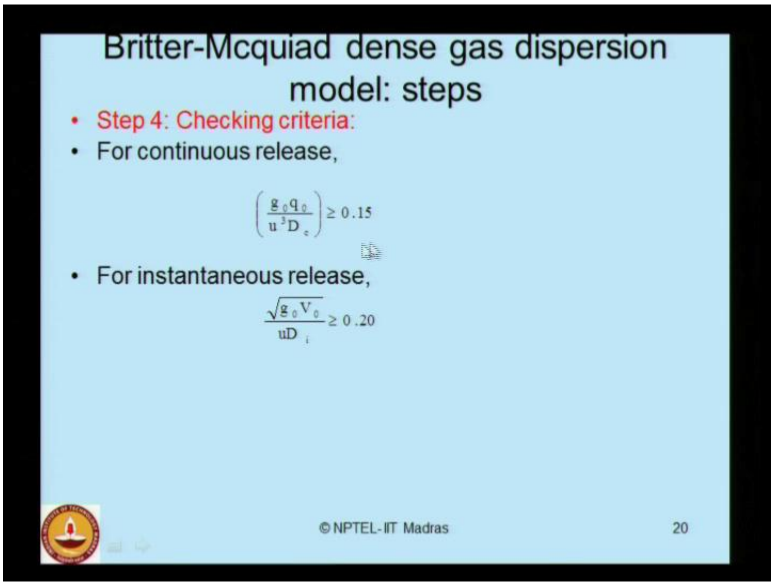

Then let us say, what would be the checking criteria? For a continuous release and for instantaneous release we have got to estimate q naught, g naught, u cube, d c or d i for instantaneous and continuous respectively. If these values are more than or equal to 0.15 and 0.2 respectively then we can check the status

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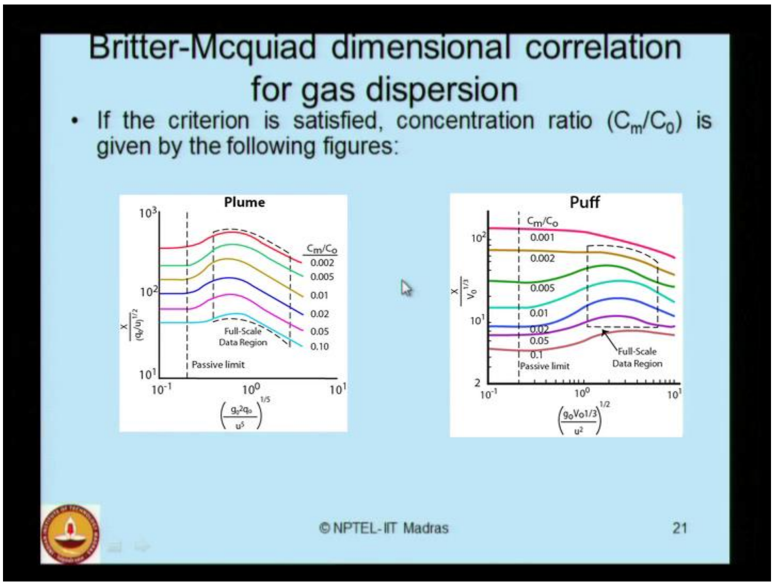

Now the dimensional correlation for gas dispersion in the Britter-Mcquaid model can be discussed. If the criterion is satisfied, as we see in the previous two equation then we estimate what is call concentration ratio C m by C naught is given by two figures for plume model, puff model. On the other hand, one is for the continuous release, one is for the instantaneous release.

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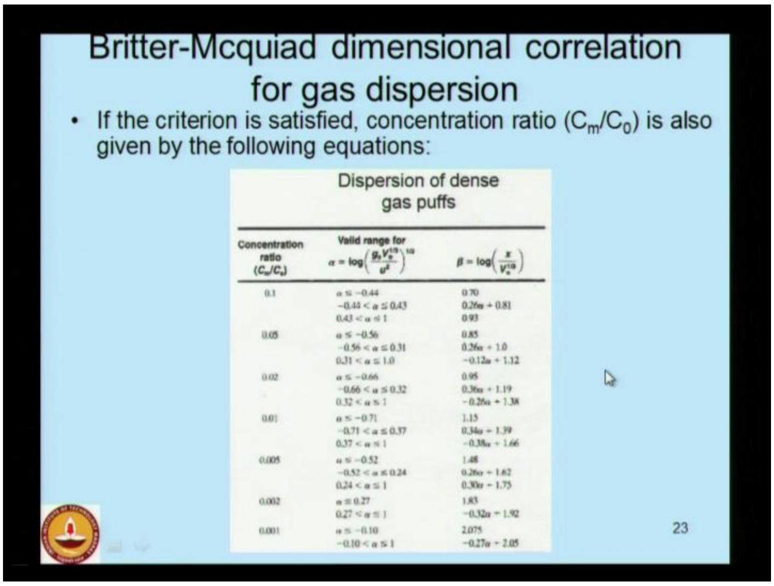

You can also estimate a dimensional correlation using the following set of equations and you can find the concentration ratio C m by C naught for plume models. You can also find for the dense gas puff models using the following equations. You can either use the graphical formats to estimate the correlation dimensions or you can use the equations to find the correlation dimensions. If the criterion is satisfied as expressed in the previous equation, the concentration ratio C m by C naught can also be given for the puff model from the following equations.

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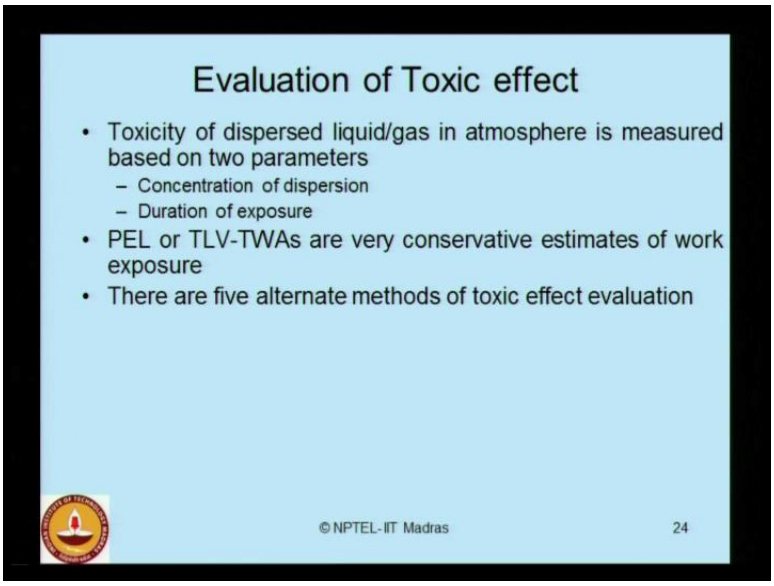

Now, after understanding whether it is an instantaneous release or a continuous release. After understanding whether it is the dense gas dispersion or a vapor cloud dispersion, we have estimated the concentration; we have estimated the duration; we have checked and we've said what to be the concentration ratio of mixture. Then we will talk about what is called the toxic effect. If at all the gas or vapor cloud get dispersed in atmosphere, it causes what we call toxicity. So, what is the toxic effect, or how to evaluate this toxic effect? Toxicity of a dispersed liquid or gas in atmosphere is usually measured based on two parameters. The foremost parameters is the concentration of dispersion; obviously, the second is also very important what is the duration of exposure to this toxicity by the human being. Because as we said in the previous modules, ladies and gentlemen, you can recollect that the safety the ocean standard for safety depends not only on the concentrations of the chemicals being exposed, it also depends on what is the duration of exposure during the working hours of the employees.

So, we have already remember that PEL or TLV - time weighted average are very conservative estimates of work exposure. They are considered as standards we discuss them in detail in the previous modules, we already know how they are estimated algebraically or arithmetically, but there is always a feeling that the TLV-TWA estimates are very conservative for a given work exposure. Then what are the alternatives for PEL or TLV-TWAs. There are five alternative methods suggested to evaluate a toxic effect. Let us see what are they.

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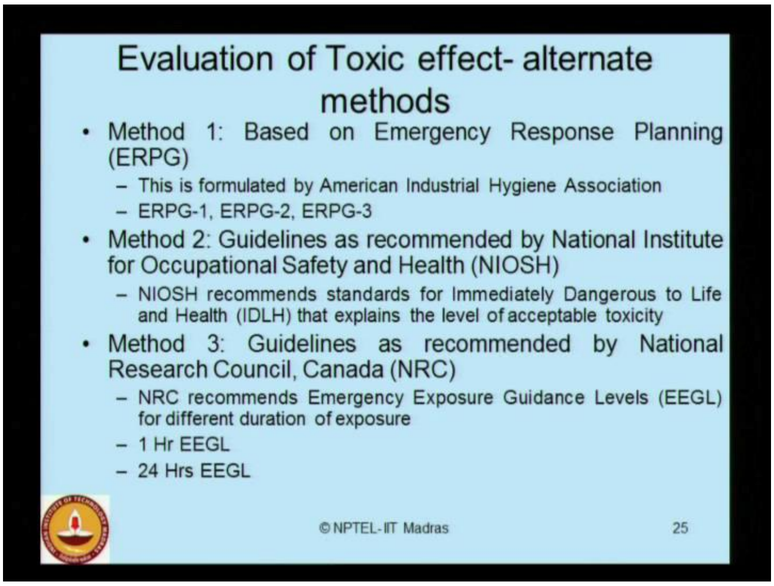

Method number one is based on emergency response planning ERPG. You will be recollecting this terminology we have been using this for my HAZOP analysis which I have explained in the previous module. This is actually formulated by American industrial hygiene association. There are different levels of emergency response planning guidelines they ultimately give you what is called hazard distance; ERPG level one, ERPG level two, and ERPG level three.

Here I leave a small tutorial question to the listeners that what do you understand ERPG-1, 2, and 3 as explained by AIHA and what are the technical differences between these three levels of exposure of toxic effect on human being in the working environment? You can try to answer this question, the previous modules on HAZOP analysis has answers for these questions. The second method of evaluating toxic effect is suggested by the recommendations given by the national institute for occupational safety and health what we called as NIOSH. NIOSH recommends standards for immediately dangerous to life and health. These standards are shortly called as IDLH which explains the level of acceptable toxicity.

There is third method by which we can evaluate toxic effect on human being for work exposure. These are as per the guidelines and the recommendations given by national research council, Canada, which is called as NRC. NRC recommends emergency exposure guideline levels. So, they give you EEGL levels for different duration of exposure for one hour EEGL, 24 hours EEGL. These are standards available in the literature.

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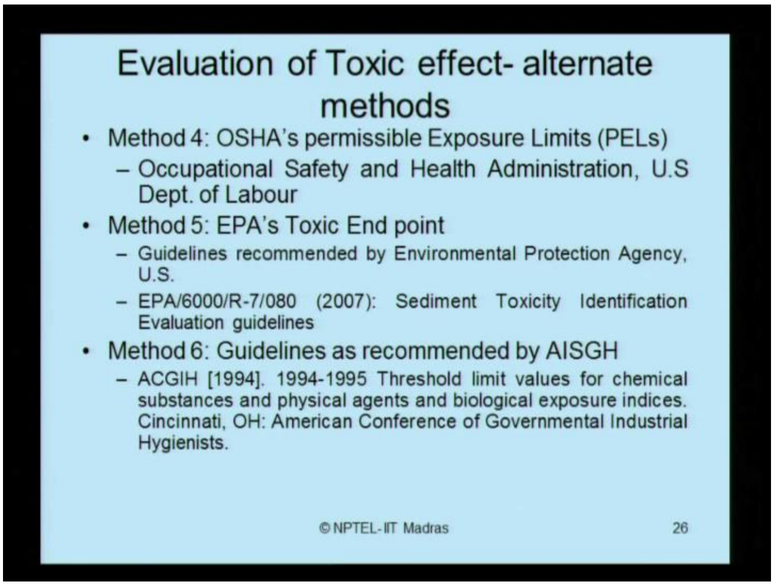

The fourth method is based on OSHA's permissible exposure limits what we famously called as PEL's. OSHA is abbreviating for occupational safety and health administration US departments of labor. There is the last method by which you can evaluate the toxic effect on working exposed work personal that is given by EPA's toxic end point. These are based on the guidelines recommended by environmental protection agency united states. So, the specific class which I recommends this is EPA 6000 R-7 080, 2007, which talks about sediment toxicity identification and evaluation guidelines.

There is a sixth method by which you can do the evaluation of toxic effect. This is as for the guidelines and the recommendations given by AISGH 1994. This is basically the threshold limit values for chemical substances and physical agents and the biological exposure indices given by an American conference of governmental industrial hygienists.

Thank you.