**NPTEL**

**NPTEL ONLINE CERTIFICATION COURSE**

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

**Module 3:**
**Environmental issues and Management**
**Lecture 6: Dispersion release models for gas**

Dear friends welcome to the 6th lecture on module three there we are focusing environmental issues and management in this lecture we are going to discuss about dispersion release models which are applicable to gaseous releases this is lecture under module three in the course of HSE in offshore and petroleum engineering at NPTEL IIT Madras.

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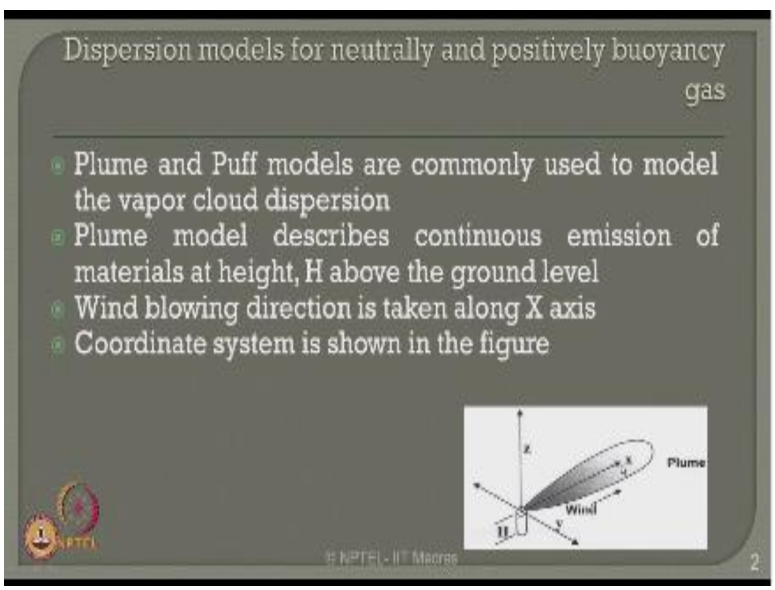


There are various dispersion models available in the literature which we are seen in the earlier lectures or chemical releases now let us talk about various dispersions models the playing one pluck models which are useful for neutrally and positively buoyant gases the plume of puff models are commonly used to model the vapor cloud dispersion which we are see in detail in the last lectures also the plume model describes the continuous emission of materials of height H above the ground level.

The wind blowing direction is generally taken along the X-axis and the coordinate system for evaluation or estimating the dispersion model for a plume release is given in the figure here where along the wind blow direction will always see X is taken along the wind direction Y is taken normal to the wind direction and Z is measured along the altitude of height of the building so the entire cloud dispersion which is form but dispersion of the gas from the specific source which can be a stack of a building is actually a plume model which can be estimated from the equations which will given to you in the next slide onward.

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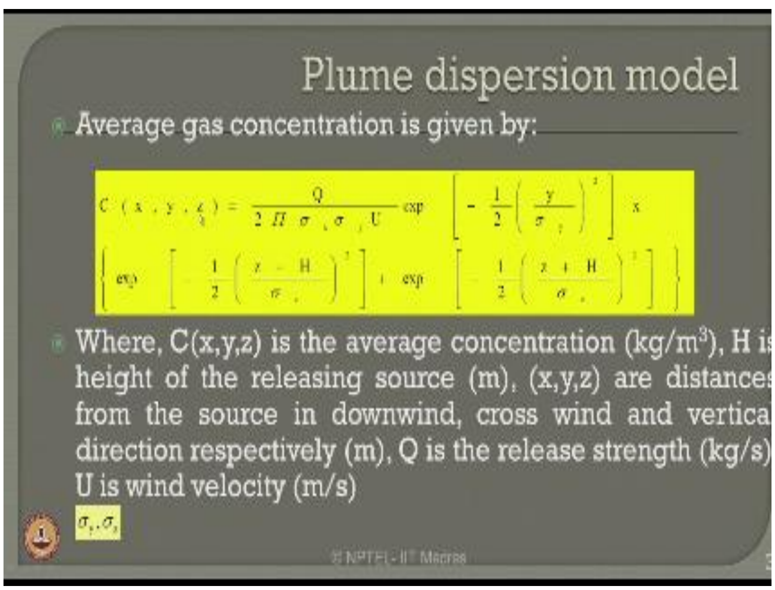


Then the plume release models or dispersion model gives you average gas concentration from equation available in the screen now by in this equation C function of xy and z where xy and z.

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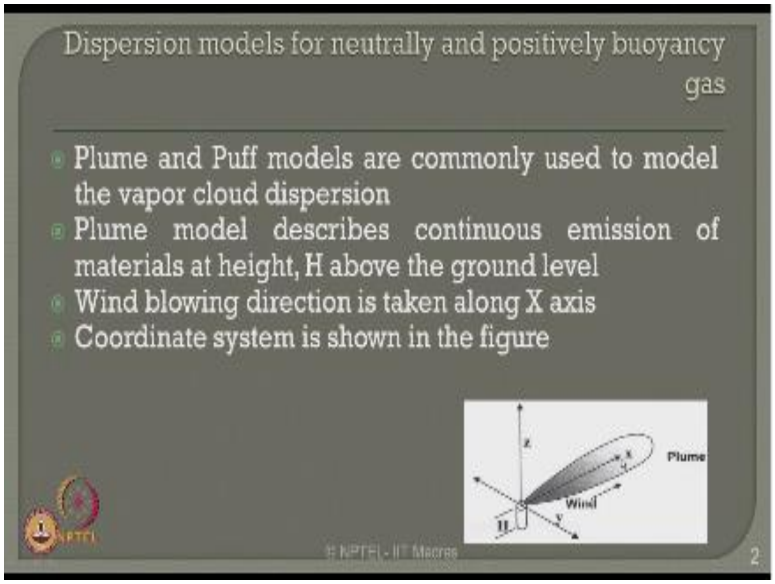


Or measure respectively along the wind direction normal to the wind direction and along the altitude of the height of the building respectively.

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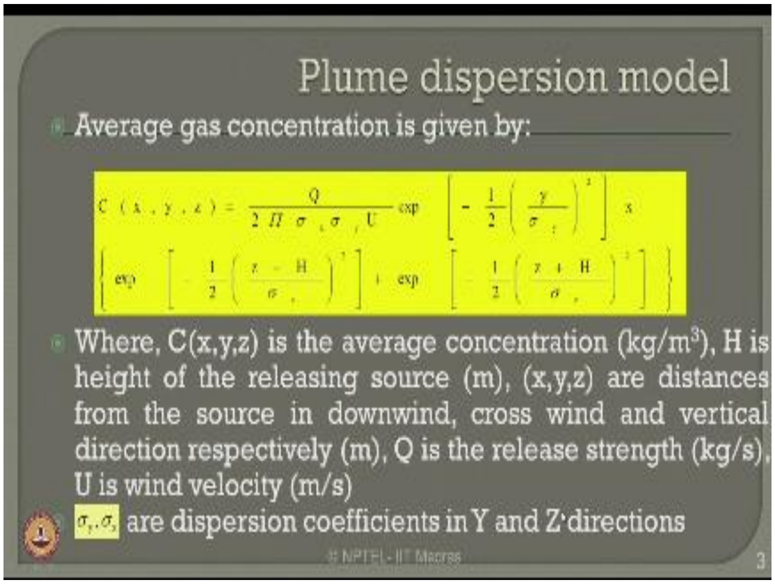


So see x y z is actually the average concentration of the gas released using the plume dispersion model which is given in the units of Kg/m3 h in this equation what you see is the height of the releasing source which is given in meters x y z are nothing but the distances from the source in the downwind cross wind and vertical directions respectively all of them in meters because you have multiply as here Q is the release strength which is kg/s which is the release strength of the gas of the specific concentration and you use in this equation is nothing but the wind velocity in m/s.

Whereas the σ, σy use in this equation in terms of σy and z x y and z are the dispersion coefficients in the x y and z direction respectively.

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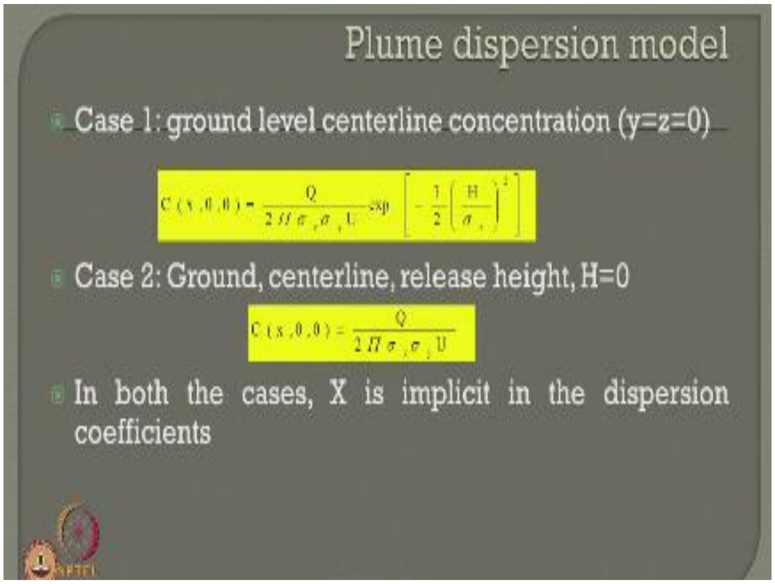


The plume release model can be calculated as different cases arise for example let us take case 1 where the ground level center line concentration can be given by this equation the moment is a ground level I would always associate z = 0 I am talking about a specific point of release concentration therefore y is also 0 when I said in this equation y and z is 0 I will get c( x) which can given by this equation case 2 can be ground center line and release height but of course h is taken as 0 in this case.

So I can always find out the ground center line release of the plume model by given this equation as the concentration of the gas release in both the case of the some equation X you can see is implicit is in dispersion coefficients automatically.

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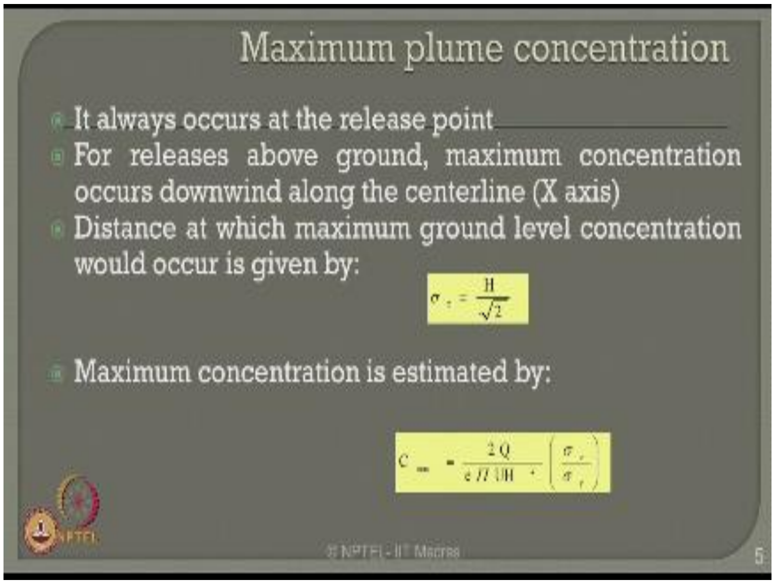


In σy and σz respectively now a question comes what to be the value of maximum plume concentration maximum plume concentration always occurs at the release point the release point can be tip of the stack of any chimney or any tower which is dispersing gas into the environment for releases above ground the maximum concentration occurs in the downward wind direction along the center line which is taken as x axis for the whole calculation the distance at which maximum ground level concentration.

Would occur is given by a relationship I just see from here the maximum concentration see max is estimated by your relationship as you see here whereas σz and σy are the dispersion coefficients available along z axis and y axis respectively.

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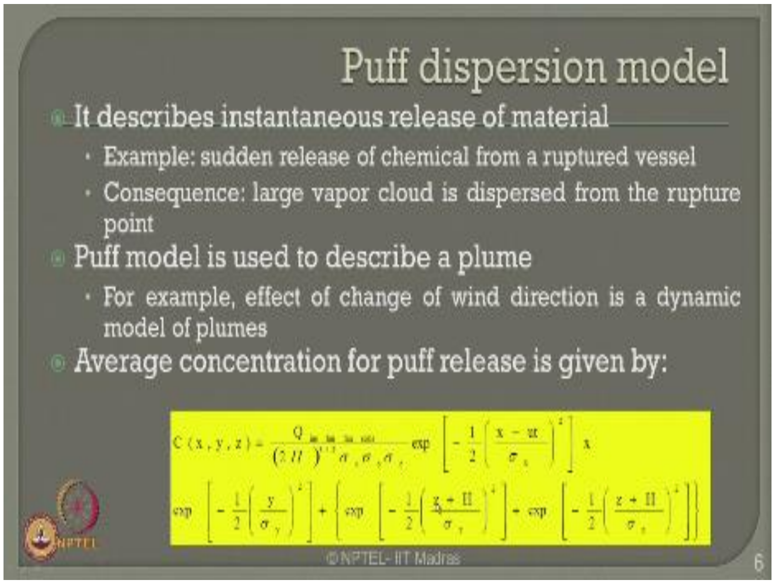


Alternatively for instant time is release we can also look at puff dispersion models for continuous release you have already seen plume dispersion models for instantaneous release one looks for a puff dispersion model this describes instantaneous release of material example could be a sudden release of chemical from a rupture vessel consequences can be large vapor cloud is dispersed from the rupture point puff model is use to describe a plume alternatively for a example effect of change of wind direction.

Is a dynamic model of plumes the average concentration for puff release is given by the equation shown here where c x y z is actually the con concentration at different points of x y z measured respectively as shown in the previous slide so depends upon instantaneous release of energy Q where are the $\sigma x$ $\sigma y$ and $\sigma z$ and of course h x y and z to carry the same conventional meaning as expressed in the last equation.

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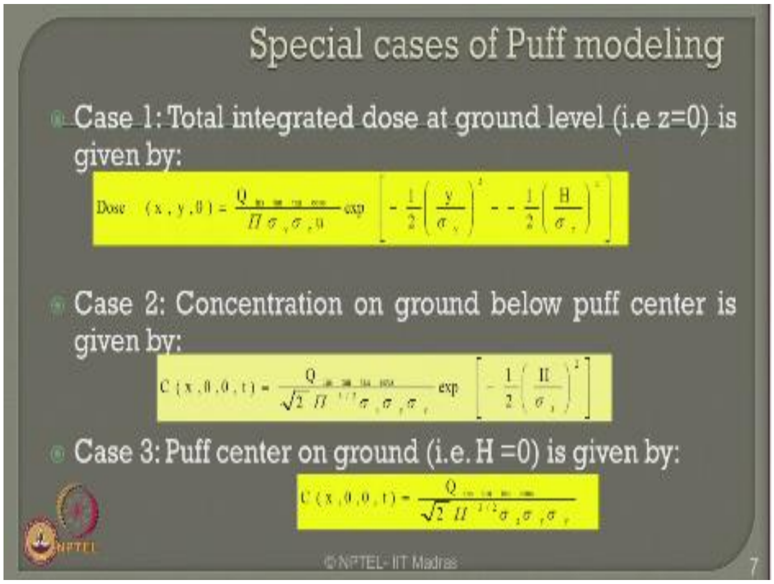


There can be some certain specific cases what you called special cases of puff model let say case one the total integrated dose to be obtained a ground level that is where z is 0 is given by a dosage x y where 0 where can taken an energy of instantaneous is releases of the gas given by this expression if one wants to find out the concentration on ground exactly below the puff center then it came a given by this equation as you see here y is also said to 0 in this case if one is interested to find out.

The puff center on the ground where h is given to be 0 then one can find in this case of given equation as you see here in all the questions the σz y and x are actually given by the dispersion coefficient concentrations at various access x y z respectively.

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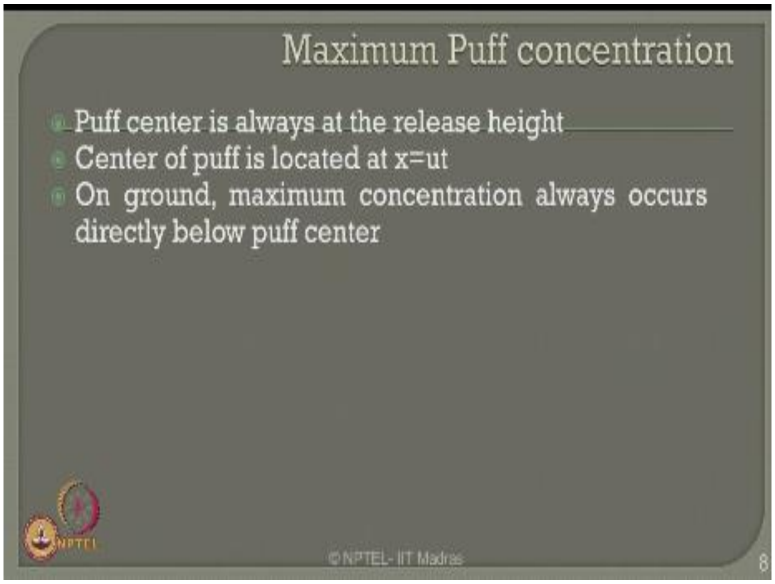


The maximum puff concentration is always at the release height the puff center is taken as release height the center puff is located at x = ut on ground the maximum concentration always occurs directly below the puff center.

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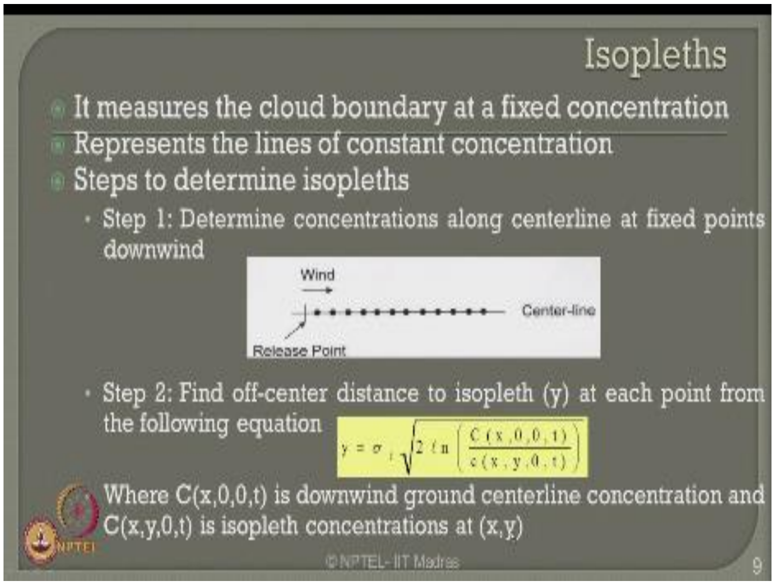


Friends there is a concept in dispersion release models what to call as Isopleths, Isopleths measure the cloud boundary at fixed concentration Isopleths actually a represent lines of constant concentration there are different steps available in the literature to compute or to plot Isopleths step number 1 determine the concentrations along the center line and fixed point in the down wind direction as you see here is may be in progressive direction this becomes a center a line of my dispersion model.

Is a release point keep on plotting or finding out concentration at different points along the fixed line which is in the progressive direction of downwind word no at these points we know the concentrations available step number 2 find the option that distance to Isopleths which is given by y at each point from the following equation for example in each point I want to find the half center distance to Isopleths which is given by this equation where in this equation see x 0 0 T is a downwind ground center line concentration what to get from this particular point. And see x y 0 t is an Isoplethe concentration at a specific value of x and y respectively.

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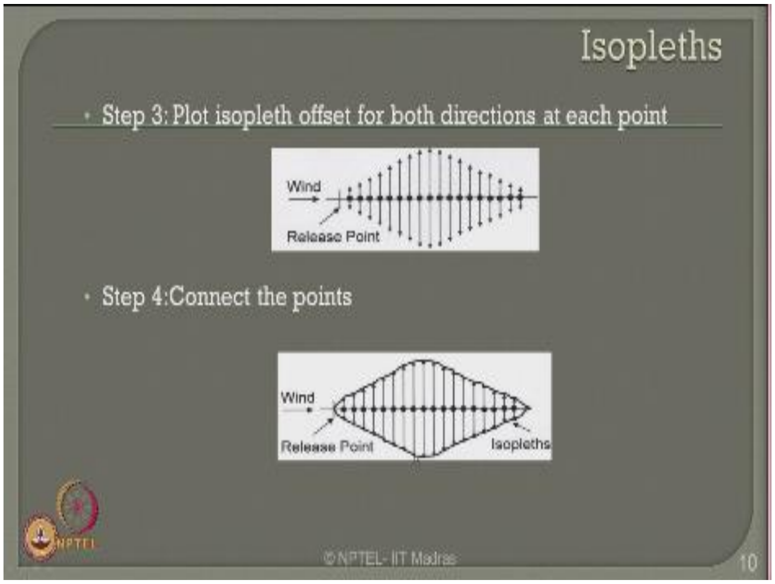


In step number 3 I plot the Isopleths because I know the opposite of the concentration in different points now I plot the Isopleths opposites for both the directions at each point then I connect the opposite points as you see here and I draw Isopleths.

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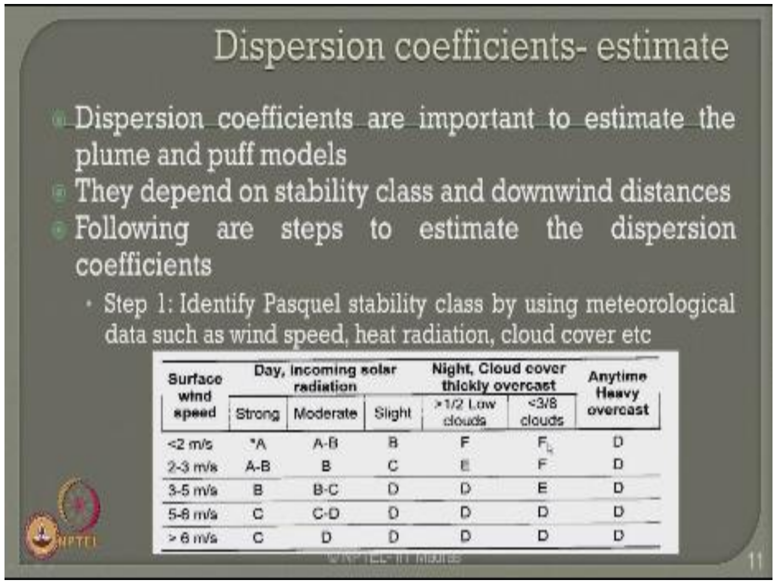


| Surface wind speed | Day, incoming solar radiation | | | Night, Cloud cover thickly overcast | | Anytime Heavy overcast |
|---|---|---|---|---|---|---|
| | Strong | Moderate | Slight | >1/2 Low clouds | <3/8 clouds | |
| <2 m/s | *A | A-B | B | F | F | D |
| 2-3 m/s | A-B | B | C | E | F | D |
| 3-5 m/s | B | B-C | D | D | E | D |
| 5-6 m/s | C | C-D | D | D | D | D |
| > 6 m/s | C | D | D | D | D | D |

One major issue which is generally focused in estimate of release models is the dispersion coefficient σx σy and σz respectively which are very vital to estimate the gas release concentration do it instantaneous model or be the continuous study state release models the dispersion coefficients are important to estimate the plume puff model releases they actually depend on stability class and downwind distances following are some of the steps to estimate the dispersion coefficients.

One can identify the Pascal stability class by using meteorological data such as wind speed heat radiation and cloud cover etc.  Now you can see here for the surface winds speed varying from 2m/s to more than 6m/s I have the Pascal stability class varying from A to that of F where they are normal clattered as ABCDF depends upon what could be the dispersion coefficient for different day incoming solar radiation and night cloud cover or alternatively at any time during the heavy overcast.

So I divide the stability class into different normal cluster not only depending upon the surface wind speed but also depending upon whether it is day or night further it is subdivided to slight moderate and strong incoming solar radiation where as for the night cloud cover can be taken as either more than 50% the low clouds or less than 38 of the cloud formation.

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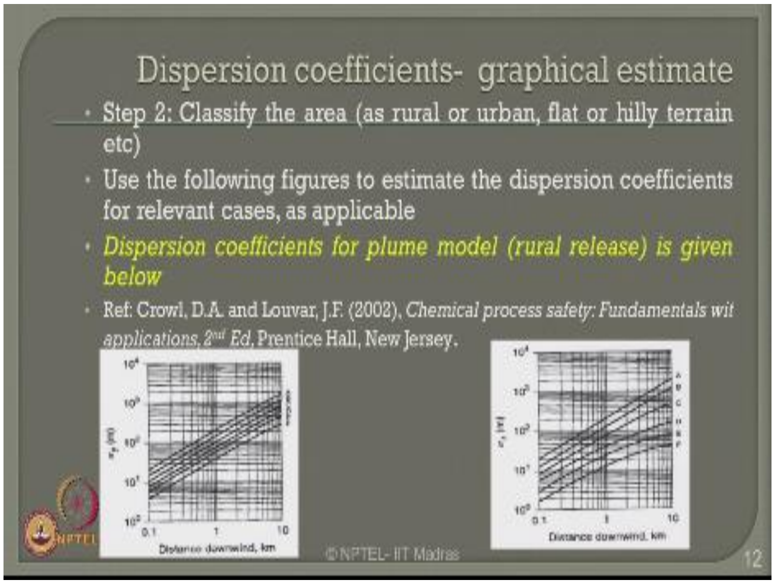


So for different Pascal stability class I can estimate the dispersion coefficients graphically using this figures seen here a step number 2 classified area find out whether it is a rural urban or hhilly terrain use the following figures to estimate dispersion coefficients for relevant cases as applicable dispersion coefficients for plume release model for a rural sector is given below to the reference to crowl and lower in 2002 this is actually a log, log plot which talks about x axis a downward distance in kilometers.

And y axis as gone to dispersion release coefficients σy and σz respectively so for different Pascal stability class varying from ABCDF in both the cases you will see that if you know the downward wind distance whether you want to calculate if you know the stability class project that a stability class and get the dispersion coefficient respectively on the other hand in this case as well if you know the downward distance vary want to calculate the stability class where you want to calculate dispersion coefficient.

Who stability class is known for you then depending upon the downward distance in kilometer draw a vertical line intersect that line to the respective stability class lines and projective it horizontally to get back a dispersion coefficient maybe σy or σz respectively which need to use them in the release models in the equation shown in the few slides earlier.

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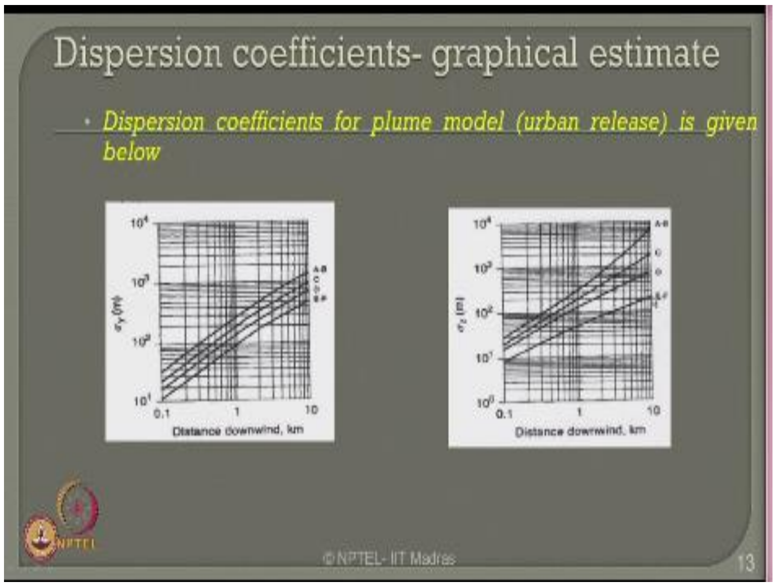


Similarly one can also determine the dispersion coefficients using graphical estimates for plume release models for advent release centers the earlier figure was given for rural release is for urban release again in this case you got Pascal stability class plotted we will always the see the Pascal stability class in more or the cases remains linear in a log, log plot but of course in all the cases earlier as well as in this case both rural and urban you will see the values for the stability class A and B or much higher compared that are the value for triple class E and F respectively.

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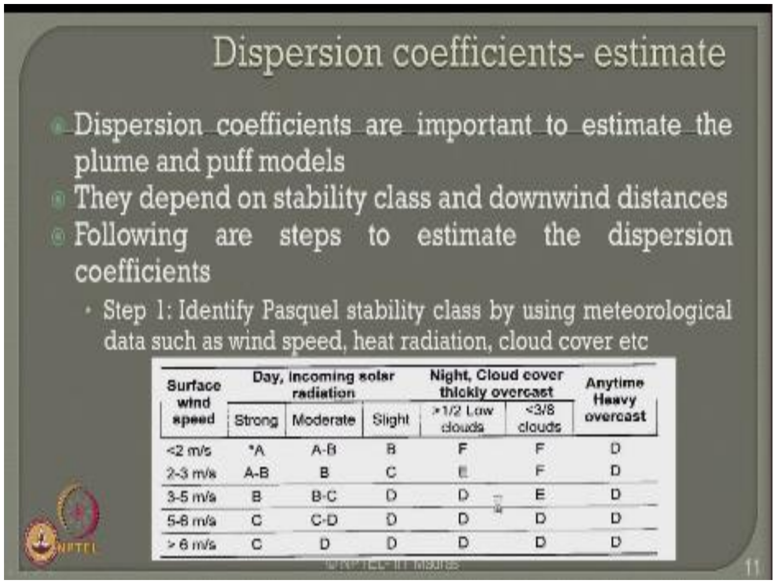


Where Ab refers to AB refers to the wind speed surface wind speed as low as 2m/s are varying from 2 to 3m/s whereas E and F have a marginal variation which can vary from 2 to 5m/s and so on and so forth.

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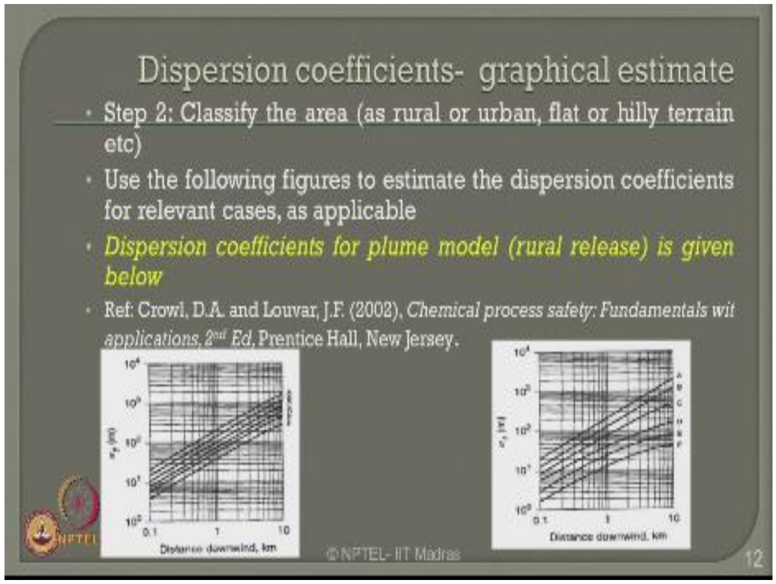

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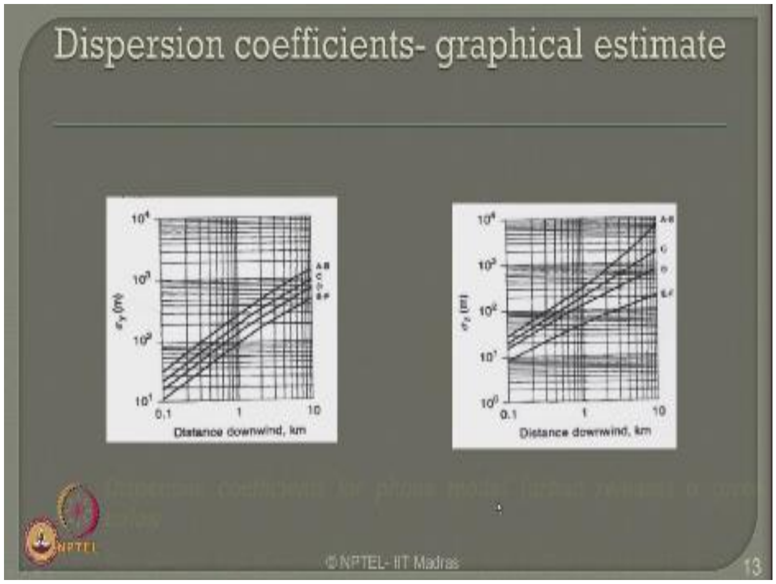

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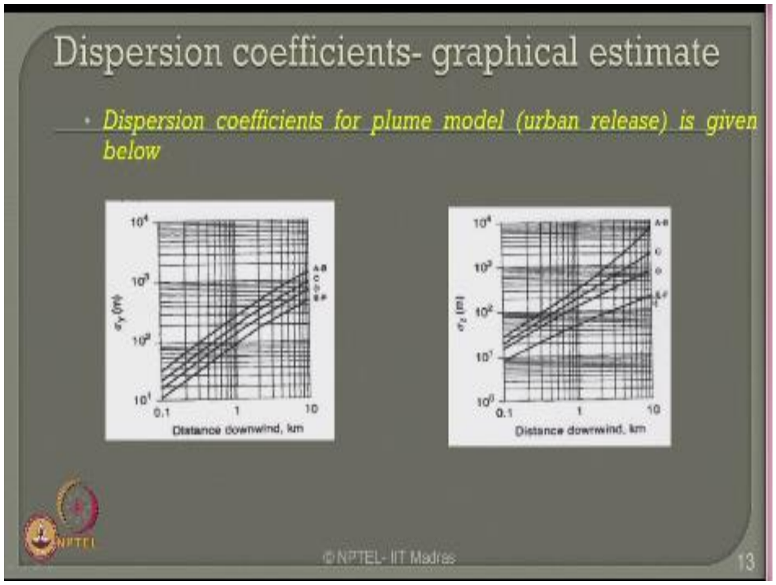

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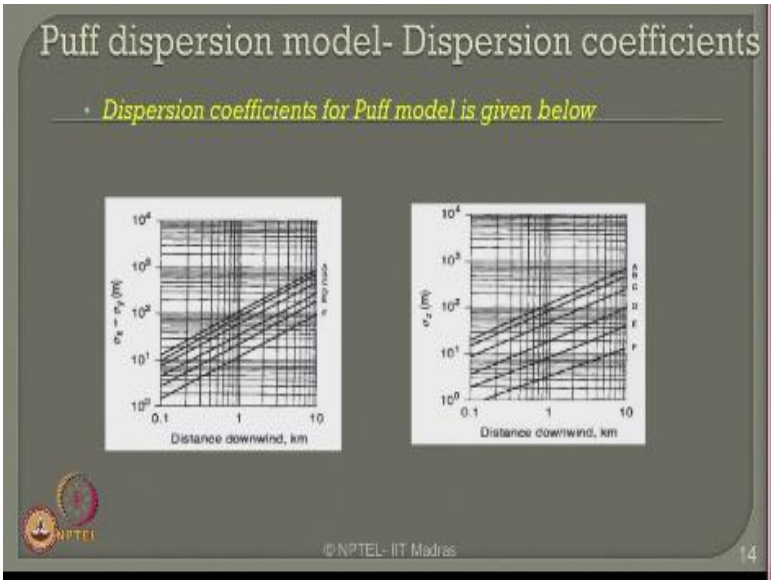


One can also estimate the puff dispersion model dispersion coefficients for puff release model from the graphical estimates as you see here again the plot shows x axis as distance downward downwind side in kilometers and the plot is available for all Pascal stability class varying from A to F respectively in this case you will see that σx is as same as σy because it is a puff release model and σx varies along the altitude which is given by h height of the release from the graph.

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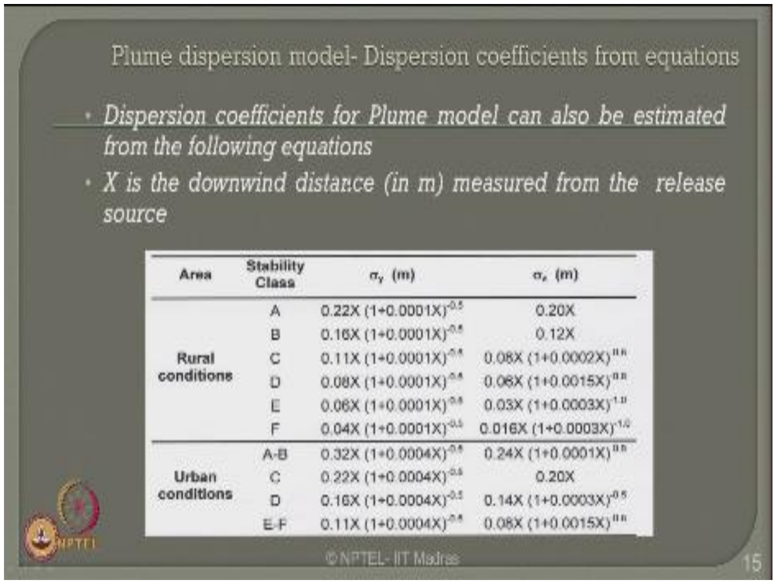


Alternatively friends one can also estimate these coefficients from the equations given below for rural and urban conditions respectively for a plume release model can always use these equations if you know stability class if you know the rural are urban condition in use the respective equations or estimating the dispersion coefficients σy as σz for as in this only variable so got to know is x, where X is a downward distance in meters measured from the point of release of the gaseous model.

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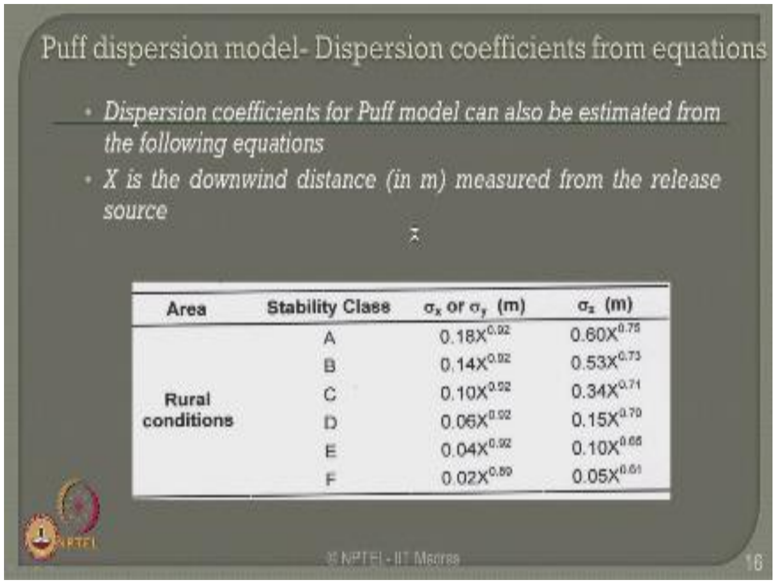


One can also estimate the dispersion coefficients from the equations where puff dispersion model. For puff dispersion model you have the equations given for different stability class varying from A to F for rural conditions whereas the variable here shows either $\sigma_x$ or $\sigma_y$ or $\sigma_z$ for X being the distance measured in meters in the downwind side measured from the release point.

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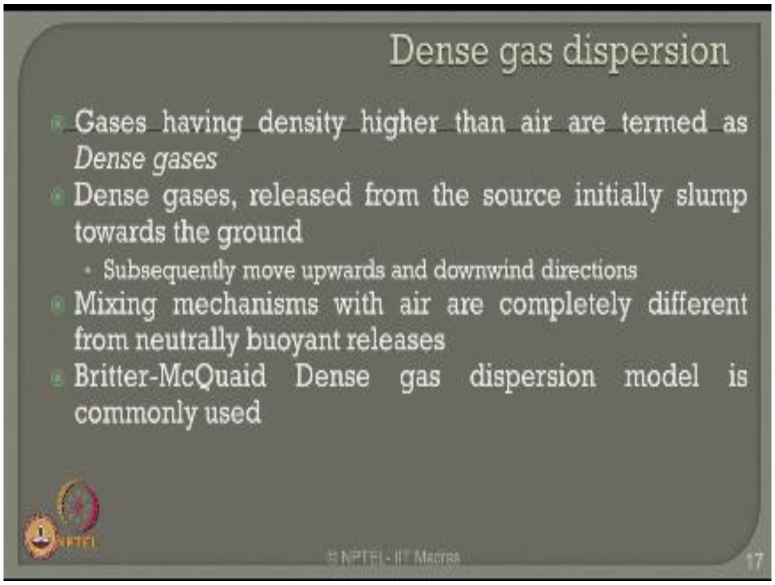


One can also look at the dense gas dispersion relationship. Gases having density higher than air are termed as denser gases. The dense gases released from the source initially slump towards the ground. Subsequently they move upwards and in the windward direction in the downwards side. Mixing mechanisms with air are completely different from neutrally buoyant releases. Britter-McQuaid dense gas dispersion model is commonly used to estimate the consequences and the dispersion release models for this kind of dense gases.

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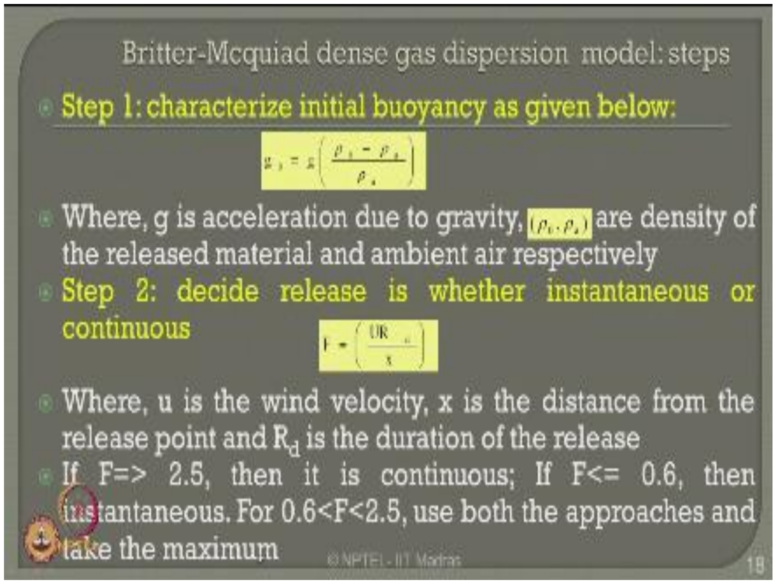


Britter-McQuiad dense gas dispersion models have different steps to calculate the step number 1, characterize initial buoyancy which can be given by the equation $g_0$ where g is the acceleration due to gravity in the equation and $\rho_0$ and $\rho_a$ are density of release models and ambient air respectively. In step number 2, once you know the value of $g_0$ decide the release whether it is instantaneous or continuous.

In this case u is the wind velocity and x is the distance from the release point where as $R_d$ is called as the duration of release. If the value estimated from the equation 2 here and step number 2 exceeds 2.5 then you treat this as a continuous model which can be taken as a plume model. If the F value comparability to this equation is less than 0.6 then it remains instantaneous which can be used as a puff model.

If the value lies between 0.6 and 2.5 you can use both approaches of plume and puff model and see which ever gives you the maximum value take that for your dispersion release.

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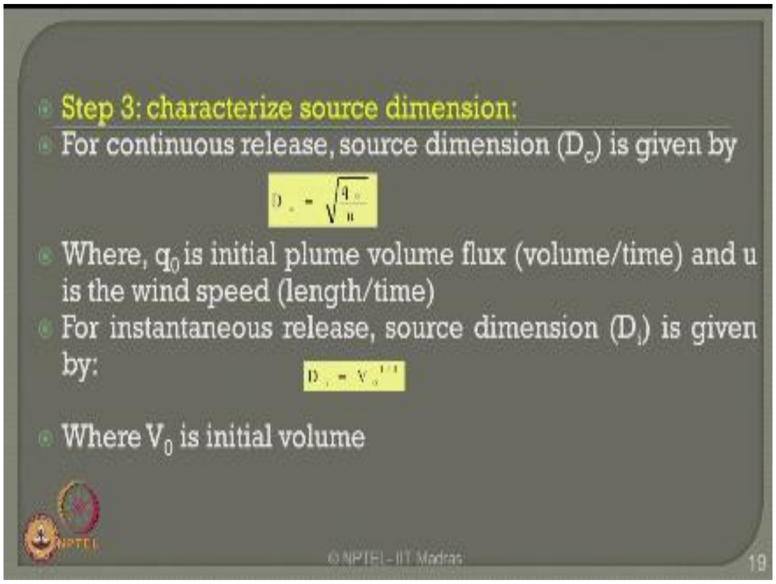


In step number 3 you calculate the characterization of the source dimension for continuous release which is the plume release model the characteristic source dimension $D_c$ is given by this equation. Where in this equation $q_0$ is initial plume volume flux which is given in volume per unit time and u is the wind speed in length per time. For instantaneous release models like puff release model the source characteristics dimension $D_i$ is given by this equation. Where $V_0$ is initial volume to be used in the calculation.

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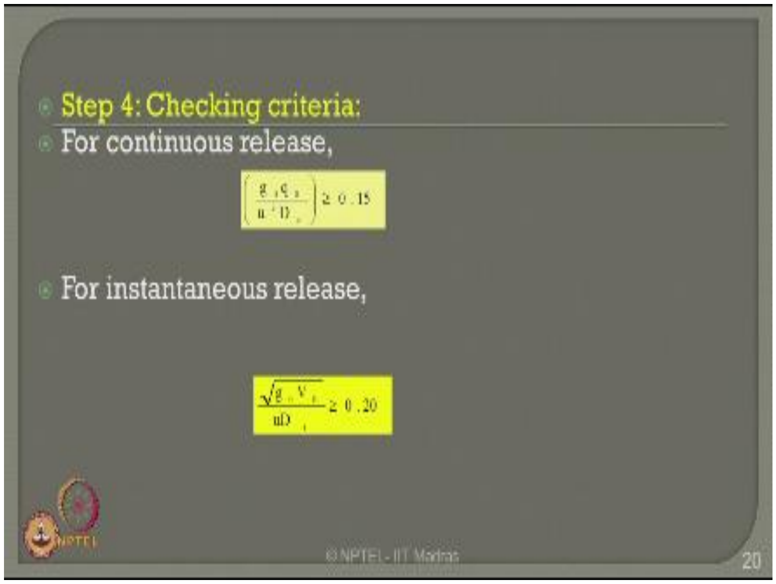


In the next step can check the criteria you already know the value of $g_0$ obtain from step number 1. You know $D_c$ or $D_a$ depending up on whether it is continuous release or instantaneous release therefore of a continuous release you try to work out the checking criteria.

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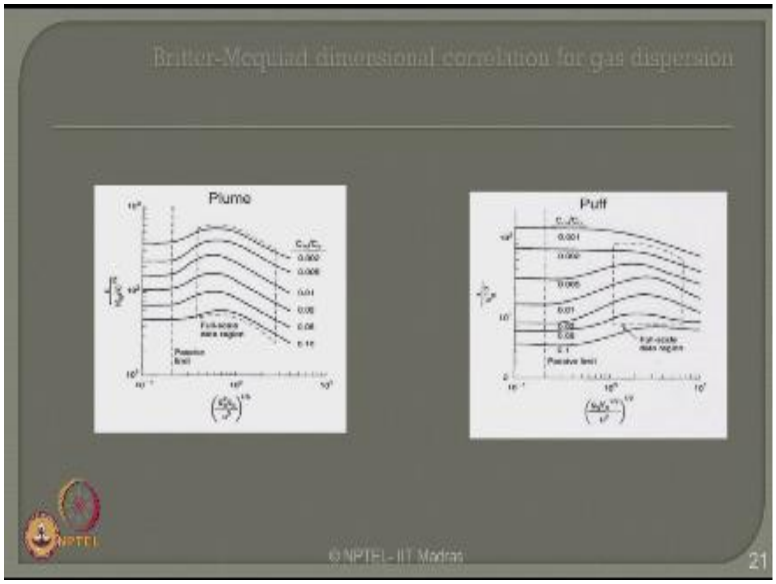

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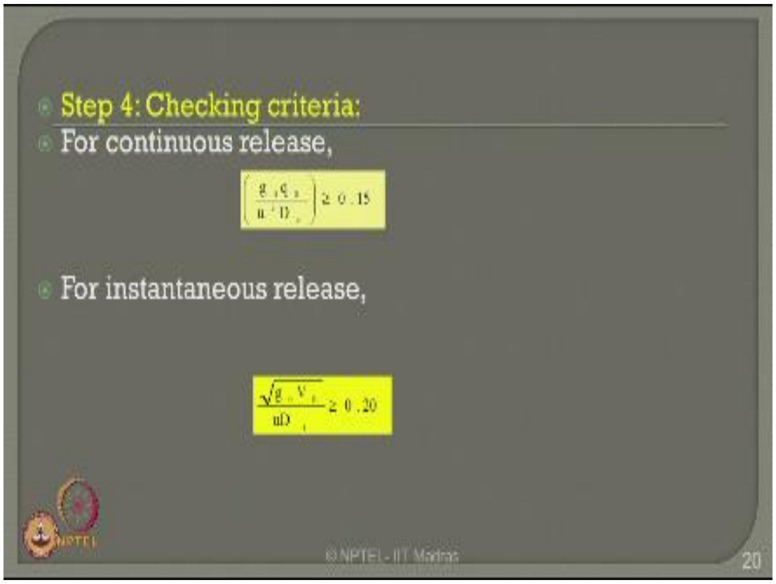


Whether it satisfies the relationship that this equation the value should remain greater than or equal to 0.15 for the model to be remain in the continuous release state. If the value is more than 0.2 for this equation substituted then we can consider this model as an instantaneous release model I can in this case use puff release models. Where as in this case I will use plume release models.

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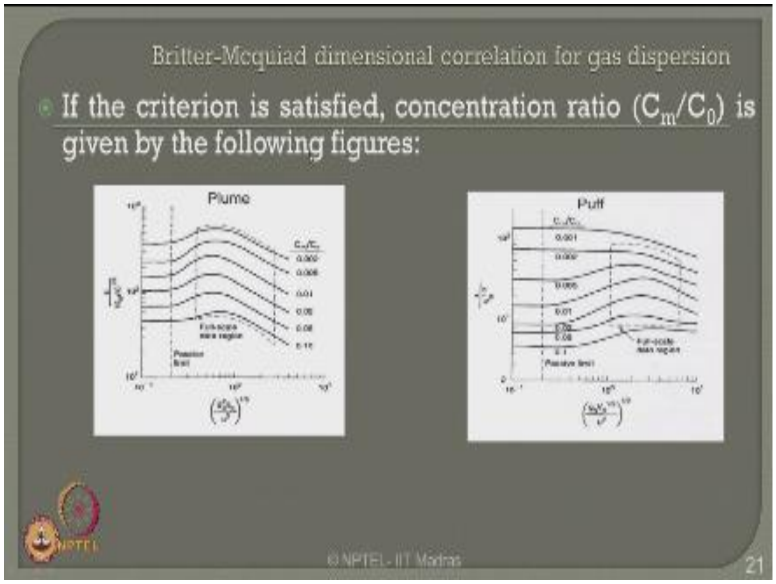


Now Britter-McQuiad dimension correlation is also available for gas dispersion. If the criteria is then satisfied as given in the previous slide for example.

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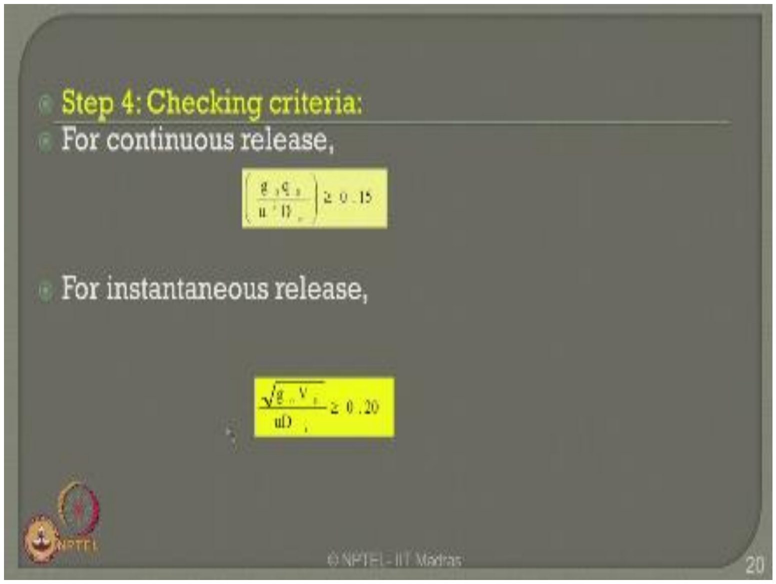


In case of instantaneous release this criteria should be satisfied, in the case of continuous release this equation should be satisfied for instantaneous release this equation should be satisfied.

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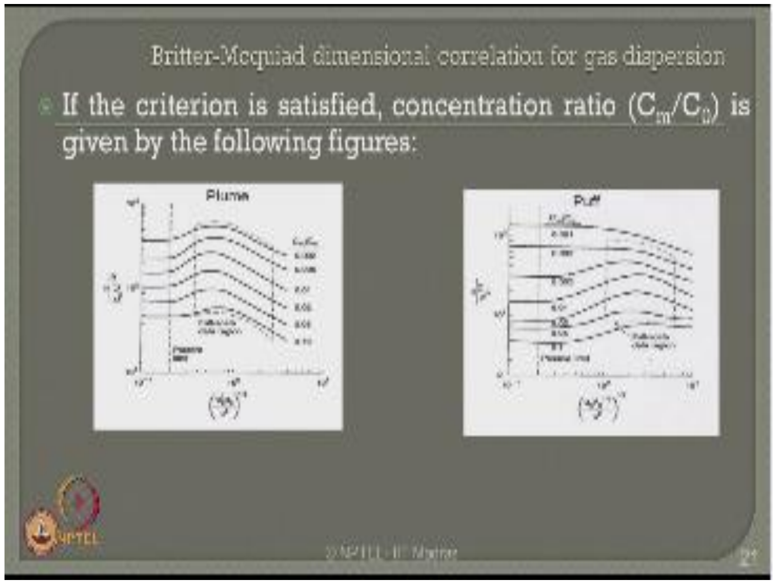


If this criteria is satisfied then the concentration ratio which we call as $C_m/C_0$ is given by the following figures. Now for different values of plume and puff models as you see here for different ratios of this constants of $(X/q_0u)^2$ or $g0^2qpu_5$ you try to work out this values in x and y axis and try to know what could be the intersection point and from that point you can always find out what could be the value of the concentration ratio $C_m/C_0$ whether it is an instantaneous release model or a continuous release model where you can use either a plume release or a puff release respectively.

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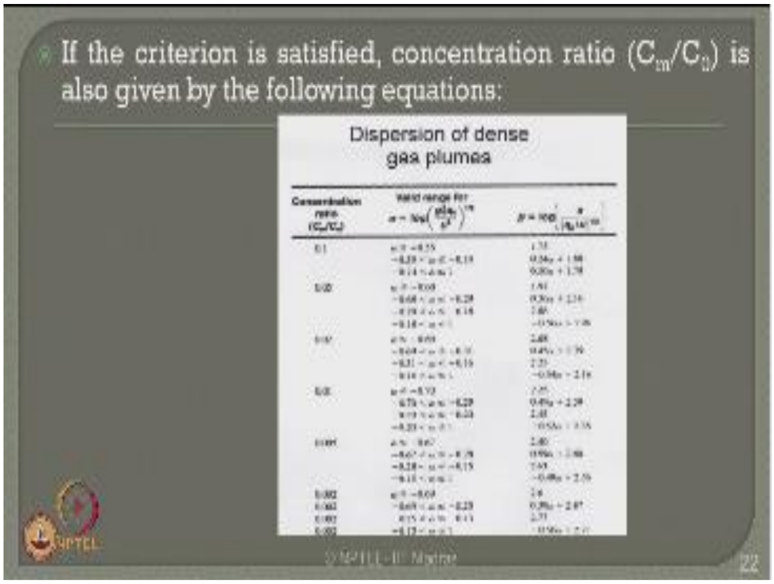


Alternatively one can also compute the concentration ratio $C_m/C_0$ by the following equations as you see in the slide now.

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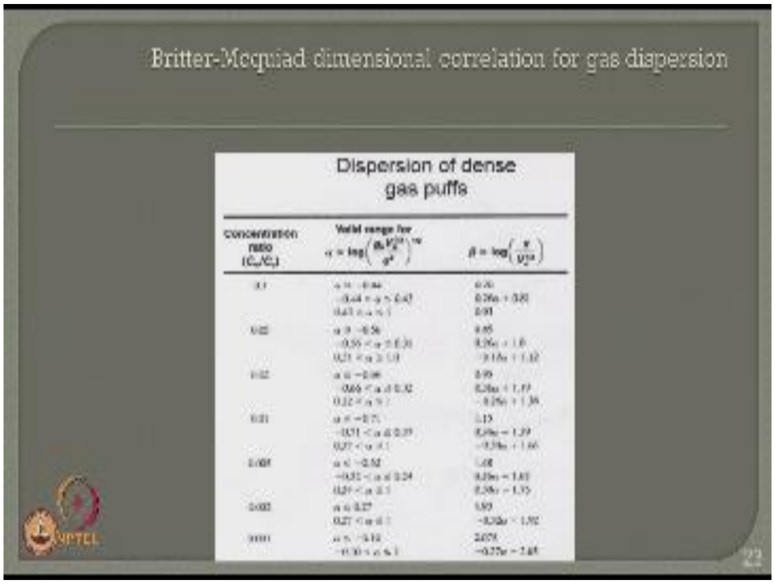


Similarly one can use the dimension correlation for gas dispersion for the puff model one can find out the concentration ratio $Cm/C_0$for the puff release models as you see from the slide now.

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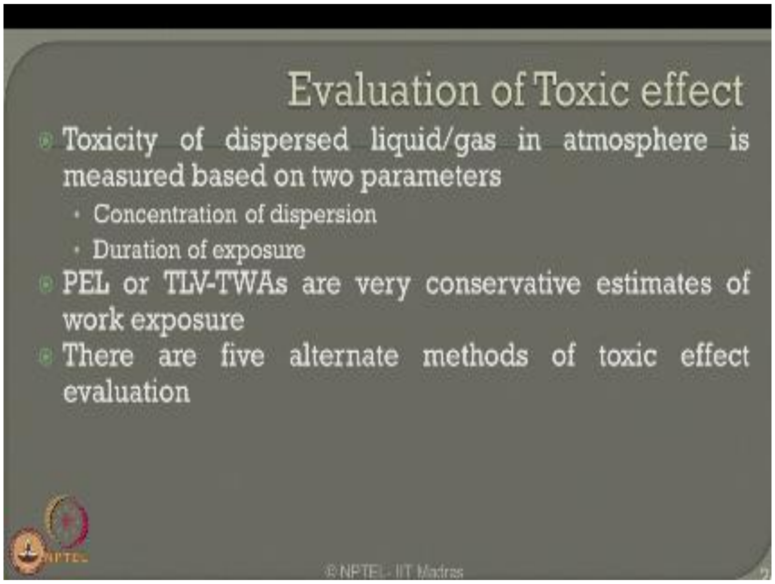


One can now estimate evaluation of the toxic effect cost by these kind of release models toxicity of the dispersed liquid or gas in the atmosphere is measured based on two parameters the first parameter is a concentration of the dispersion the second parameter is a duration of the exposure, there are two standards by which one can always check these estimate are remaining within the conservative values you can use either PEL estimates or TLV-TWAs consider to be very conservative estimates for work exposure. There are five alternate methods other then these two to check whether these releases are within the permissible limits for toxic effect valuation.

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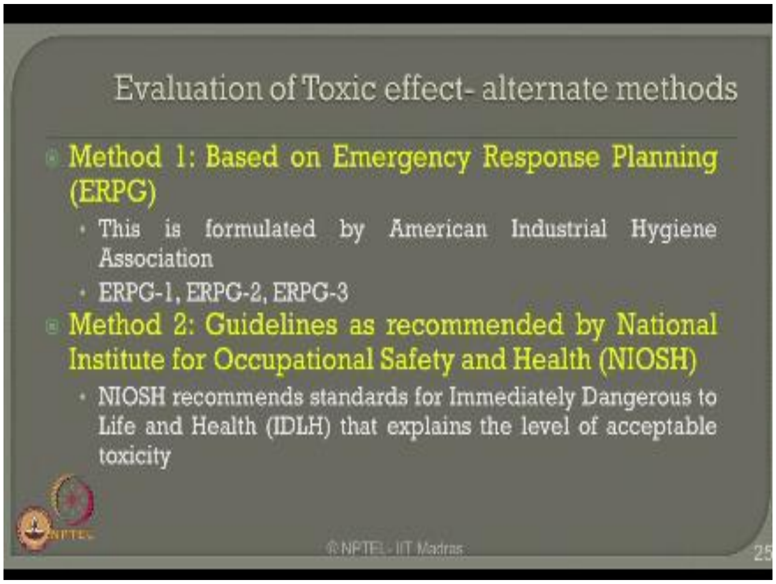


Method 1 is based on emergency response planning is ERPG this actually formulated by American industrial hygiene association depending upon the type of gas releases and the chemical release for every release available in the hand book chemical engineering hand book you have what is called ERPG level 1, level 2 and level3 respectively.

So based on this ERPG guideline available given by AIHA one can always check what is evaluation of the toxic effect on human kind the second method is actually the guidelines proposed by the national institute for occupational safety and health which is NIOSH, NIOSH actually recommends standards for immediately dangerous life and health that explains the level of acceptable toxicity therefore the level of toxicity acceptable to human kind is given by IDLH values alternatively instead of ERPG guide lines as you see in the method 1.

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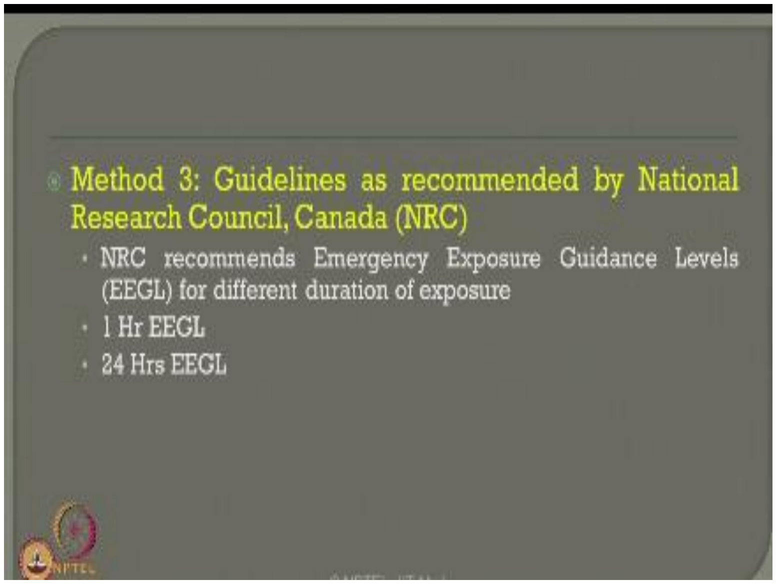


The third method is actually depending on the guidelines given by the national research council Canada which is NRC, NRC recommends emergency exposure guidance level EEGL for different duration of exposure, varying from one hour EEGL value to the top twenty four hours EEGL value. The next alternate method available to check toxicity permissibility on human mankind is given by method 4.

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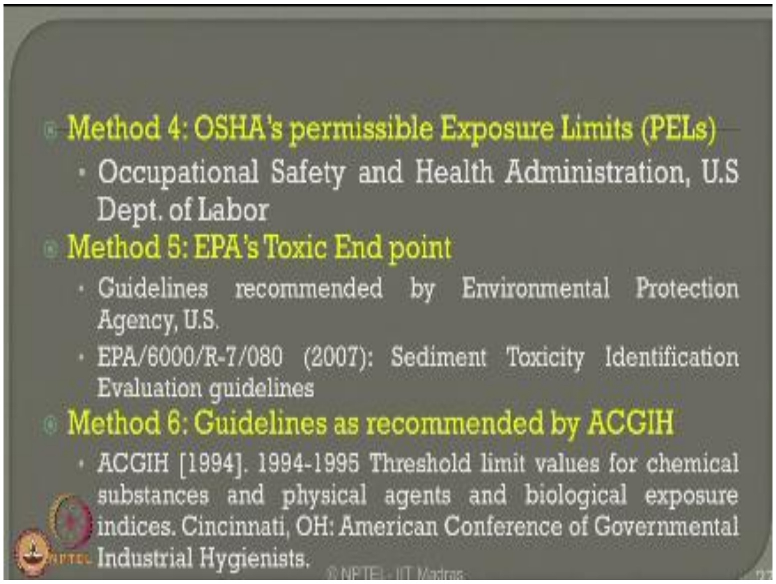


Which is OSHA's permissible exposure limit what we called PEL occupational safety and health administration US department of labor recommends permissible exposure limits of different toxic chemical and human kind one can check whether they are within the limits given by PEL of their portion, and one can say whether they safe for the human kind or not the fifth method is actually depending upon the EPAs toxic end point which is based in the guidelines recommended by environmental protection agency EPA of inerter states.

EPA 6000 resolutions 7/80 on 2007 which talks about sediment toxicity identification evaluation guidelines so as a target value for checking the toxicity limits on human mankind. The sixth method is based on the guidelines recommended by American conference of governmental industrial hygiene's which is ACGIH in 1994 ,they give threshold limit values for chemical substances and physical agents of biological exposure indices which is conducted in Cincinnati by the American conference of governmental industrial hygiene's so they give guidelines depending on which one can check whether the toxicity limit of exposure on mankind is within the permissible limits as admissible by the standards.

So friends in this lecture we discussed about different levels of gas releases models for instantaneous and contentious release models which can be a derive relationship for fume and puff models we have seen different equations we have also understood how to compute the dispersion release coefficient and how to find out the dispersion relation $Cm/C_0$ for different states from the log curves as obtain we also found out what will be different levels of acceptability of toxic limits as given by different standards in international measures thank you very much.

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