Health, Safety and Environmental Management in Offshore and Petroleum Engineering

Prof. Srinivasan Chandrasekaran
Department of Ocean Engineering
Indian Institute of Technology, Madras

Module – 01
Lecture – 08
Pollution Modeling III

Welcome friends to the online course back again on health, safety and environmental management in offshore and petroleum engineering.

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We are talking about lectures on module one. We are discussing about dispersion release models. In today's lecture, that is, lecture 8, we will talk about pollution modeling three.

So, in this lecture, we will discuss about dense gas dispersion; gases which have density higher than air are termed as dense gases. So, dense gases are those whose density is greater than density of air. Dense gases released from the source initially slump towards the ground; that is the characteristic feature. The most important characteristic feature of a dense gas is once they are released, they have a tendency to slump towards the ground. So, they would like to increase the ground level concentration once they are released.

Once they touch the ground, subsequently they move upwards. Once they move upwards, they progress in the windward direction. That is how the flow is generally seen for dense gases once they are dispersed in the environment.

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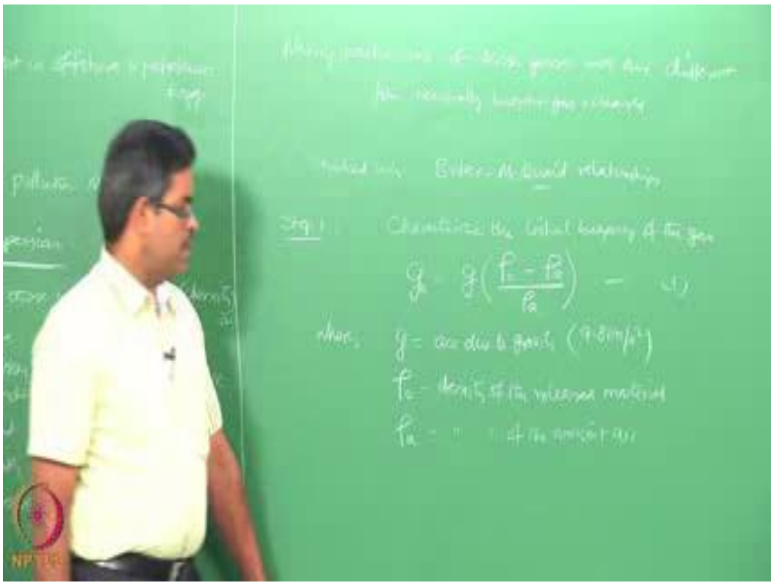

The mixing mechanisms of dense gas with air are different completely from the neutrally buoyant releases. So, this is different from neutrally buoyant gas releases. Now, the gas dispersion model of dense gases is generally studied using Britter-Mcquaid relationships, which we will see now. To compute the dispersion model of the dense gases, there are different steps involved. Let us say step number 1. You have got to characterize the initial buoyancy of the gas. Now, how do you characterize this? Use this equation g 0 is given by g of rho 0 minus rho a by rho a; where, g is acceleration due to gravity – 9.81 meter per second square. Rho 0 and rho a are density of the released material or density of the ambient air. So, try to compute g 0 first from this equation.

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Then, in step number 2, check whether the release is instantaneous or continuous. How do you do this? Compute a value called F, which is given by U R d by x; where, U is the wind velocity; R d is the duration of release; and, x is the distance from the release point. So, this will be in meter. This will be in seconds. This will be in meter per second. So, I compute F. The moment F is greater than or equal to 2.5, the release is said to be continuous. For the value of F less than or equal to 0.6, the release is said to be instantaneous. So, you can use plume model for this, you can use puff model for this. In case F lies between 0.6 and 2.5, then you have to use both the relationships and check for the maximum, which should be used in the design. So, step number 2 – we have checked or we have found out whether the release is instantaneous or continuous.

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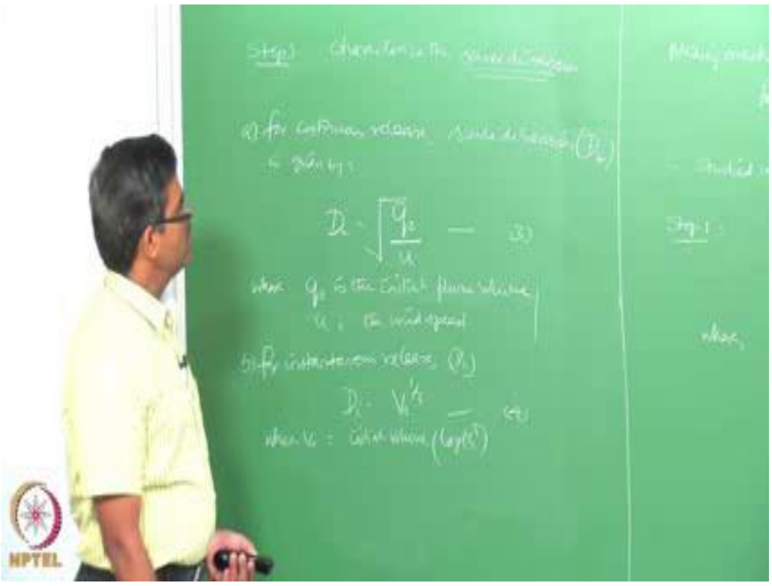

In step number 3, characterize the source dimension. So, a – for continuous release, the source dimension that is D c; the c stands for continuous is given by D C is equal to root of q 0 by u – equation number 3; where, D c is of course, a source dimension and q naught is the initial plume volume; and of course, u is the wind speed. Now, for instantaneous release, the source dimension D i; i stands for instantaneous, is given by V 0 raised to the power 1 by 3; where, V 0 is initial volume, which is in terms of length q. So, step number 3 – you will be going to calculate the source dimension using either equation 3 or equation 4 depending upon whether you identified the release as continuous release or instantaneous release.

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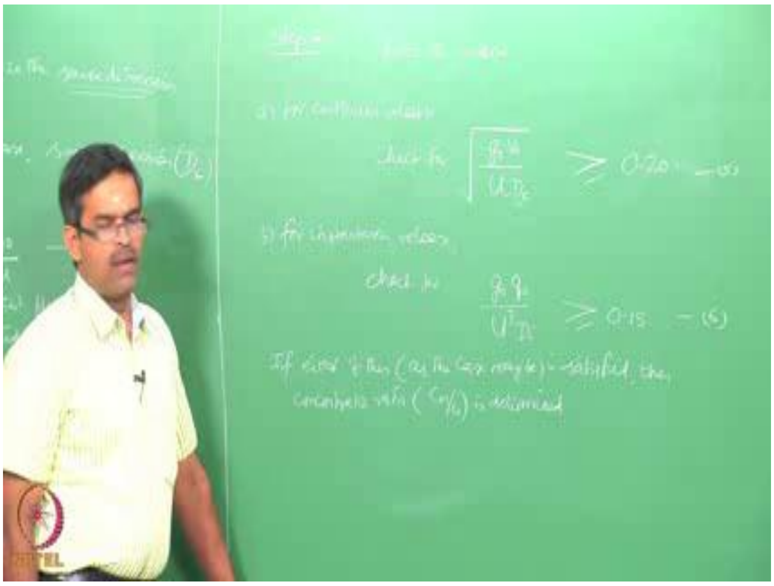

In step number 4, you got to check the criteria. For continuous release, one should check the value root of g 0 v 0 by u D i to be greater than or equal to 0.2; where, D i is calculated from the earlier equation; for D c is calculated from the earlier relationship what we already know. For instantaneous release, check for g 0 q 0 by U q D i for this value more than or equal to 0.15. If both these conditions for the respective equations; that is, for continuous release, equation 5; for instantaneous release, equation 6. If either of them as the case may be is satisfied; then, you can workout the concentration ratio, which is given by c m by c naught is determined. This can be now obtained graphically from the figure which I am going to show you the screen now.

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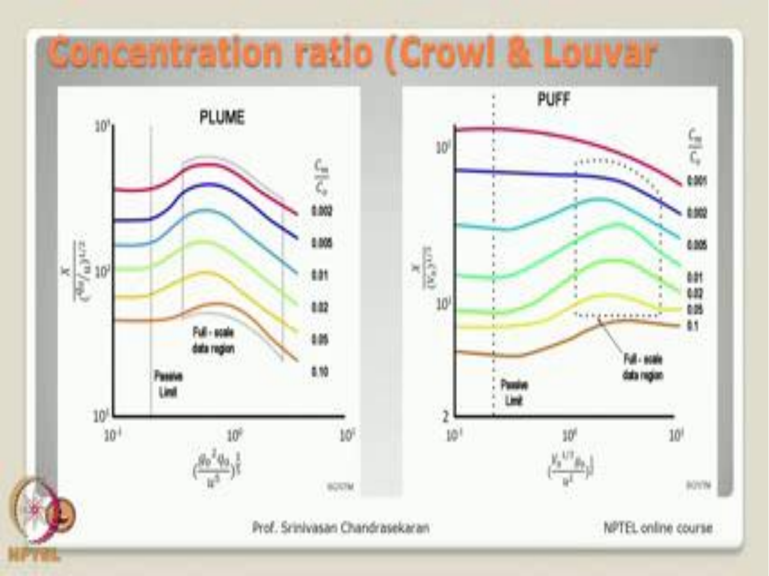

Please pay attention to the figure shown on the screen now. The concentration ratio is now given for the plume release and for the puff release depending upon what you have identified as the condition is satisfied. In the x axis, the value varies from 0.1 to 10; and, in the y axis, the value varies from 10 to 1000; whereas, these are the computed quantity, which makes it dimensionless. And, c m by c naught depending upon the value of the specific ratio, you can always find out and see what is the corresponding value, which curve is being intersected. And, that c m by c naught is what we call as concentration ratio for the plume model; the left side figure is used. And, for the puff model, the right-hand side figure is used. Both of them are used for rural conditions. Alternatively, you can also calculate the dispersion in the concentration ratio based upon the equations, which are shown in the screen now.

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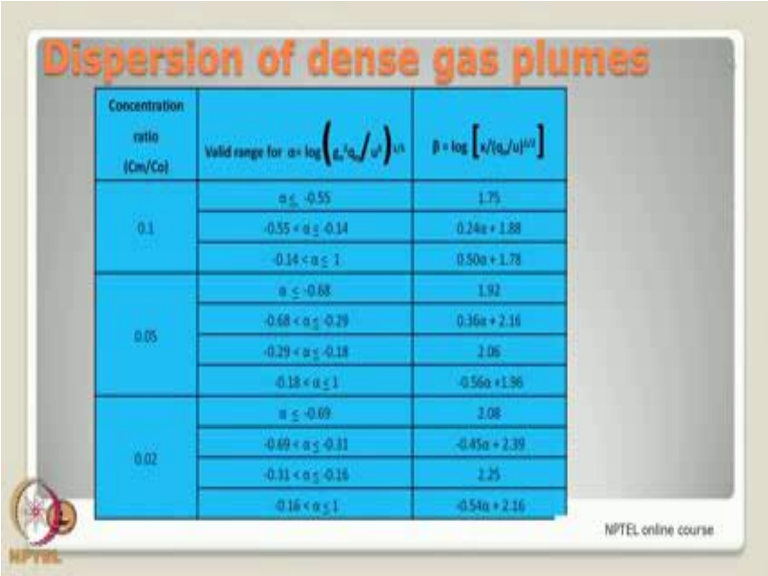

Concentration ratio (Cm/Co)	Valid range for $\alpha = \log\left(g_o^2 q_o / u^5\right)^{1/5}$	$\beta = \log\left[x/(q_o/u)^{1/2}\right]$
0.1	$\alpha \leq -0.55$	1.75
	$-0.55 < \alpha \leq -0.14$	$0.24\alpha + 1.88$
	$-0.14 < \alpha \leq 1$	$0.50\alpha + 1.78$
0.05	$\alpha \leq -0.68$	1.92
	$-0.68 < \alpha \leq -0.29$	$0.36\alpha + 2.16$
	$-0.29 < \alpha \leq -0.18$	2.06
	$-0.18 < \alpha \leq 1$	$-0.56\alpha + 1.96$
0.02	$\alpha \leq -0.69$	2.08
	$-0.69 < \alpha \leq -0.31$	$-0.45\alpha + 2.39$
	$-0.31 < \alpha \leq -0.16$	2.25
	$-0.16 < \alpha \leq 1$	$-0.54\alpha + 2.16$

Please pay attention to the table, which gives series of equations for the dispersion of dense gas plumes. As you see in the picture here, the concentration ratio of c m by c naught can be computed in groups. As you see here, for different values of alpha and beta, which are calculated depending upon g 0, q naught and u, which has been already explained as you see here. So, for a specific value of alpha obtained and the range of alpha and for the specific value of beta and the condition satisfied, can always choose the corresponding value of c m by c naught, which is concentration ratio given by the equations in a tabular form.

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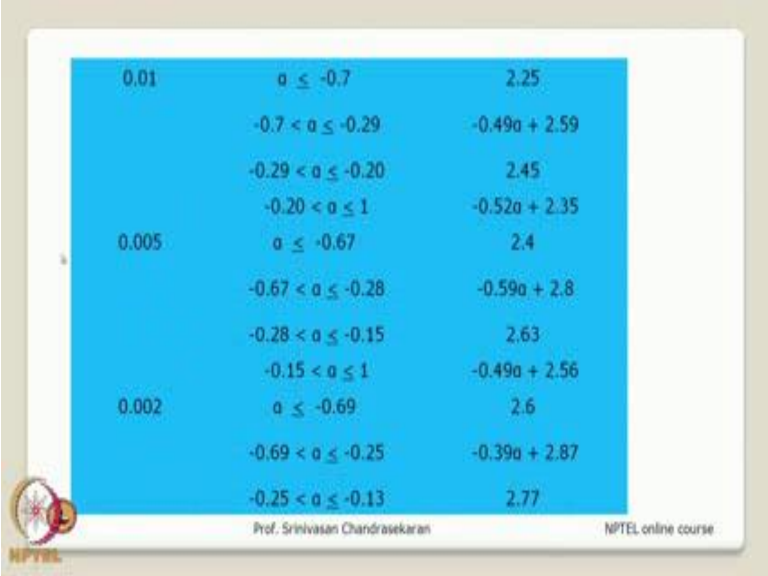

0.01	$\alpha \le -0.7$	2.25
	$-0.7 < \alpha \le -0.29$	$-0.49\alpha + 2.59$
	$-0.29 < \alpha \le -0.20$	2.45
	$-0.20 < \alpha \le 1$	$-0.52\alpha + 2.35$
0.005	$\alpha \le -0.67$	2.4
	$-0.67 < \alpha \le -0.28$	$-0.59\alpha + 2.8$
	$-0.28 < \alpha \le -0.15$	2.63
	$-0.15 < \alpha \le 1$	$-0.49\alpha + 2.56$
0.002	$\alpha \le -0.69$	2.6
	$-0.69 < \alpha \le -0.25$	$-0.39\alpha + 2.87$
	$-0.25 < \alpha \le -0.13$	2.77

For other extended values, you can always see the table further to compute the concentration ratios.

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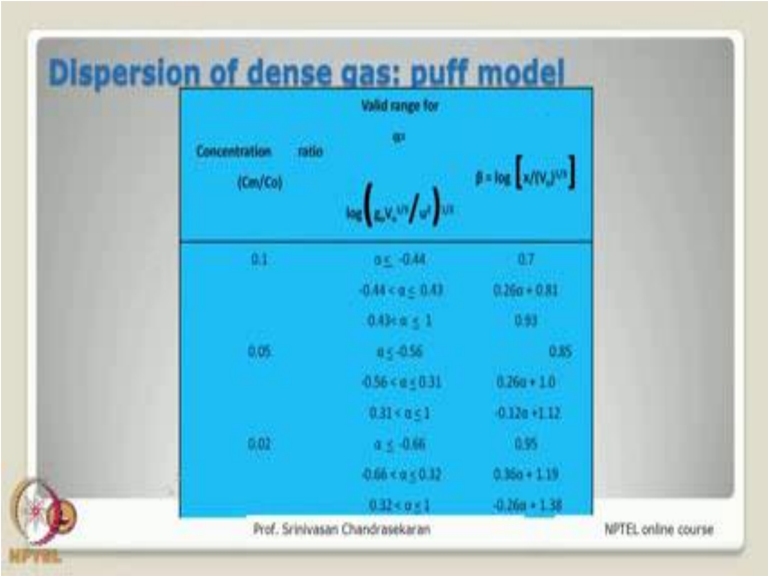

Concentration ratio (C_m/C_o)	Valid range for $\alpha = \log\left(g_o V_o^{1/3}/u^2\right)^{1/2}$	$\beta = \log\left[x/(V_o)^{1/3}\right]$
0.1	$\alpha \le -0.44$	0.7
	$-0.44 < \alpha \le 0.43$	$0.26\alpha + 0.81$
	$0.43 < \alpha \le 1$	0.93
0.05	$\alpha \le -0.56$	0.85
	$-0.56 < \alpha \le 0.31$	$0.26\alpha + 1.0$
	$0.31 < \alpha \le 1$	$-0.12\alpha + 1.12$
0.02	$\alpha \le -0.66$	0.95
	$-0.66 < \alpha \le 0.32$	$0.36\alpha + 1.19$
	$0.32 < \alpha \le 1$	$-0.26\alpha + 1.38$

Similarly, if you want to do it for a puff model.

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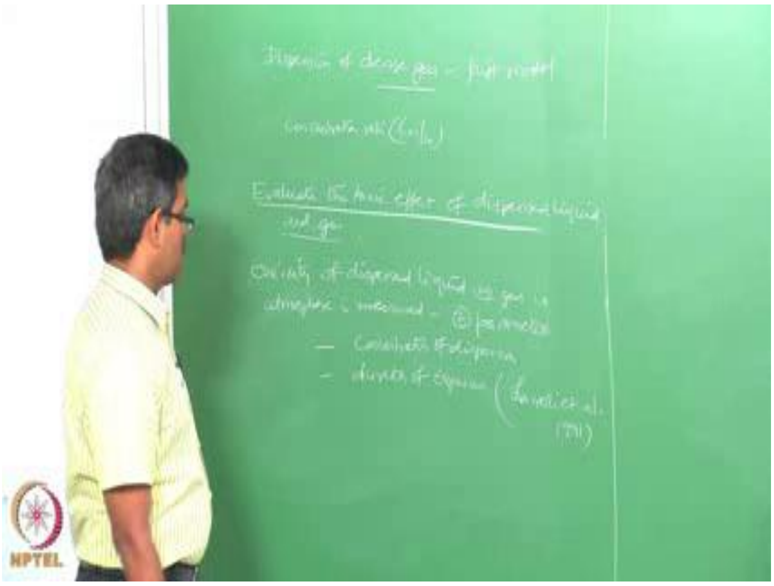

If you want to now consider dispersion of dense gas for an instantaneous release, which is going to be the puff model; one can use again set of relationships to compute the concentration ratio c m by c naught by paying attention to the equations given on the screen now in a tabular form. Please look at the table given in the equation form in the screen. So, the concentration ratio c m by c naught is given in groups for different values of alpha and different values of beta, which can be computed from v naught, g and u, which has been explained earlier. For the value of alpha computed and for the value of beta in the range of given here, one can always choose the value of c m by c naught as available in the table here.

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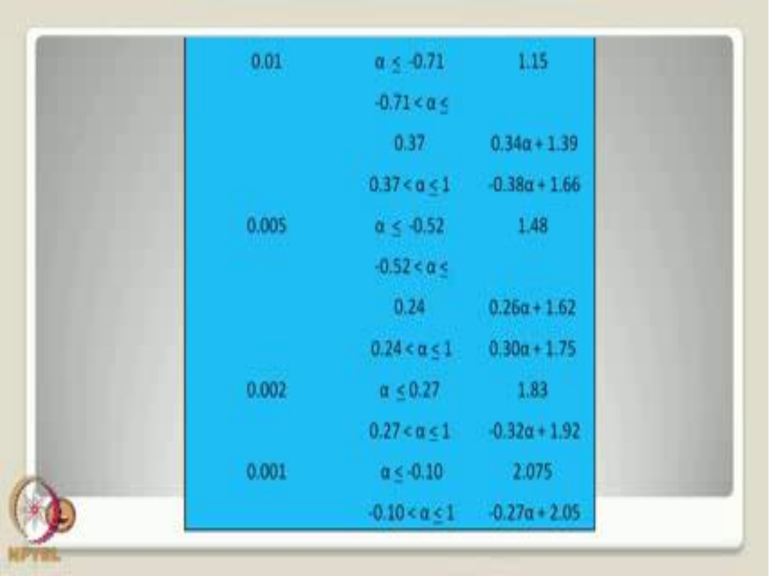

0.01	$\alpha \le -0.71$	1.15
	$-0.71 < \alpha \le 0.37$	$0.34\alpha + 1.39$
	$0.37 < \alpha \le 1$	$-0.38\alpha + 1.66$
0.005	$\alpha \le -0.52$	1.48
	$-0.52 < \alpha \le 0.24$	$0.26\alpha + 1.62$
	$0.24 < \alpha \le 1$	$0.30\alpha + 1.75$
0.002	$\alpha \le 0.27$	1.83
	$0.27 < \alpha \le 1$	$-0.32\alpha + 1.92$
0.001	$\alpha \le -0.10$	2.075
	$-0.10 < \alpha \le 1$	$-0.27\alpha + 2.05$

Further values of this ratio are also extended till the value of 0.001 as you see from the table on the screen.

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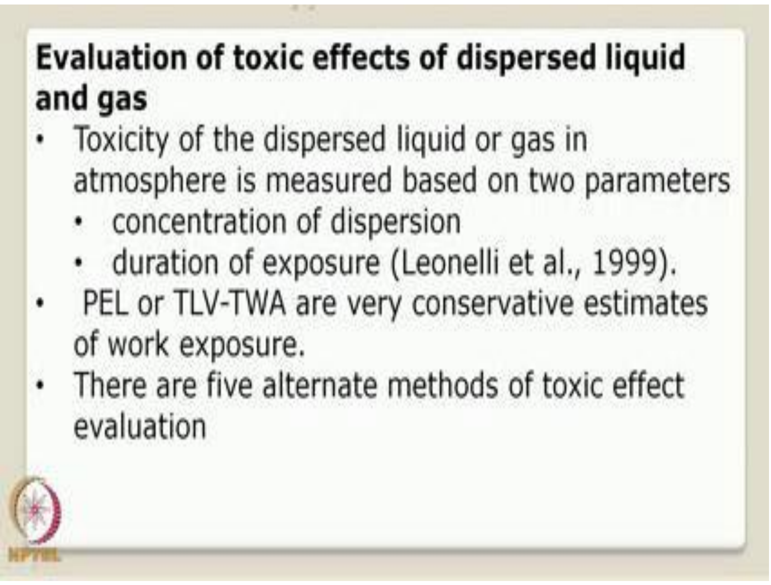

Now, let us continue the discussion of evaluation of toxic effects on dispersed liquid and gas.

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Let us say I am interested now to evaluate the toxic effect of the dispersed liquid. So far, we have discussed about the cloud vapor or positively buoyant gases and dense gases. Now, we are talking about dispersed liquid and gas. Toxicity of a dispersed liquid or gas in atmosphere is measured based on two parameters – based on two parameters namely, concentration of dispersion and duration of exposure. So, this is given by La melli et al., 1991.

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There are other forms of estimates available in the literature, which can also compare the toxic effects of liquids; that is called permissible exposure limit, which we call PEL or threshold limit value for time weighted average, which is called TLV-TWA. These are also parallel type of parameters, which can also assess the toxic effect of a liquid dispersed in atmosphere; however, the parameters depending upon these two, which will evaluate the toxic effect will be different. And, these two will give you conservative values. I mean the estimates given by these two limits for a specific chemical release will be always higher compared to that of considering the parameters of concentration of dispersion and duration of exposure and evaluating the toxic effect.

Now, to evaluate the toxic effect there are five methods available in the literature; methods to evaluate toxic effect suggested by various international regulatory bodies. Let us say method 1; this is based on emergency response planning guideline, which is abbreviated as E R P G. Generally, these values are given for all kinds of liquids and chemicals, which is generally formulated by American Industrial Hygiene Association. E R P G values for different chemicals are available in three levels namely, E R P G 1, E R P G 2 and E R P G 3, which will explain in detail when we talk about chemical release modeling in the further lectures.

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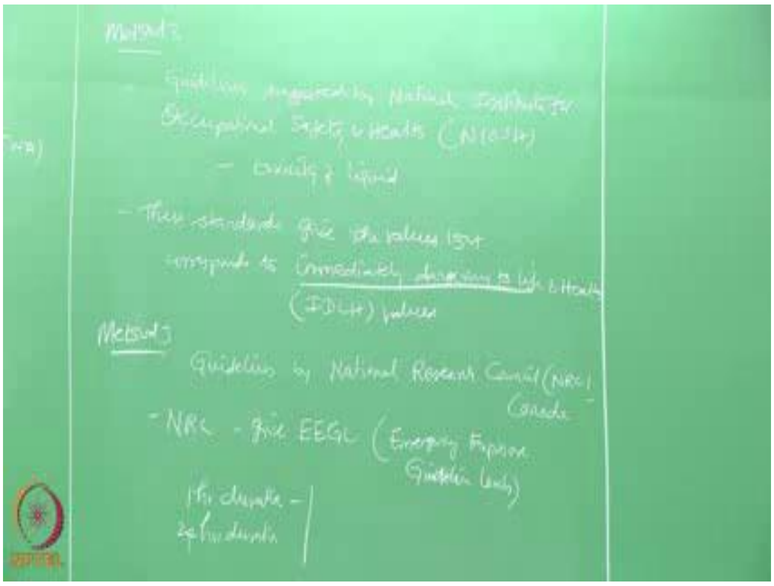

The next method which is method 2 is suggested based on the guidelines recommended by National Institute of Occupational Safety and Health based on guidelines suggested by National Institute for Occupational safety and Health, which is N I O S H. So, this is useful in evaluating toxicity of a liquid dispersed in environment. These standards generally gives you value for immediately dangerous to life; like they can be seen it is an upper limit; immediately dangerous to life and health, which we abbreviate as immediately dangerous to life and health values, which explains the level of acceptable toxicity in a maximum content.

The third method by which you can explain the toxicity is based on the guidelines recommended by National Research Council, Canada. Generally, N R C recommends what we call emergency exposure guidelines levels for 1 hour duration and 24 hours duration. So, what is a maximum value, which a human being can sustain on emergency exposure on a chemical for an hour or for 24 hours. These are the value suggested by National Research Council, Canada, which can also be used as a guideline to measure the toxicity of the released chemical in atmosphere.

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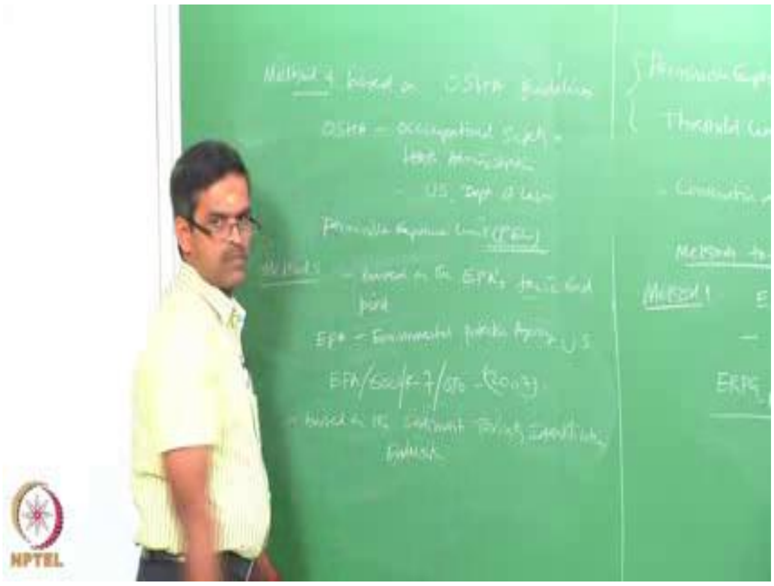

The fourth method is based on OSHA principle or OSHA guidelines – Occupational Safety and Health Administration, which is actually dominated by US, Department of Labour in United States. So, they also give you guidelines in terms of permissible exposure limits, which is P E L. So, one can also check the permissible exposure limits of a given chemical when it is released in the environment and check the toxicity whether it is within the permissible limits or not.

The fifth method is based on the E P S toxic end point; E P S stands for environmental protection agency, which is again in the United States. For example, E P A 6000 or that is a recommended guideline 6000 or 7080 is revised in the year 2007, is one typical report; we suggest what is the maximum toxic limit of a chemical, which can be dispersed in atmosphere. It actually depends upon the sediment toxicity indication – identification evaluation. It is based on the sediment toxicity identification and evaluation, which can be used as a guideline.

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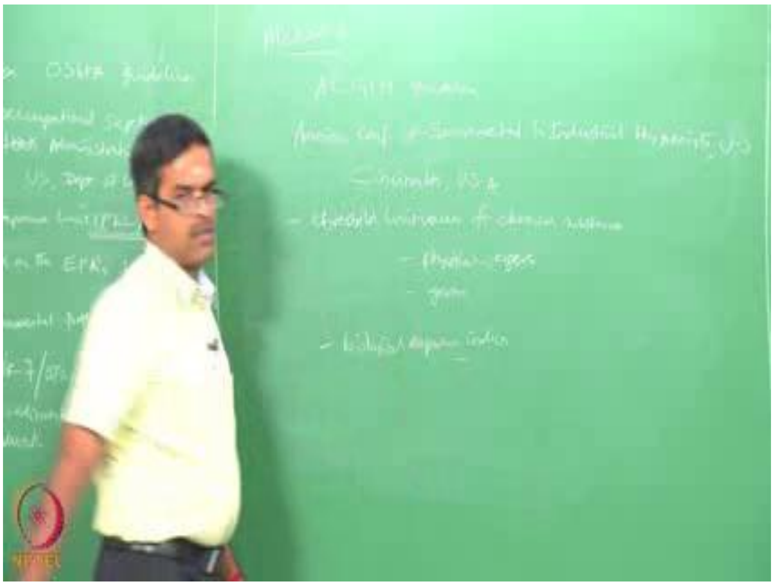

Alternatively, one can use another method, which we may say as method 6, which is based on A C G I H guidelines. A C G I H stands for American Conference of Governmental and Industrial Hygienists, United States; which generally housed in Cincinnati. Actually this recommends the threshold limit values for chemical substances, which can be released in air. It is also applicable to physical agents and gases. It can be also used for biological exposure indices. So, ladies and gentlemen, by this six methods or any one of this method can quantify the permissible exposure limit of a toxic chemical, which can be released in the environment, which can be sustained by a human being without causing any irreversible – reversible effects on his health.

So, friends, in this lecture, we discussed about the extension of the plume and puff model for dense gases. We have also understood how to estimate the concentration ratio for a given model both from algebraic equations on also from graphical formulas or equations. Then, we have understood if we really wanted to find what is the permissible limit of exposure for a human being, who can sustain the dispersed chemical or a liquid in the environment, I have six methods by which I can classify and quantify the maximum permissible acceptable limit, which can be allowed to get dispersed in the environment. Various agencies globally and internationally do agree to the standards. And, every oil and gas industry especially the process industry is located onshore need to abide to these guidelines to fix to the international norms of environmental management issues as we put together in the specific particular title of this lecture.

Thank you very much.