NPTEL

NPTEL ONLINE CERTIFICATION COURSE

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

Module 2:
Accident modeling, Risk assessment & Management
Lecture 1: Safety regulations and Dose assessment

Dear friends, now welcome to the second module lectures on online course at health, safety and environmental management in offshore and petroleum engineering under the aspics of ITT Madras NPTEL Program. We have successfully completed the lectures on first module there were about 4 tutorials which you must have answered in the first module you have evaluated for them which are also become a part of the major examination at the end of the semester.

We will now move on to the lectures of second module the second module will focus on accident modeling, risk assessment, and management. In the second module the first lecture will now focus on safety regulations and dose assessment. The movement we talk about safety regulations with respect to dose assessment we are entering into intricacy of process safety management there we will talk about chemical exposure index or chemical risk analysis etc, in this module and subsequently in the lectures in this module.

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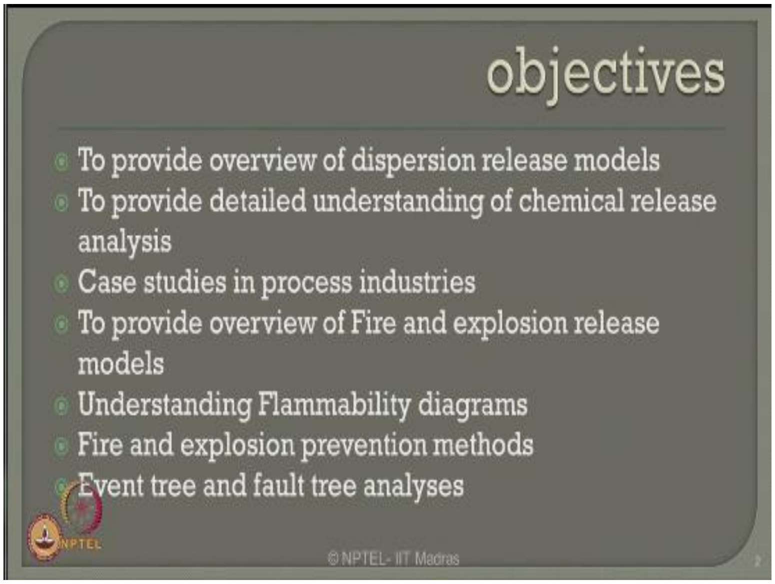

Let us quickly see what are the objective of the lectures in the second module we will try to provide you an overview of dispersion release models. We will explain detailed understanding of chemical release analysis. We would also present few case studies in the process industries how to do risk analysis for process safety management. We will provide you an overview of fire and explosion release models. We will talk about flammability diagrams and enable you to understand the use of flammability diagrams in mitigation or prevention of fire and explosion problems in process industries. We will talk about fire and explosion prevention methods in this module, and we will finally discuss some examples on event tree and fault tree analyses in this module.

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Let us principally ask a question what do we understated by safety regulations as applicable to process industries like offshore and petroleum industry. Safety is essentially characterized by international electro technical commission what we briefly as IEC standards. IEC standards are extensively used as a bench mark standards in oil and gas industry. IEC 61508 which talks about functional safety of electrical, electronic, programmable electronic safety related systems released in Geneva, 2000 is a very good hand book talks about functional safety of these process industries.

IEC 61511 also talks about functional safety related to instrumented system in process industry which is also released in 2003 in Geneva. IEC standards are dear friends, voluminous and lead to extensive process and design inputs based on which safety implementation becomes instrumental and very decisive.

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IEC standards are actually based on familiarity and definition of equipment under control. So it is important for us to understand what are those equipments we deal with that of the standards to be emphasized and we should be familiar with operation of the equipments where we are imposing safety standards. You should be capable of identifying the hazards given in the process system, you should also have one pre requisite idea about interaction between the equipments under control.

It is very important that what would be the overlay of one equipment working of one on the other is important to understand the safety emphasis on different equipments working in the series. Ultimately one should focus on risk assessment under process equipments which is covered in this module. Interestingly when you talk about safety evaluation it is important for us to understand all safety evaluations need to be carried out in a very generic manner.

Safety regulations and evaluation should not be problem specific because you must apply a generic rule to approach the problem in a more prescribed manner. It is essentially because of certain reasons only few details about installation shall be available to you in the early conceptual stage, because when the process starts as the process becomes complex because of the operational temperature and pressure variations is very difficult to foresee the hazards in the beginning.

So you will know a very few details about installations with you which will talk about the mechanical configurations specifications of the equipment the working principles, working temperature in pressure etc. In case of pressure and temperature being violated during the operation or during the process is very difficult that you will not have much details about these installations at those high pressure temperature functioning.

Therefore, in the early conceptual stage you will not have much details about installations. And hence decision makers have to rely upon the knowledge from other similar projects. Therefore, ICE standards invoke such generic understanding on safety regulations and it is always experienced back to decisions which will improvise safety for equipments under operation in process plans.

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Alternatively friends can also use OLF guidelines which will give you a simplified requirements of oil and safety. OLF guidelines are generally given by the Norwegian oil industry federation which is also called as Norwegian oil industry association. OLF guidelines eliminate the need for extensive analysis, they are more or less prescribed rules which is got be followed for safety improvisation in oil and gas industries.

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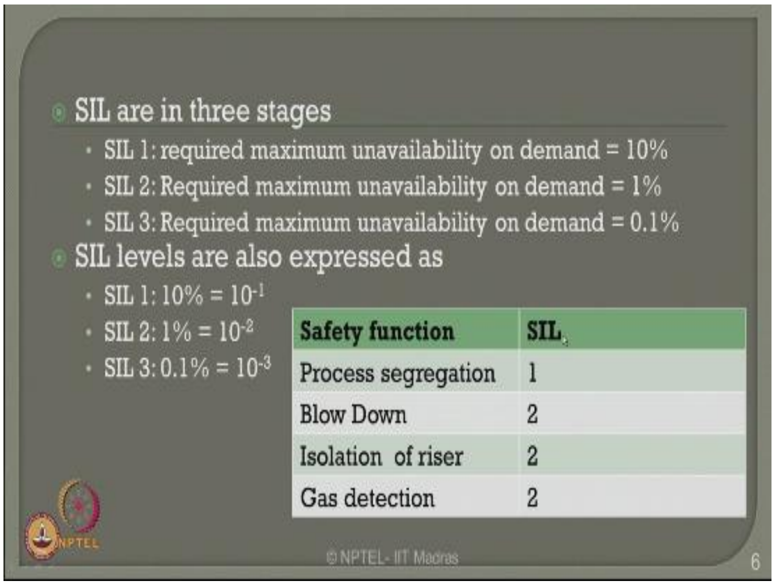

In addition to it we also have something called safety integration limits which comes in three stages, they are categorized as SIL level 1, level 2 and level 3. Let us quickly see what do we understand by SIL level 1, SIL level 1 means it is a required maximum unavailability of the equipment or demand is 10% whereas if the unavailability or demand is 1% we call that as SIL level 2 and if the unavailability is on demand point 1% we call that as SIL level 3. One can easily remember these numbers 1, 2 and 3 related to these percentage when you see this slide.

SIL levels are also expressed as 10% which is 10^{-1} that is 10/ 100 SIL 1% becomes 10^{-2} and 0.1 becomes 10^{-3} and the numbers of these 1, 2 and 3 is what you actually see as SIL levels 1, 2 and 3 respectively. Now for your understanding let us quickly look at the table on the right hand side, for different safety functions SIL indicators are shown in the table which is extracted from the oil and safety industrial directed standards process segregation should have a safety inter deviate as 1 where as blow down is 2 and isolation of risers and gas detection is also 2 respectively. Now does this mean is if the process segregation has imposed a safety integrity limit or level as 1 it means the process segregation can be maximum unavailable on demand about 10%. So if you have got let us say 100 equipments in the pipeline to work at 10 of this 100 can be remaining out of order. So even if 10 on 100 scale remains out of order one can say SIL level one is implemented in the standards.

Whereas the blown preventers, isolation of risers are maximum should be made unavailable maximum to a level of only 1%. So as the SIL level goes higher and higher you can see the equipment or the process importance gets deeper or more important in the process industry.

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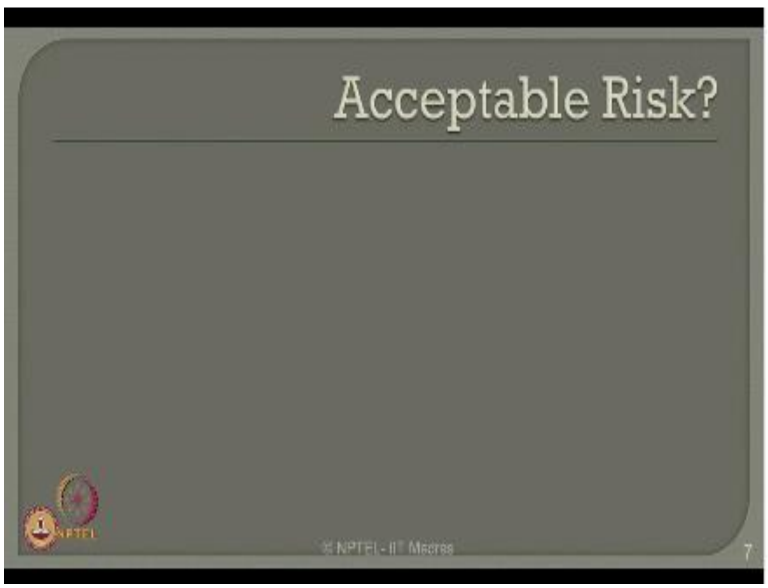

As we said in oil and gas industries there are something called acceptable risk we discussed about this in the first module as well. Let us quickly see how do we categorize acceptable risk in industrial standards.

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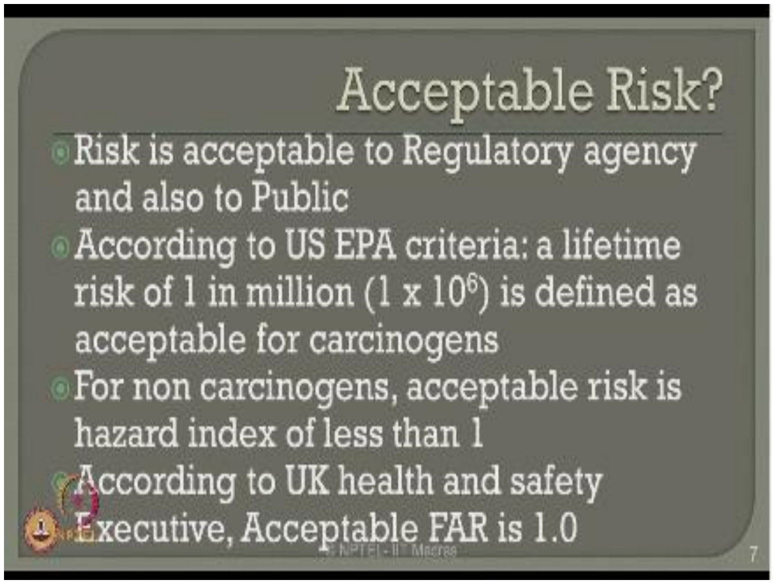

Risk is acceptable to regulatory agency and also to the public. According to the United States environmental protection authority criteria, a lifetime risk of 1 in million is defined as acceptable for carcinogens. Whereas for non carcinogens the acceptable risk is hazard index lesser than 1, whereas according to UK health and safety executive the acceptable fatality extent rate is 1.0.

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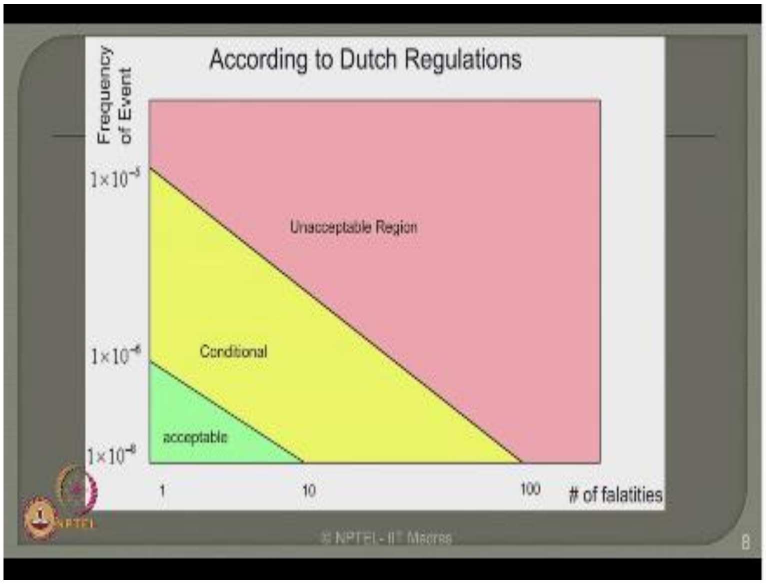

If you looked at the other international regulations for example the Dutch regulation the acceptable level of risk is given in a figure as you see here in the slide. It is closely related to the number of fatalities and the frequency of the event causing these fatalities. If the number of fatality is exceeding 100 and the frequency is about 1 x 10^{-5} which is as higher compared to that of 10^{-8}.

Then we call this region as an unacceptable risk whereas if the number of fatality is lower than 10 and occurrence of those events causing these fatalities ranging from 10^{-6} to 10^{-8} we call that kind of risk in the plan as acceptable risk according to the Dutch regulations. So dear friends depending upon the countries stringent regulation imposed on process industries the acceptable risk level in process industry also varies.

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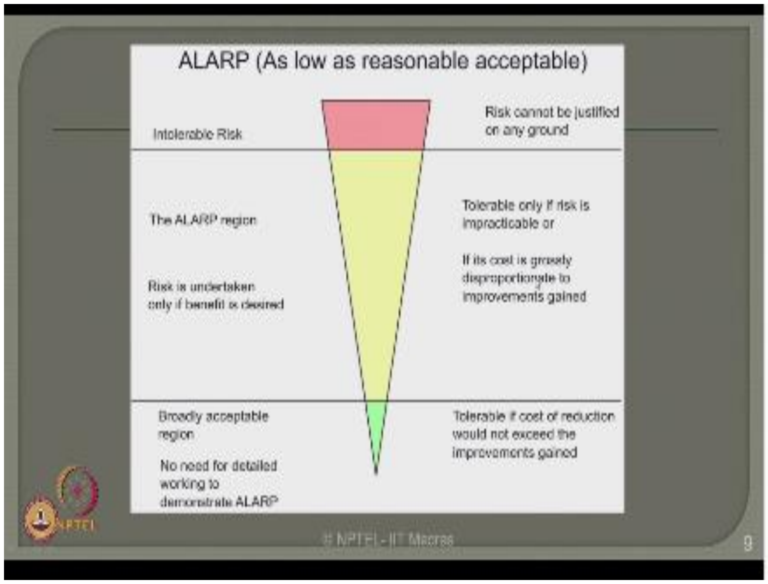

As far as India is concerned and in general global considerations are there we consider what is called as ALARP triangle as an acceptable norm of risk, ALARP is expanded as lay as reasonably practicable that we also say is an acceptable standard. So as low as reasonably practical. So ALARP triangle has got three distinct segments as you see here as painted green, yellow, and red. The red zone is indicating intolerable risk.

It means on any cost risk cannot be justified is a risk falls in the criteria. However, if a risk falls in the green criteria it is broadly acceptable region therefore there is no need to work for detailed demonstration of ALARP when the risk falls in this criteria. Most of the cases in oil and gas industry the risk will fall in a larger domain which is not as yellow here which is called as an ALARP region.

So if the risk is tolerable only if the cost is grossly disproportionate to its improvement. For example, you have got a risk identified in a given process industry you want to eliminate this completely, but the cost involved in eliminating that risk is highly disproportionate then you accept that risk as a part of your process industry.

So risk is undertaken in such case only if the benefit which is from the cost of control of risk is desirable. So you decide how the risk is acceptable dependent on the financial regulations and the benefit drawn from the financial in position on the risk level. Dear friends please understand in oil and gas industry the acceptance level of risk is also related to the economic viability of imposing and the risk in terms of its mitigation.

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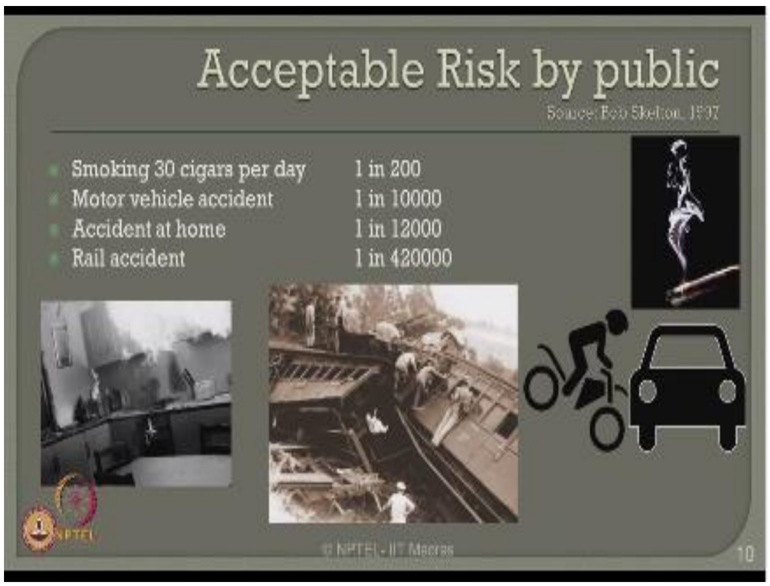

However, it is interesting for you to know risk is there in every walk of life for example, cigarette smoking, for example, accidents while you travel in automobile, in railway even when you stay in the house there came a risk which is categorized, which is also declare as acceptable societal risk by the public. For example, smoking 30 cigars per day will give a risk of 1 in 200, motor vehicle accidents is 1 in 10,000 and so on as you see in this slide. Even rail accidents will also have an acceptable level of risk, it means risk is an acceptable format in every walk of life it is not only acceptable in oil and gas industries as you may perceive as a wrong idea.

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When we talk about chemical risk especially when you talk about process safety regulations in process industries we underline what is called inherent safety which is imposed in chemical plants or process plants. The aim of inherent safety is basically to prevent accidents instead of relying on the control systems, it is very intelligent way of improvising safety you prevent the accidents instead of controlling them after they occur.

It includes reducing inventories of hazardous materials, use alternative process route involving lower pressure or more moderate temperature in a process routine, the catch words of inherent safety as define the OSHA, OSHA expands for occupational safety and health administration or the following, minimize the risk, substitute the process deviations, moderate and attenuate or limit the effects of consequences caused by the moderation, and simplify or make it error tolerable. So these are the key words what the inherent safety means as per OSHA recommendations.

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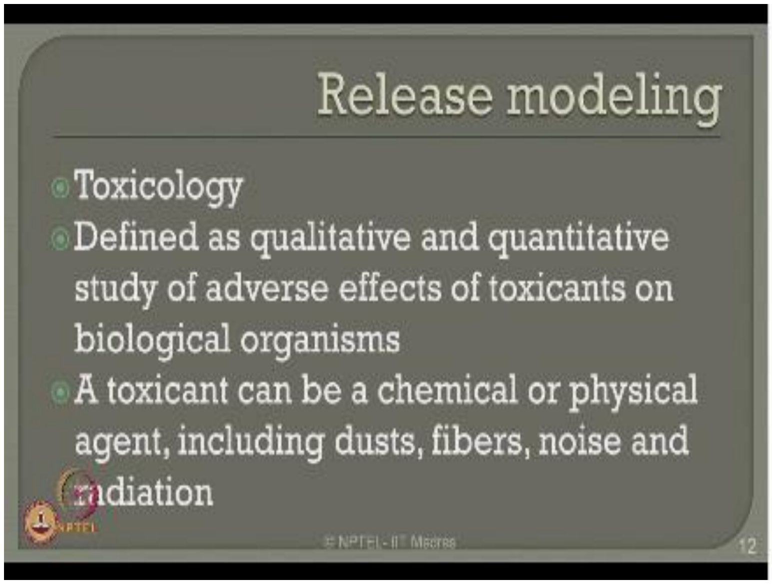

The moment we are talk about safety in chemical industries are the process industries which is as applicable to oil and gas industries. The moment we get in our mind is a release model. So what is a release model, toxicology is a term which one has got to understand before understanding the release model or dispersions models, when the question comes in mind what is toxicology, toxicology is defined as a qualitative and quantitative study of adverse effects of toxicants on biological organisms.

Please understand this is the domain of science which talks about the qualitative and quantitative implications of the consequence of toxicants and biological organisms. These organisms can be human beings, can be animals, plants etc. So the study deals with the consequence of effects it is not dealing with the characteristics of toxicology itself.

Please understand the turner reply or applicable to the chemical disposition, but it is the effect of dispersion of chemical in the environment. A toxicant therefore defined as a chemical or a physical agent including dust, fiber, noise and radiation all of them cause toxicants, toxicant does not mean only a chemical, it can be even a physical agent as simple as dust and fiber and noise and radiation effects as well.

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Now the question comes, how do these toxicant enter biological organism? They can enter in ingestion that is they can enter through the mouth into the stomach, they can enter inhalation they can enter through the mouth or nose into the lungs, they can enter through injection they can enter through the cuts in the skin, they can be also dermal absorption it can enter through skin membrane itself. So toxicants can enter in human organism in all these four manners.

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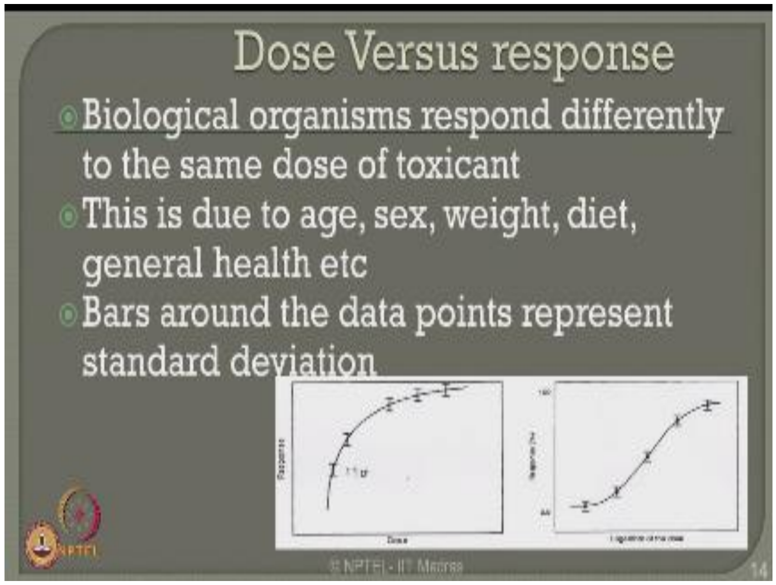

Once we talk about toxicants present of disposed environment then we are talking about acceptable of safety while integrating these two let us talk about dose versus response requirements. These are two graphs which are shown to you which will explain what is dose versus response in terms of acceptable standards, all biological organisms respond differently to the dose for which they have been inherit to, the same dose of toxicant can cause different variations in different organisms, because of the following reasons.

It can be due to age, it can due to the sex, it can be due to the weight, diet, general health etc. Therefore, a standard study has been conducted and statistical average has been taken which is plotted as shown in the figure. One is a normal plot they shows the standards deviation and these bars are all the variations along the line and the curve is plotted along its mean, the other plot is a another one variation of the dose versus response in percentage varying from 0 to 100.

Now based on these two curves we are going to define the acceptable standards of dose response on biological organisms.

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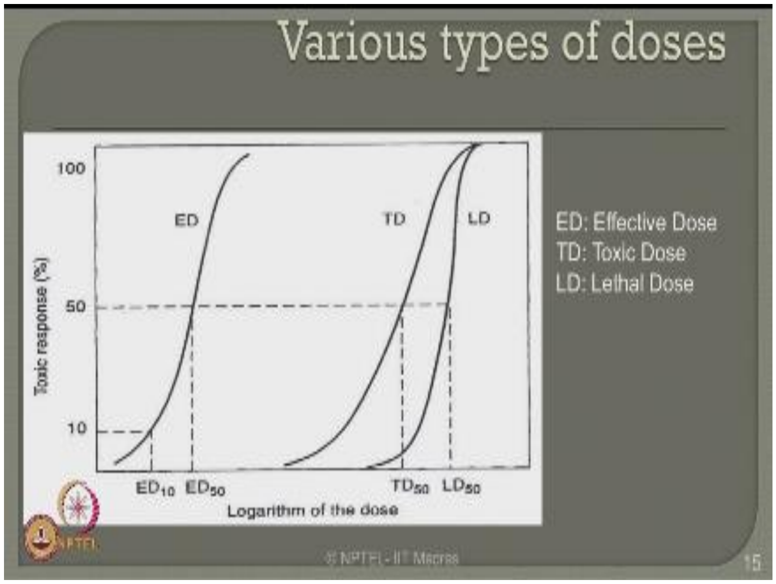

When we talk about various types of doses which are available in chemical industry, then there are three dose which can be explained in the literature, effective dose, toxic dose, and lethal dose. In the same curve as we saw in the last slide the logarithm is based to the respective toxic response in percentage is indicative of ED toxic dose, and the lethal dose as you see in the picture here.

Now as well as ED and TD and LD are concerned there are some standards called TD 50, LD 50, and ED 50. It is very simple that the corresponding dosage of that effective dose will be the toxic response caused 50% of the population. So 50% of the population toxic response is then projected to the respective curve and then projected vertical to get the corresponding dose which is responsible to cause the toxic response of 50% and the dose can either effective, it can be toxic, it can lethal. Now the question comes what we understand by effective toxic and lethal dosage.

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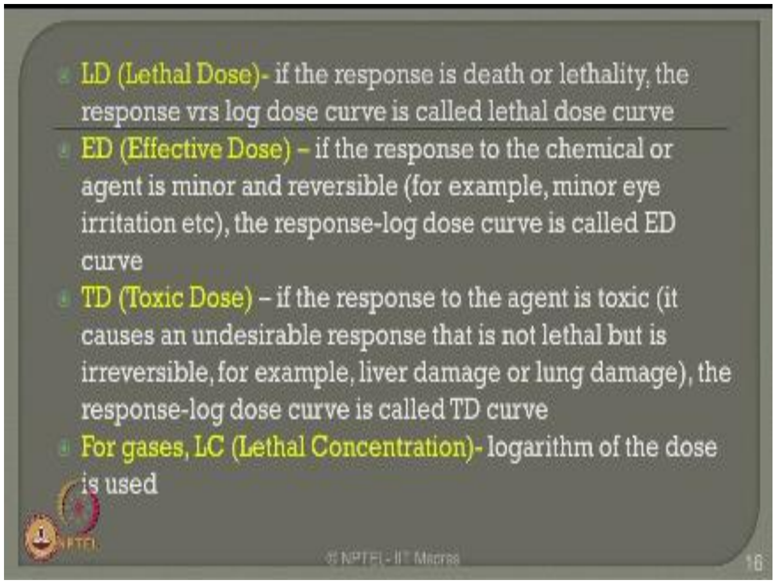

Lethal dosage is defined as the following, if the response is ultimately fatal or lethality the response versus log dose curve is called lethal dose curve. If the response to the chemical or agent is minor and reversible for example, the exposure causes you minor eye irritation etc. The response log dose curve is called ED curve. The toxic dose is defined as the response to the agents if it causes undesirable response that is not lethal but it is irreversible.

For example, it can result in liver damage, it can result in lung damage etc, then the corresponding curve of the response versus log dose curve is called TD curve. There are something on lethal concentration which is applicable for gases this is logarithm of dose which is being used in the lethal concentration this is applicable to gaseous states.

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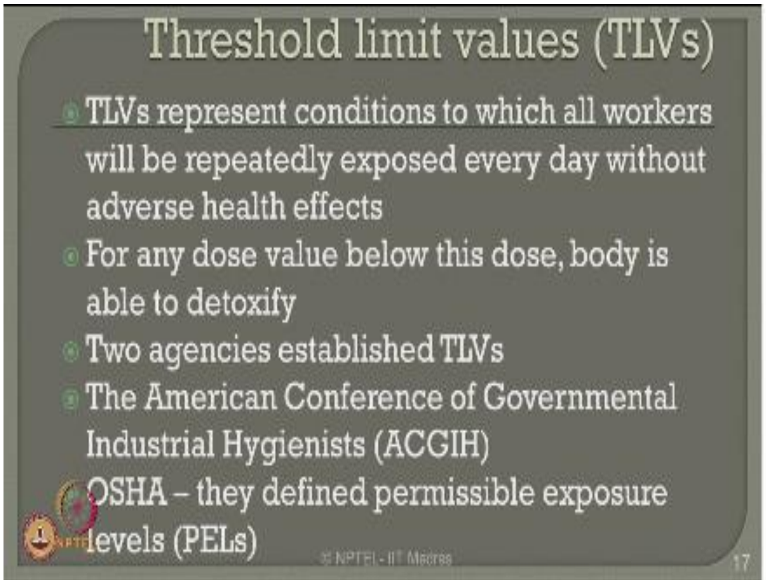

Once you understand what are the different doses which can be toxic, we have also seen what are different forms by which these dosage or these dispose chemicals can enter in human organism. Then comes a question what is a maximum value of these dosage is acceptable as well as safety norms. Now to talk about threshold limit values in short TLVs, TLVs actually represent conditions to which all workers will be repeatedly exposed everyday without adverse health effects.

Friends please note threshold value is a limitation imposed on exposure to a human being who is working in the plant without causing any adverse health effects. So it is the consequence of the dose on human body which is one of the safety regulations imposed by various ID. Therefore, for any dose value below this dosage body is able to detoxify, it means for a given chemical it your able to explain the threshold limit value if a human being or a biological organism is exposed to a value lower than the TLV then it is understood that the body can be detoxify and it will not cause any irreversible damage to the body.

Now the position comes how do you estimate this? There are two agencies which can established TLVs in process industry, one agency is the American conference of governmental industrial hygienists ACGIH, the other one is OSHA as we defined earlier. OSHA of course gives the value in permissible exposure levels briefly called as PELs.

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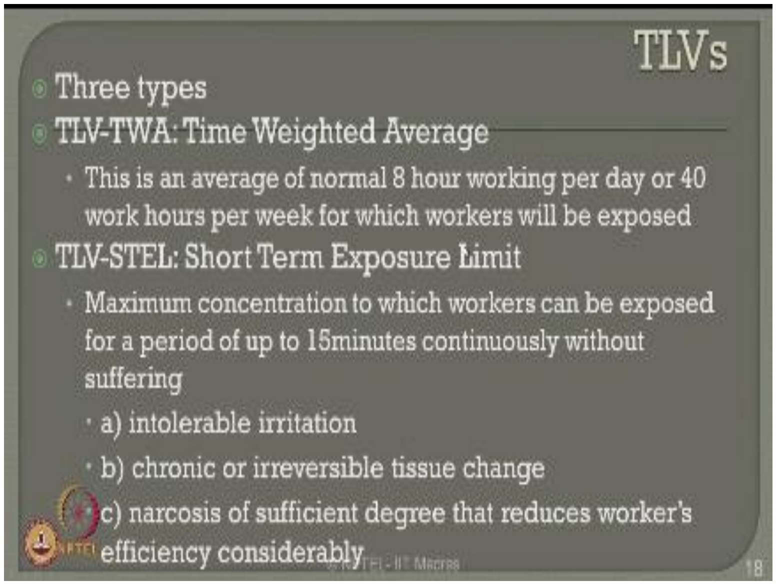

Now let us see what are TLVs, there are three types of TLVs namely as TLV-TWA, TLV-STEL and one more. TLV-TWA is called time weighted average, this is an average of normal 8 hours working per day or 40 hours working per week for which the workers will be exposed. So you talk about the threshold value in a time weighted average you would try to measure the exposure limits of the chemical on biological organisms like a human being for 8 hours or 40 hours a week and take an average you call this as time weighted average of TLV.

The other TLV value is call STEL which is call short term exposure limit. The term short term it so very clear that it is talking about the maximum concentration to which a worker can be exposed for a period only into a maximum 15 minutes continuously, but however within 15 minutes he must not suffer intolerable irritation, chronic or irreversible tissue changes and narcosis of sufficient degree which reduced workers efficiency considerably.

If the worker is not exposed to these three consequences for 15 minutes we call that as short term exposure limit of the chemical.

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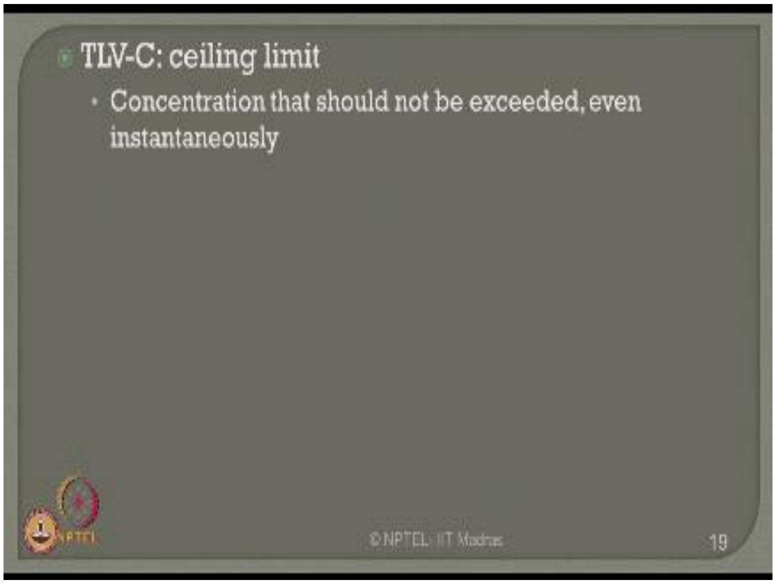

The third one is call a ceiling point or ceiling limit, that is called TLVC it is the maximum concentration that should not be exceeded even instantaneously there is even for a second this concentration value of the chemical should not be exceeded because this will not be sustain by a human being or a biological organism.

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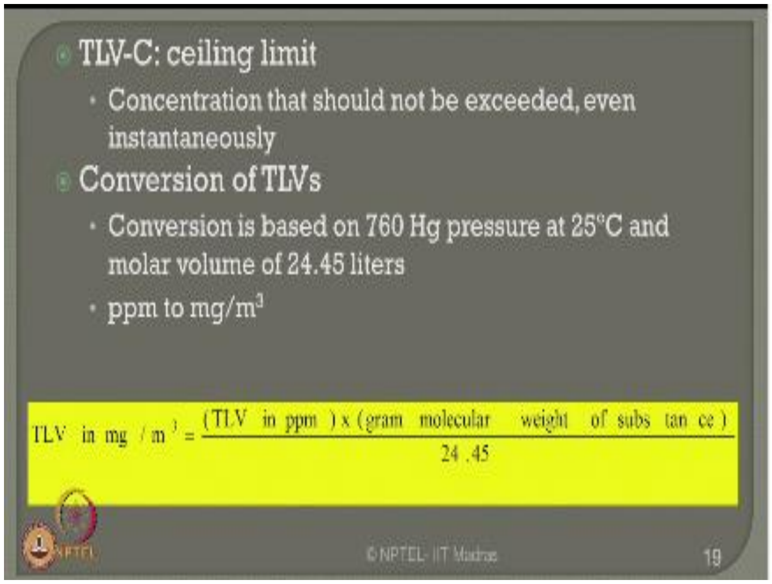

Now one can convert TLVs to pass by million or milligram of cubic meter the conversion is actually based 760 mercury pressure at 25·C with the molar volume of 24.45 liters now the equation for converting TLV which available in mg of m^3 is given to you in the slide now, so if you know the TLV in parts per million then if you know the gram molecular weight of a substance that divided by the molar volume of 24.45 then you can find TLV in terms of milligram per cubic meter.

Alternatively if you know the TLV in milligram by cubic meter then always cross multiple and get the equivalent TLV in parts per million. So TLV is available for all chemicals in both the formats either in ppm or in mg/m^3

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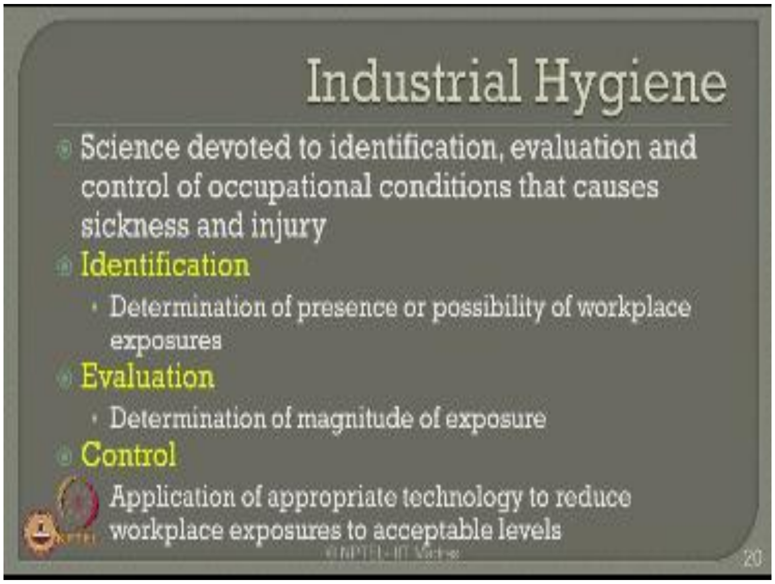

Once we understand what are the threshold values of different chemicals for which a human being can be exposed on a work environment, let us quickly talk about what do we understand by industrial hygiene. Industrial hygiene is actually a science devoted to identification, evaluation and control of occupational conditions that could result in sickness and injury. Identification deals with determination of presence or possibility of workplace exposures. Evaluation deals with determination of magnitude of exposure and control deals with application of appropriate technology to reduce work place exposures within acceptable levels.

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Let us quickly talk about identification in industrial hygiene. It requires a thorough study of chemical process, operating conditions and operating procedures which are applicable for a specific process industry. Now the question is to identify a specific industrial hygiene problem what would be the sources what you want to depend on, you must know the process design descriptions.

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You should know the operating instructions of the plants and equipment, you should have a very thorough safety reviews and you can also collect this information from material safety data sheets, which is available in the plant per every inventory.

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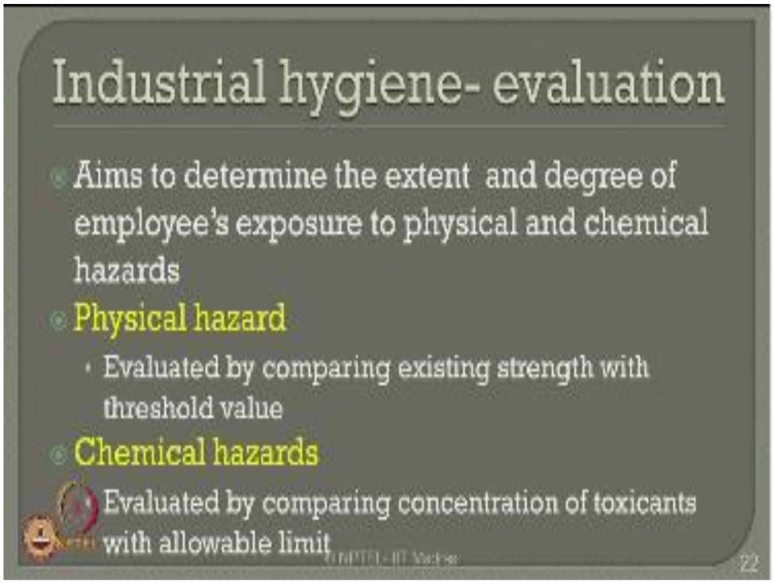

When we talk about evaluation of industrial hygiene then it aims to determine the extent and degree of employees exposure to physical and chemical hazards. Physical hazards can be evaluated by comparing the existing strength with that are the threshold value. Whereas chemical hazards can be evaluated by compare in the concentration of toxicants within the allowable limits as we saw in the previous slides.

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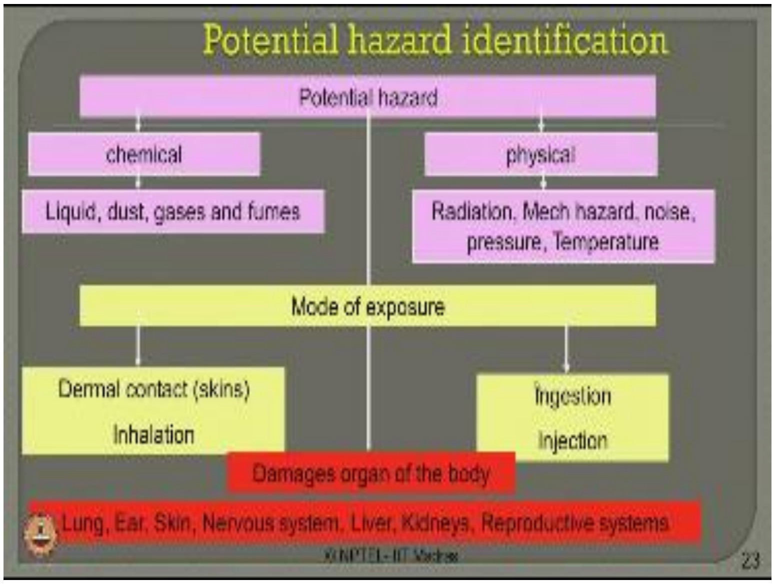

When we talk potential hazard identification the it goes by two ways when AZA by physical or chemical hazards talk about chemicals then the following could be an hazardous substance it can be liquid, it can be dust, it can be gases and fumes. But in take physical; hazards can be radiation, it C_a be mechanical hazard, it can be noise pollution, it can be pressure and temperature variations, unacceptable to the human being.

Now when we talk about the mode of exposure it can be dermal contact through skins, it can be inhalation, it can be ingestion, it can be indigestion or injection. Now the damages which can decide in an organ of a body can be lungs, ears, skin, nervous system, liver, kidney and reproductive systems. Now hazard identification is a combination of hazard identification and it is consequence of exposure in human body as you see in a given system.

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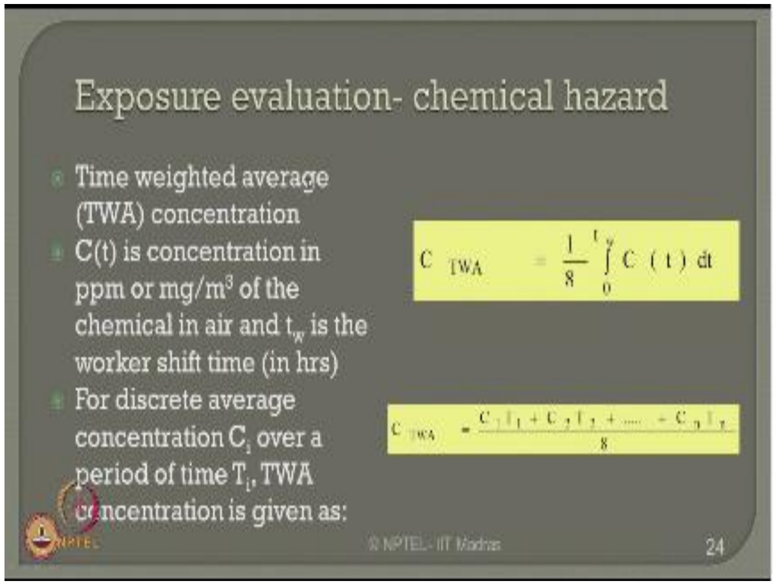

Now when we talk exposure evaluation we now focus now chemical hazard, because process industry like oil and gas industry is essentially focusing on chemical hazard let us quickly see how what to understand the chemical hazard and how do you evaluate it. For a chemical hazard we try to work out what is called time weighted average concentration. The time weighted average concentration is given by the equation the right hand side we generally averaged for a normal working hours are weight hours that is with the denominator 8 is shown here.

And which is having the integration of the concentration exposure for a weighted average of 0 to t_w where Ct is a concentration either in ppm or in mg/m^3 of the chemical in air and t_w is the worker shift time in hours. For a discrete average of concentration C_i can be over a period of T_i as you see in this equation. For example, if the working time is not continuous and the chemical exposure is also not continuous can still find TWA C with the sum of average of this over a period of 8 hours.

For example, a person is exposed for a specific chemical concentration for a specific period within 8 hours you get a sum of this and take an average of this what is we called time weighted average value.

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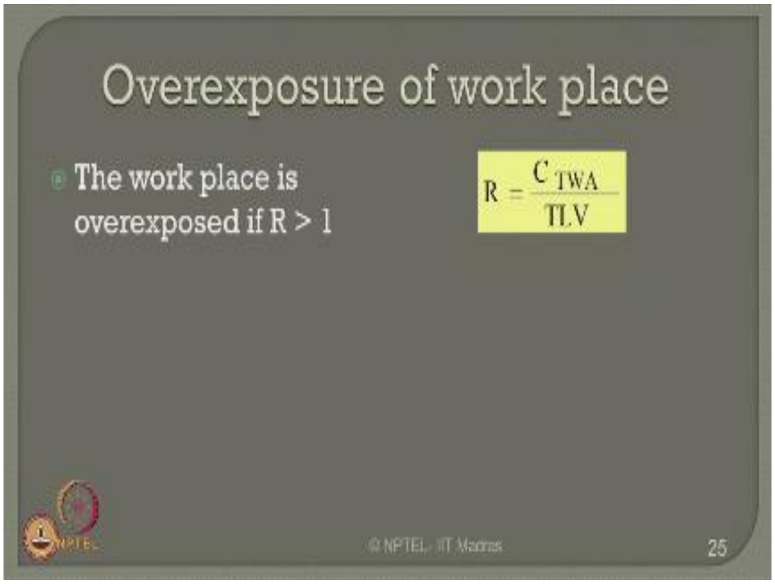

Based on this one can also find out whether the human being is exposed to over exposure in work place. The work place over exposed value is constituted to your exposure if the R value is greater than 1 where R is given by the ratio of C_{TWA}/TLV. For every chemical you have a threshold limit value, you have already know the C_{TWA} value if the ratio of this exceeds 1 then one can say the work place exposure is highly over exposed.

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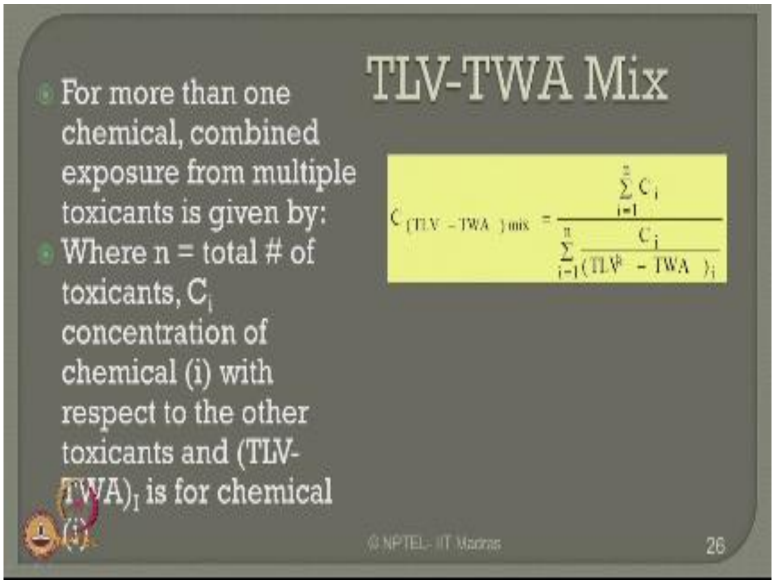

$$C_{(TLV-TWA)mix} = \frac{\sum_{i=1}^{n} C_i}{\sum_{i=1}^{n} \frac{C_i}{(TLV-TWA)_i}}$$

Sometimes in a chemical concentration can also have a mixture, so we can also work out the time weighted average now the threshold limit value for a mixture? For more than one chemical the combined exposure can be a multiple toxicants which can be given by this equation, which can be TLV-TLWA as you see here which can be the ratio of the concentration of n number of chemical where n refers to total number of toxicants and C_i is a concentration of the i^{th} chemical with respect to the toxicants as TLV TWA for the chemical i.

So you try to work out this ratio, now we can find out the TLV TWA for a mixture which can be ratio of a specific concentration with that of the concentration available for a specific value which is time weighted average.

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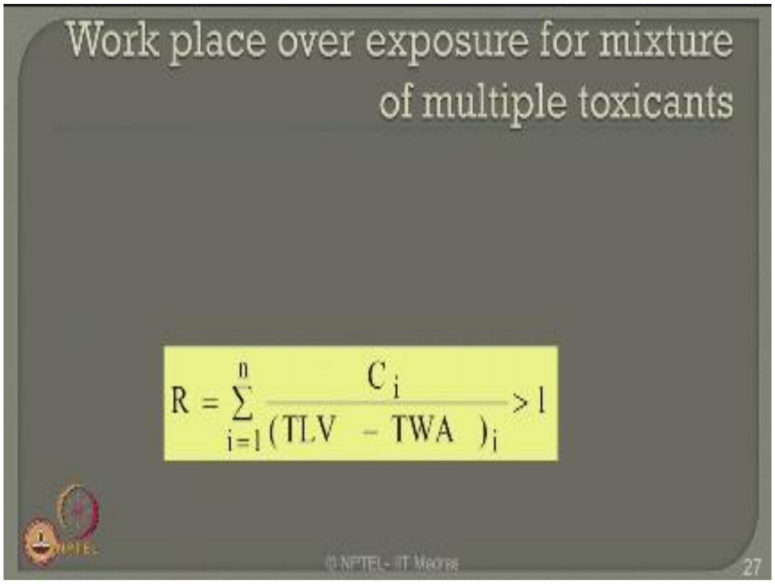

The work place over exposure for mixture of multiple toxicants can also be worked out by calculating the R value where R is now given by the equation as shown in the slide. If the R value exceeds 1 it is considered to be over exposed.

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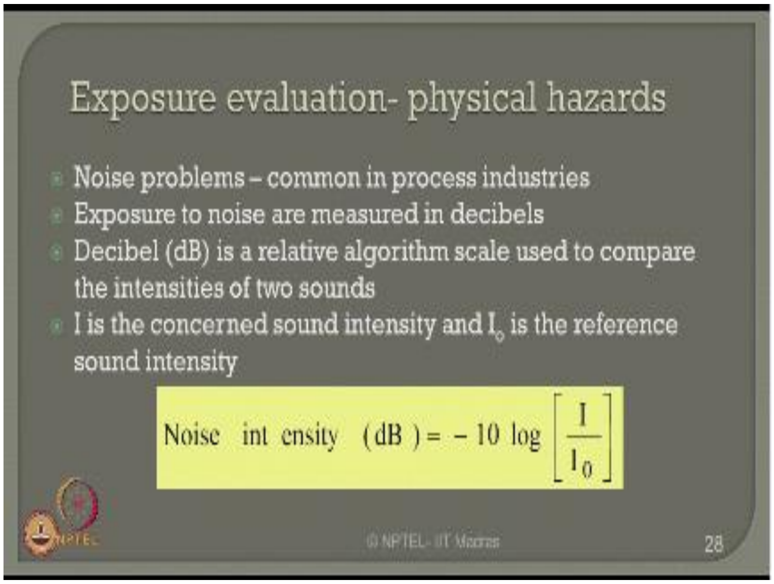

When we talk about exposure evaluation of physical hazards then we have noise problems which is common in process industry. Exposure to noise are usually measure in decibels. Decibels is a relative algorithm scale used to compare the intensities of two sounds. I is the concerned sound intensity in I_0 is the reference sound intensity then the noise intensity in decibel is given as the equation as shown in the slide now which can be computed on logarithmic scale.

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Source of sound	Sound intensity (dB)
Riveting	120
Punch press	110
Passing truck	100
Conventional speed	60
Average residence	40
Whisper	20
Threshold for good hearing	10

If you look at the acceptable level of the sound intensity in decibels for different processes involved in the industry, again see here even whispering can also have a sound 120 whereas riveting, punch press, passing truck extra are have very high decibels of 120 extra. And acceptable level of sound intensity in process industry should not cross 90, so if the value crosses 90 it is unacceptable and the exposure to be sound level should be as minimum as possible under safety regulations of process industries.

If we look at the sound level expose a in terms of the maximum permissible exposure are as the value of the sound level goes higher and higher they exposure are cannot be more than fraction of an hour so if you have a sound level of around let say 75 or 80 it is acceptable of our eight working hours. If the sound level goes above 90 disables then the working exposure ask should be ask minimum as possible which is imposed under safety regulations of oil gas industries.

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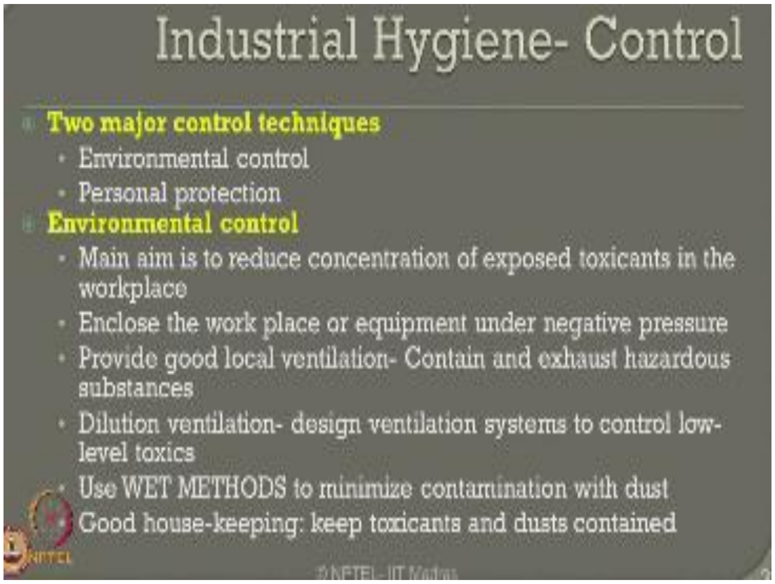

Then we talk about industrial hygiene we also talk about control to a major control techniques are generally practiced one is call environmental control the other is personal protection, environmental control the main aim is reduce concentration of exposed toxicants in the workplace therefore the best idea is enclose the workplace or equipment and a negative pressure provide local ventilation in a very high manner contain and exhaust hazardous substances.

Dilute the ventilation it meant you must design the ventilation system to control low level toxicants use essentially wed methods to minimize contamination with dust good housekeeping as it we discuss in the first module is one of the key to add variable control measures for environmental control.

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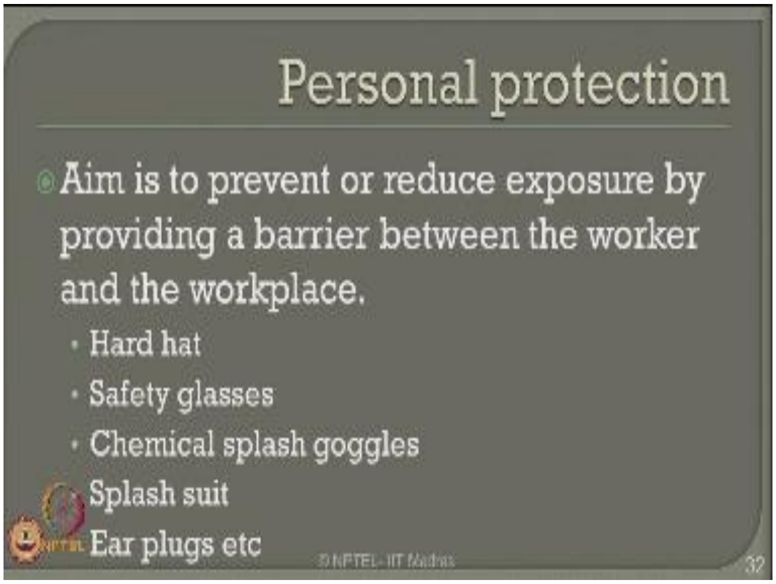

When you talk about personal protection the aim is to prevent pot reduce exposure by providing as barrier between the worker and the workplace you van provide hard hat or helmets safety glasses chemical splash goggles splash suits ear plugs etc which can act as a physical barrier which can protect the worker from noise and other physical hazards in the given workplace.

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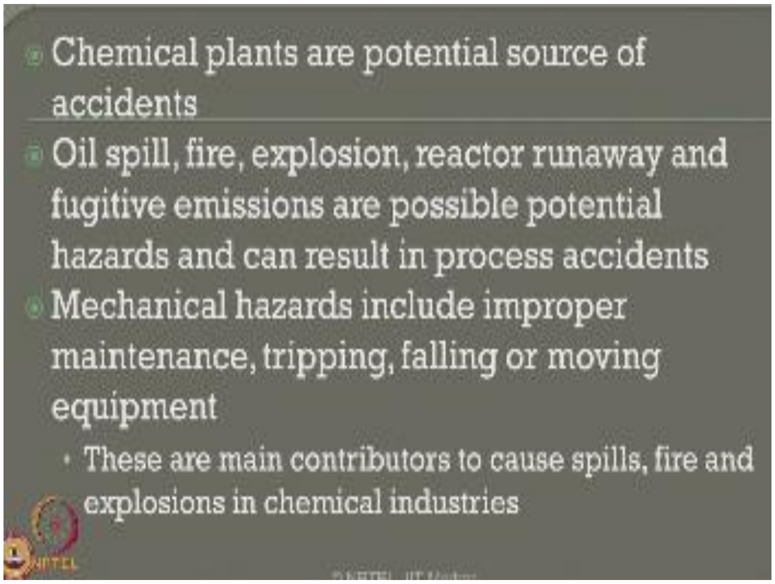

Now chemical plants are potential source of accidents oil spill fire explosion reactor runaway and fugitive emissions are possible potential hazards which can result in the process industries which can cause accidents. Mechanical hazards include improper maintenance tripping falling or moving equipment unfortunately this rods add to as main contributors to spirits fire and explosion in chemical industries.

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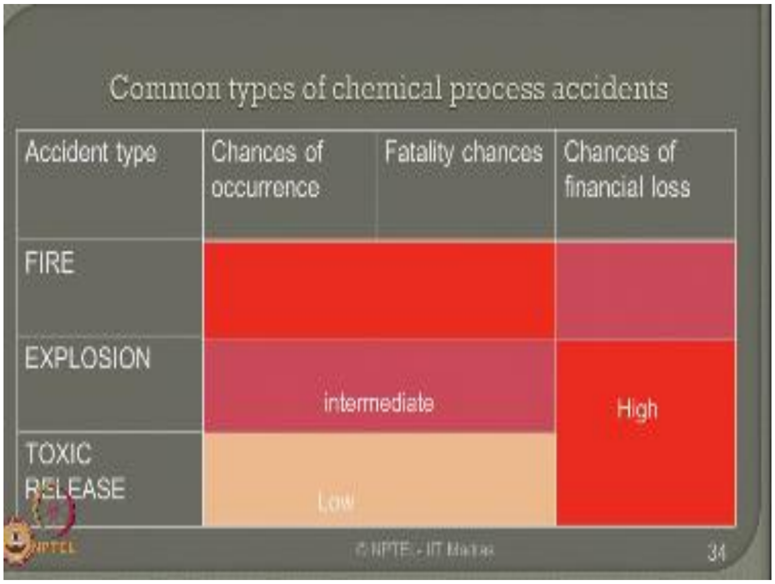

Now look at the common touch of the chemical process accidents and categories then has different accident type look at the accident type as fire explosion and toxic release if we look at the chance of occurrence fatality chances and chance of financial loss for a toxic release and explosion the financial loss is very high there has a fatality is only intermediate and low how over we look at fire the chance of occurrence is very high which is indicating a red color.

And the fatality chances are very high but the financial loss caused by fire is not in a higher range but it is only the intermediate range, so this is a graphical representation of different kinds of accidents happening in pros industries and would be the likely hope the fatality and the financial loss related to these three verities of accident which are very common in oil gas industries.

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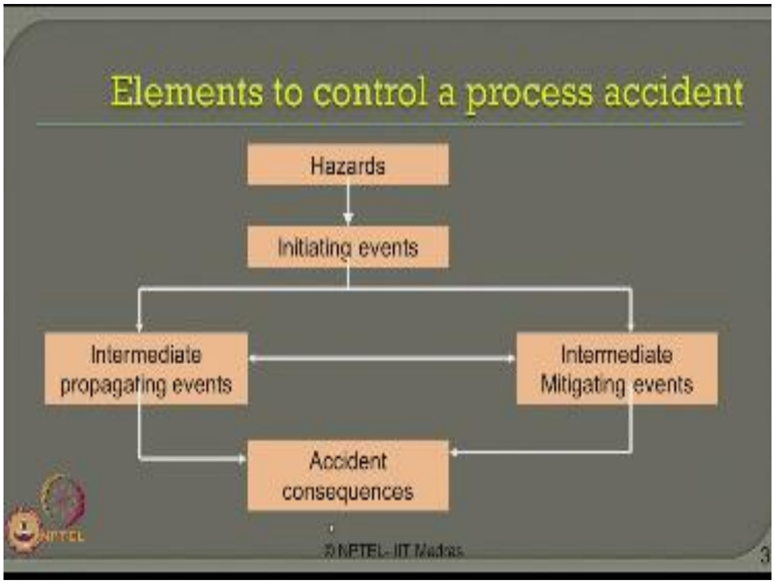

Now let us look at the element of control a process accident if identify is hazard it is have an initiating event the initiate event can be intermediate events or propagating events it can be mitigating events so one can always see the propagating events can also lead to accident consequences so hazards can the actually result in initiating events and adding together the propagating and mitigating events together inter act to form an accident consequence which need to be controlled.

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Now let us quickly see what are the types of hazards what we can see in a oils gas industry flammable material combustible materials toxic chemicals unstable materials highly reactive reactance can be examples of hazards related initiating events they can narrate from equipment malfunctioning containment failures thermal runaways human error in operations and maintenance etc.

To talk about intermediate propagating events they can be process parameter like temperature pressure flow rate etc it can be deviations from the design intents it can be toxic materials can be reactive materials can be ignition and exposable materials available as an inventory in the process plant. To talk about mitigating events it can be arraying from safety system responses like relief valves grounding backup utilities etc it can be mitigation system responses like events blow out valves containment dikes flares sprinkles etc.

Can also be from contumacy operations like alones emergency procedures personal safety equipments evacuation plants security arrangements etc, so talk about the accident consequences the consequences will be only three which can be either fire or explosion or release of toxic chemicals in the environment.

So friends please understand this is very compressive table which gives you what are the possible source of hazards what could be the initiating events what could be the propagating events what can be the mitigating events if they are all not at the control what to be the consequence accidents what to get. So it is very interesting instead of protecting equipment after the accident is always better to design a system to prevent accidents.

So identify the propagating and mitigating events have an effective control mechanisms so that these get a mitigate events are working in a proper manner were the designing effective to control accidents.

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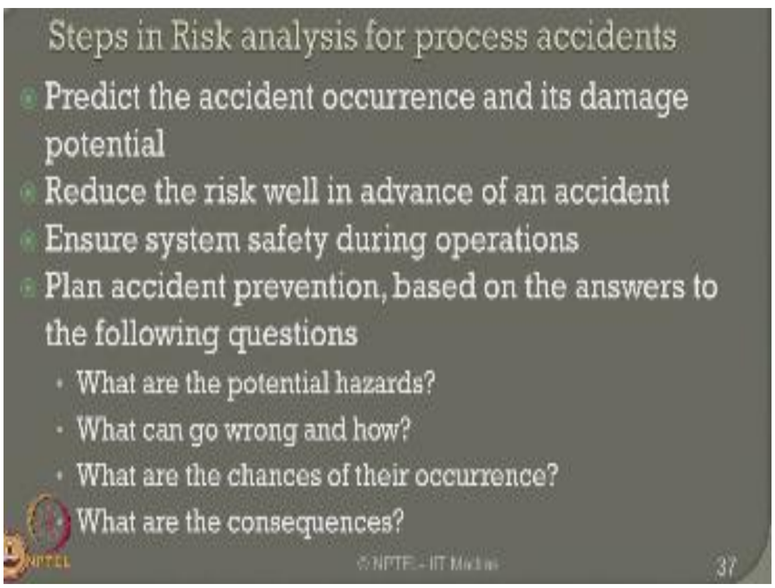

Now let us quickly see what are the steps involved and risk analysis of process accidents in particular predict the accident occurrences and the damage potential reduce the risk well in advance before in accident could occur, ensure system safety during operation and the plan accident prevention base on answers to the following question, what are the potential hazards, what can go wrong and how, what are the chances of their occurrences and what are the consequences if they occurred.

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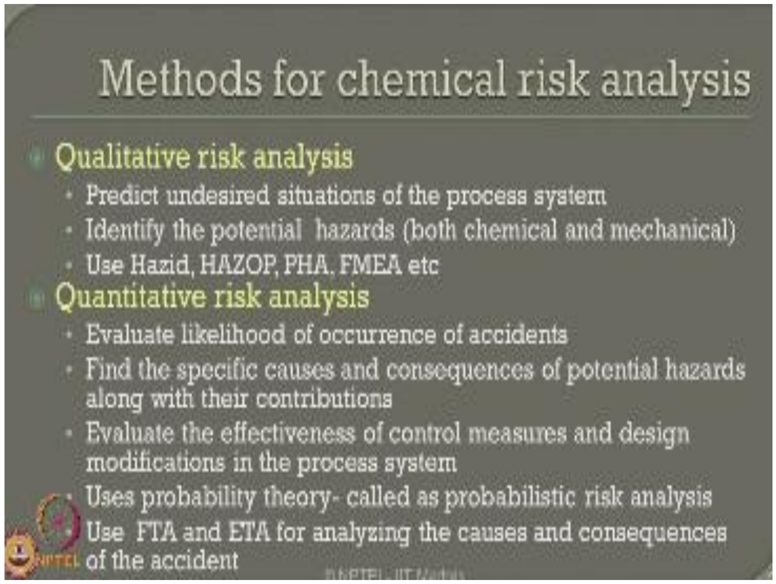

What are the different methods available in the literature for performing chemical risk analysis there are different qualitative risk analysis methods they are use to predict undesired situations of the process system they are helpful to identify the potential hazards both chemical and mechanical some of the examples are Hazid, Hazop, PHA, FMEA, etc which we are discuss in detail in the last module.

For talk about quantitative risk analysis methods they are used evaluate likelihood of occurrence of accidents they find the specific causes and consequences of potential hazards along with the contributions they are use evaluate the effective of control measures and design modifications in the process system they use probability theory therefore they are called as probabilistic risk analysis also.

Examples are FTA and ETA where they stands for fault analysis and event analysis which are used for identifying the causes and consequences of an accident.

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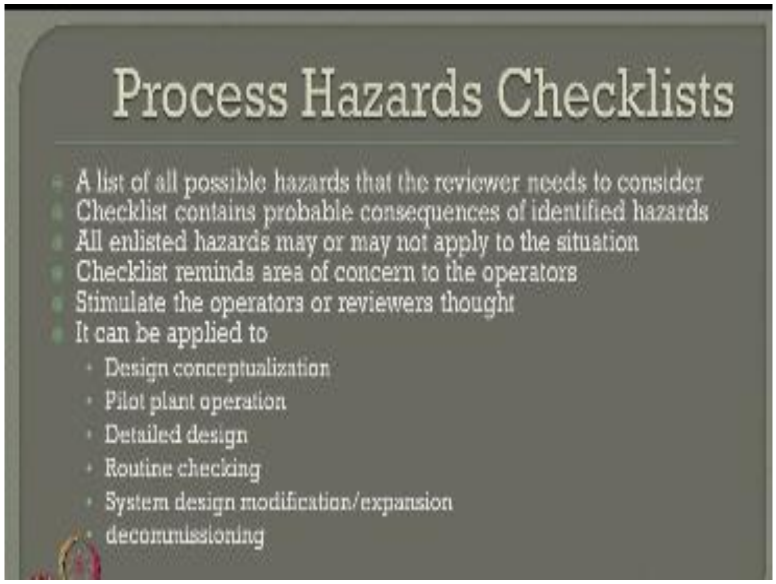

We also talk about safety review the first module let us quickly see what would be a safety review program there are two types of safety review program, one is informal safety review with generally applicable for small changes to the existing process small bench scale laboratories can be applicable for this kind of safety review program. Other formal safety program we generally used for new process for certain or process which has got huge modification in the existing system ,it require a team of experts which need to develop and review the report and inspect the process periodically.

We can also do process hazards checklist which is helpful it is actually list of all process hazards that review needs to consider ,the checklist contains probable consequences of identified hazards, all enlisted hazards may or may not apply to situation ,the check list should remain area of concern to the operators it should simulate the operators or reviewers thought process very carefully it can be applied to design conceptualization can be applied to pilot plant operation and the detain design stage at the routine checking itself can also enter in to system design modification /expansion stages it is most importantly applied in the decommissioning stages

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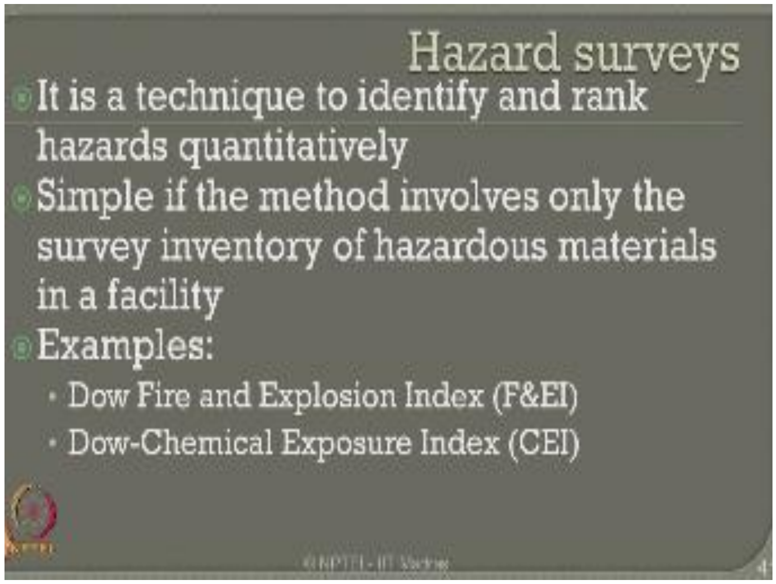

One can also conduct hazard surveys which is a essential technique identify and rank hazards quantitatively .it is simple if the method involve only the survey inventory of hazardous material in a given facility examples dow fire and explosion index dow chemical exposure index which is called CEI which will discuss in detail in the next lecture onwards CEI is one of the popular method of toxic release and dispersion models practiced in oil gas industries

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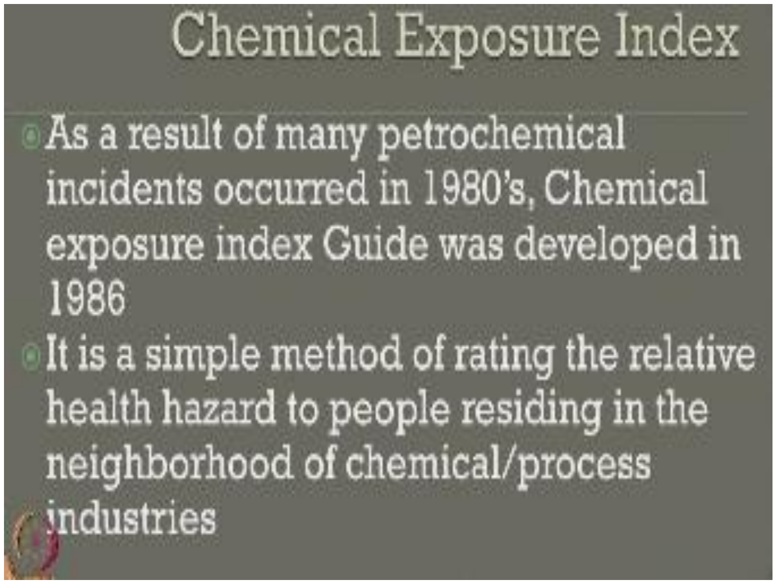

Chemical exposure index is essentially an outcome of result of many petrochemical incidents occurred in 1980's chemical exposure guide is developed 1986 which used as a procedure to evaluate risk analysis in process industries it is a very simple method of rating the relative health hazard to people residing the area where the process industry is located.

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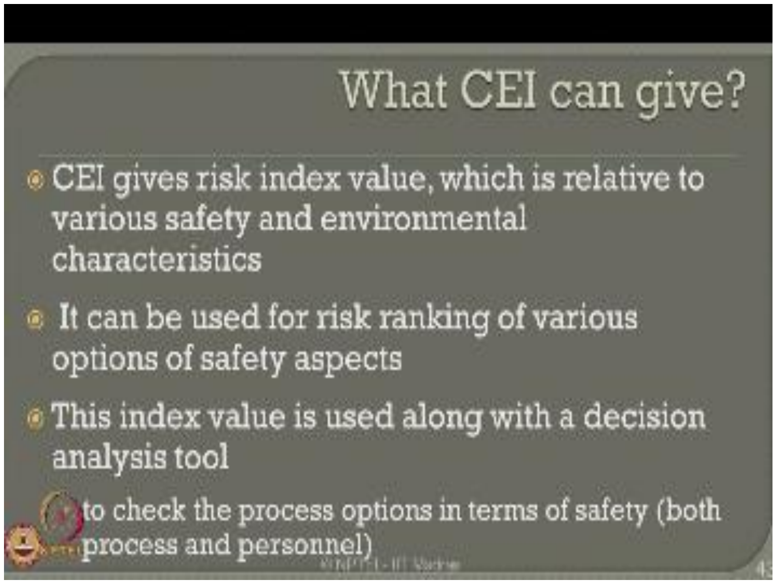

What can a chemical exponents index give mean CEI gives risk index value which is be a number which is related to various safety and environmental characteristics around the plant where it is situated ,it can be used for risk ranking or various options of safety aspects in a given system, this index value is used along with the decision analysis tool to check whether the process option in a safety system is ok or not ,it address the both process and personal safety.

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What do you actually need to do chemical expensed index analysis ,you require the plan of the process plant ,you also required the details of the surrounding area in terms of population ,you require a flow sheet which involve major piping location of containment vessel and the capacities and most importantly a list of chemical inventories present in the space of the working plant you require to identify the physical and chemical hazards from a given properties you should also know the physical mechanical and chemical properties of the material which being investigated in the given plant.

You should also know ERPG values ERPG stands for emergency response planning guide which tells me what are the ERPG values for different chemicals available in the inventory once you know that you follow CEI guide and calculate and fill up the CEI form and try to evaluate the safe hazard distance for a given chemical if it is exposed in the environment ,we I will take up an example in the next lecture and see how CEI can be done for process industry thank you very much we I will see in the next lectures.

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