Plant Design and Economics
Prof. Debasis Sarkar
Department of Chemical Engineering
Indian Institute of Technology, Kharagpur

Lecture No -54
Toxic Release, Hazard Identification and MSDS

Welcome to lecture 54 of plant design and economics. We have talked about the fires and explosions. Now, we will talk about toxic release which has the greatest potential for fatalities. We will also talk about very briefly Hazard identification as well as material safety data sheet or commonly known as MSDS.

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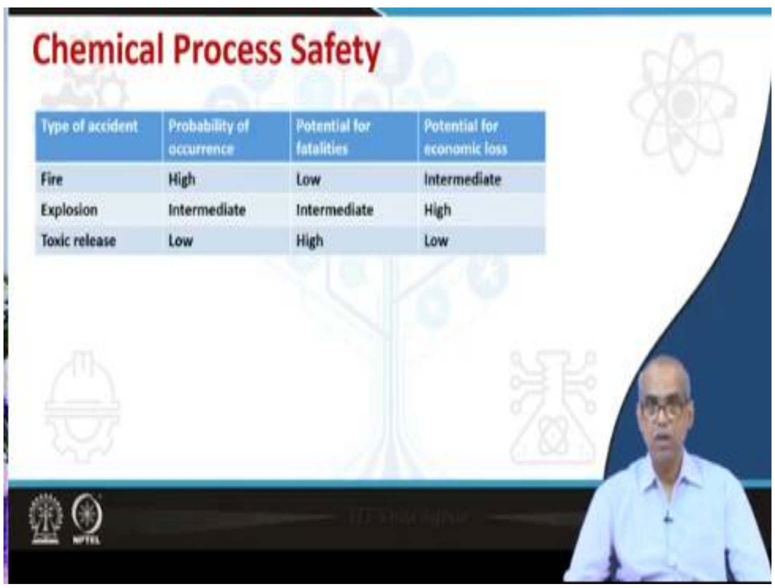

So we have been talking about these three different accidents in chemical process industries, fire explosions and toxic release. Toxic release has low probability of occurrence, also it has low potential for economic loss, but it has the highest potential for fatalities.

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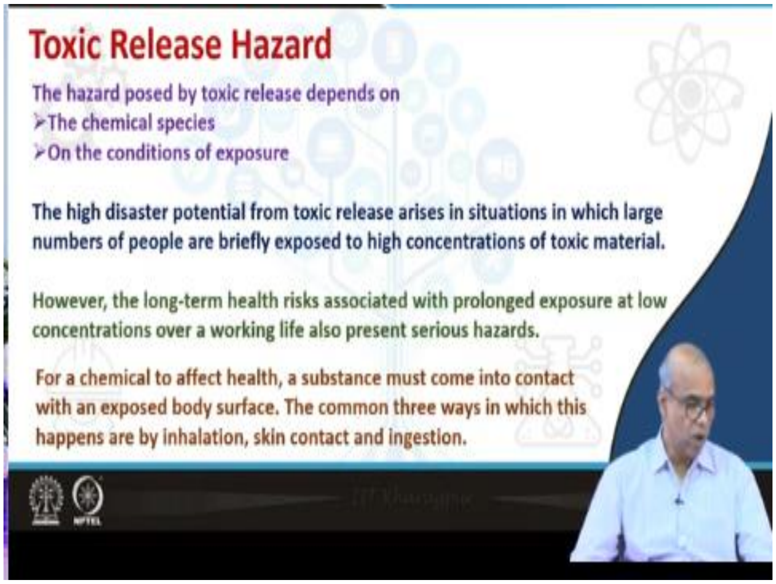

The hazard posed by toxic release depends on the chemical species and also on the conditions of exposure. The high disaster potential from toxic release arises in situations in which large numbers of people are briefly exposed to high concentration of toxic material. However, the long term health risks associated with prolonged exposure even at low concentrations over a working life also present serious hazard. So we must consider both short term exposure as well as long term exposures.

Exposures to high toxic concentrations for short duration as well as long term exposure to low concentrations, so both present serious hazards. For a chemical to affect health or toxic material to affect our health condition, a substance must come in contact with an exposed body surface. And what are the roots through which such contact is possible? They happen by inhalation, skin contact and ingestion or swallowing through mouth.

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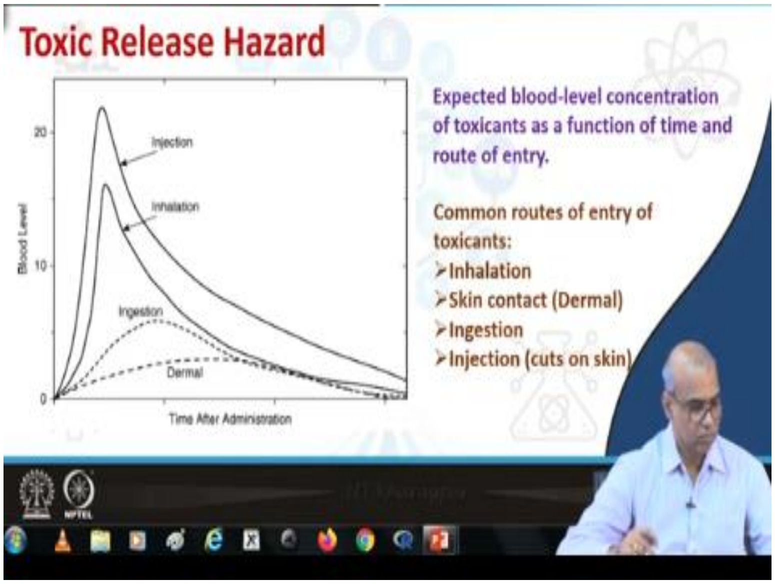

Now when toxic material gets into our body either through inhalation or skin contact, which is known as dermal or ingestion, that is through the mouth, the concentration of the toxic material in the blood will increase. And if we plot the concentration of the toxic material in the blood versus time after administration you will get typical curves like this. So this is for inhalation, this is for ingestion and this is for skin contact. Among these three, note that inhalation shows a quick peak.

Now, if a worker has say cuts on skin and then that cut portion is exposed to toxic material. So the effect will be something similar with injecting toxic material to the worker. And through injections you are sending this toxic material directly to the blood. So, obviously you will get a very high peak that means a large amount of toxic material in the blood very soon after the administration.

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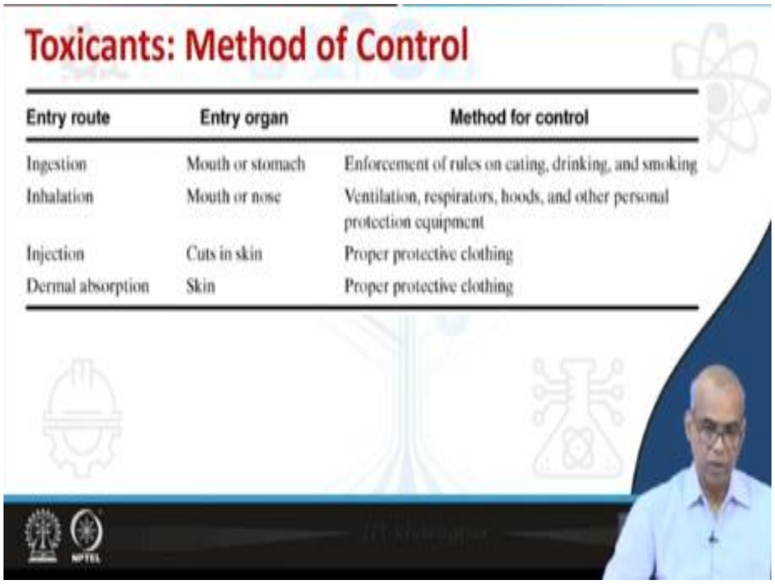

Now, these are some of the methods for controlling the entry of such toxic materials to various roots. When the entry root is ingestion, the entry organ is mouth or stomach and to avoid entry of toxic material at the workplace rules should be enforced on eating, drinking and smoking habits. When the entry root of toxic material is inhalation, the entry organ is mouth or nose and the method for control should be ventilation, respirators, hoods and use of other personal protection equipment.

If a worker has cuts in the skin, the entry root of the toxic material may be injection, so the worker must use proper protective clothing. Similarly, to avoid entry of toxic material through skin or dermal absorption, workers must be using proper protective clothing.

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Well we have different routes of entry of toxic materials to the human body. In a preliminary process design, the primary consideration is given to the contact with toxicants by inhalation. Now this happens either through accidental release of toxic material to the atmosphere or the fugitive emissions caused by slow leakage from pipe flanges, valve glands, pumps and compressor seals.

So accidental release of toxic material to the atmosphere or fugitive emissions which is caused by slow leakage of toxic material from pipe flanges, valve glands, pumps or compressor seals. Such things if happens, then the toxic material can enter the workers body through inhalation. So during the preliminary process design, we must take this into consideration. Care should also be taken while filling a tank with a liquid. Tank filling causes emission when the rise in liquid level causes vapour in the tank to be released to the atmosphere.

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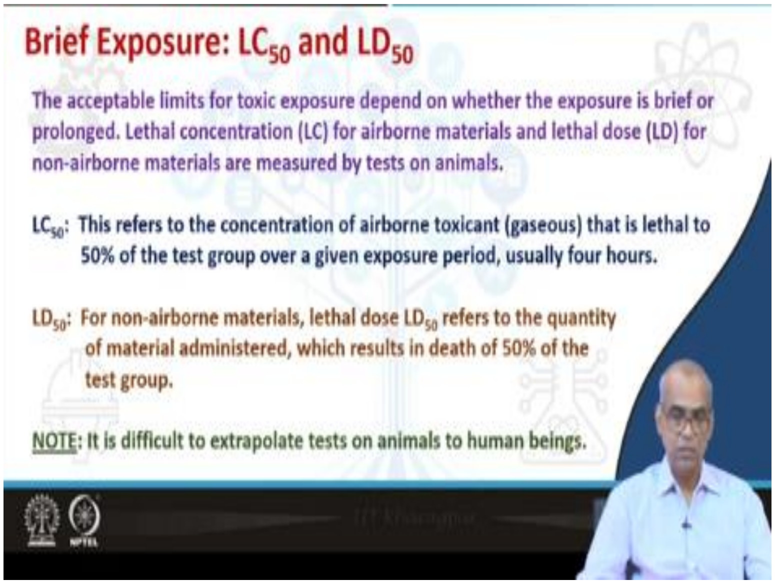

Now we will define two terms known as lethal concentration and lethal dose. These two terms are used when our workers are exposed for a brief period of time, so brief exposure. The acceptable limits of toxic exposure depends on whether the exposure is brief, that means taking place over a short period of time or the exposure is prolonged taking place over a long period of time. The lethal concentration is used for airborne material and the lethal dose is used for non airborne metric toxic material.

That means, how much toxic material is lethal for a living organism? So these lethal concentrations or lethal doses are measures of that. Now, such tests are conducted on animals and then extrapolated for human beings. So let us first define lethal concentration and this refers to concentration of airborne toxic material. If we are using toxic material that is airborne, the quantity that is lethal is determined by LC50.

LC50 refers to the concentration of airborne toxicant, which is the gaseous toxicant that is lethal to 50% of the test group over a given exposure period. And this exposure period is short because you are talking about quantifying brief exposure and this is confusedly taken as 4 hours. So LC50 refers to the concentration of airborne gaseous toxicant that is lethal to 50% of the test group over a given exposure period, usually 4 hours.

So test groups constitute the candidates over which such tests are being conducted and as you have discussed before the test is conducted on animals and extrapolated for human beings. For non airborne material, we use lethal dose, so LD50 will be used for non airborne material and LD50 refers to the quantity of material administered which results in death of 50% of the test group. So, both the definitions are very similar in fact same definitions, one is for airborne gaseous toxic material and the other one, which is lethal dose is for known airborne material.

So both represent a quantity which is lethal; that means we will kill 50% of the test group over a given exposure period. Note that it is difficult to extrapolate tests on animals to human beings but these numbers will give us an idea about their lethality on human beings.

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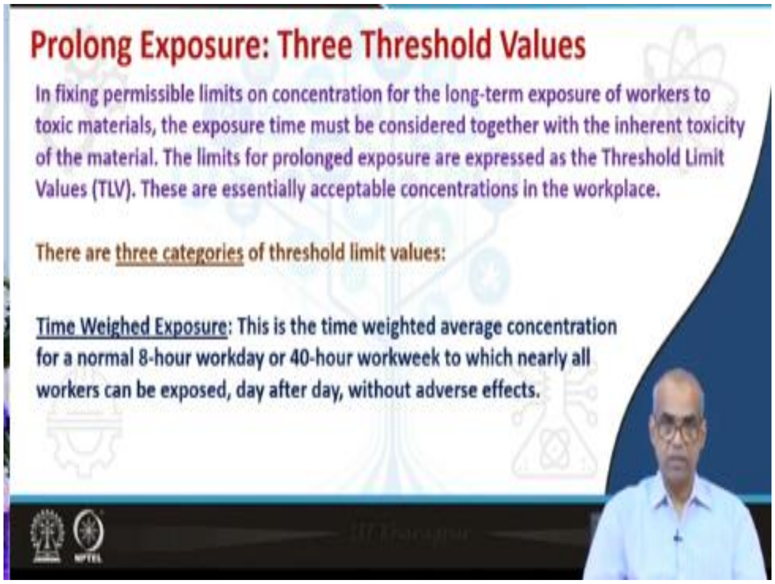

Similar to brief exposure we can also quantify such exposures for prolonged periods and we use three different threshold values for prolonged exposure to toxic materials. So the way LC50 and LD50 represents the quantity that is lethal to 50% of the test group for a brief exposure, we have threshold values and we use three threshold values which basically gives us permissible limits on concentration of the toxic material to which workers can be exposed.

In fixing permissible limits on concentration for the long term exposure of workers to toxic materials, the exposure time must be considered together with the inherent toxicity of the material. The limits for prolonged exposure are expressed as the Threshold Limit Values and these are basically acceptable concentrations of the toxic materials in the workplace. Typically, these values are expressed in terms of ppm, parts per million. There are three categories of threshold limit values.

So all basically represent the permissible limits on the concentration of the toxic material to which the (())(16:20)) can be exposed for long term. Time weighted exposure; so one of the three threshold limit values or TLV is time weighted exposure. This is the time weighted average concentration for a normal 8 hour workday, that means 8 into 5 Monday to Friday, say 5 days a week, 40 hour workweek to which nearly all workers can be exposed day after day without any adverse effect.

So time awaited exposure is the time weighted average concentration of the toxic material for a normal 8 hour workday or 40 hour workweek to which nearly all workers can be exposed, day after day, without adverse effect.

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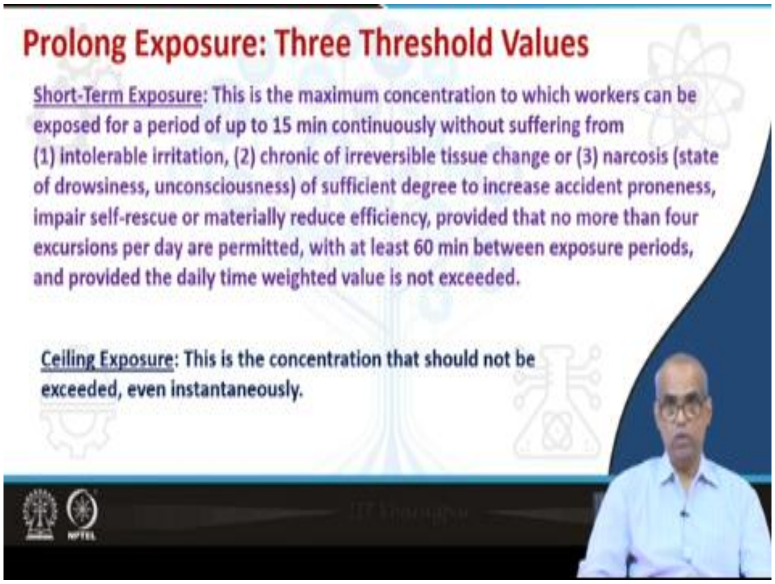

The second threshold values short term exposure. This is the maximum concentration to which workers can be exposed for a period of up to 15 minutes continuously without suffering from certain adverse effects such as; intolerable irritation, chronic irreversible tissue change or narcosis. Narcosis means a state of drowsiness or unconsciousness upon taking a drug. So this gives you short term exposure.

The maximum concentration of the toxic material to which workers can be exposed for a period of 15 minutes continuously without suffering from certain effects which are intolerable irritation, chronic irreversible tissue change or state of drowsiness or unconsciousness, which is called narcosis. Finally ceiling exposure. This is the concentration that should not be exceeded even if the workers are exposed for a very very brief period of time instantaneously. So, these are three different types of threshold values.

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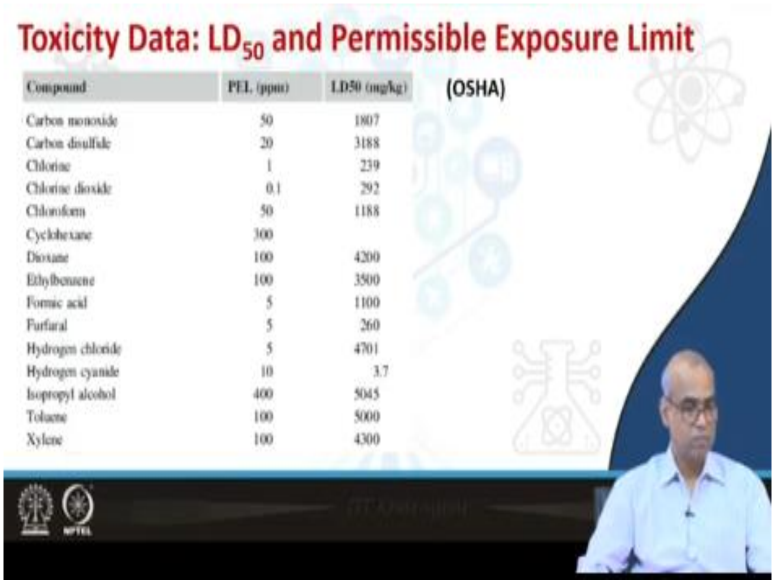

Compound	PEL (ppm)	LD50 (mg/kg)
Carbon monoxide	50	1807
Carbon disulfide	20	3188
Chlorine	1	239
Chlorine dioxide	0.1	292
Chloroform	50	1188
Cyclohexane	300	
Dioxane	100	4200
Ethylbenzene	100	3500
Formic acid	5	1100
Furfural	5	260
Hydrogen chloride	5	4701
Hydrogen cyanide	10	3.7
Isopropyl alcohol	400	5045
Toluene	100	5000
Xylene	100	4300

So here some LD50 values and the permissible exposure limit PEL expressed in ppm for various compounds. Note that hydrogen cyanide is also reported here which has LD50 values of only 3.7 mg per kg. So the OSHA, Occupational safety health administration has released a very long list which reports the LD50 values as well as PEL or permissible exposure limit for a wide range of compounds that is common that we use in chemical process industries and these toxicity data are very important and safety measures should be taken accordingly.

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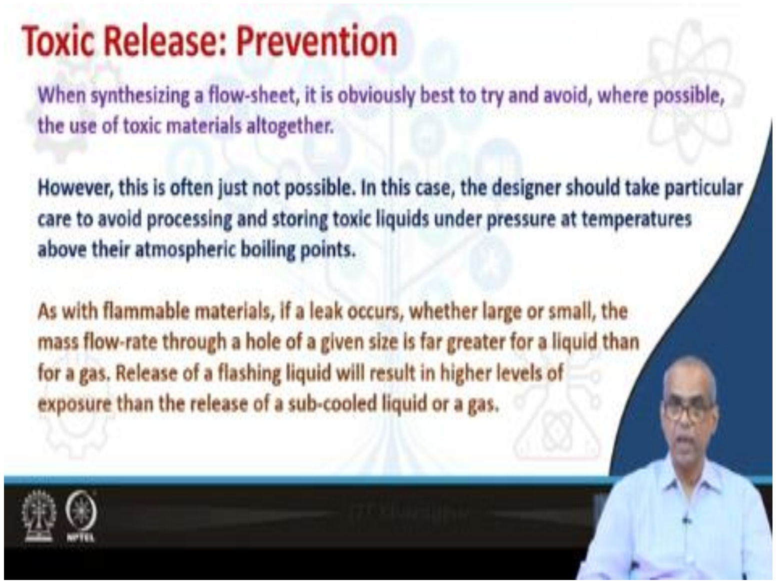

Now, let us see how we prevent toxic release. When synthesizing a flow sheet, it is obviously best to try and avoid as far as possible, the use of toxic materials all together. However, this may not be possible all the time. So in that case, the designer should take particular care to avoid processing and storing toxic liquids under pressures at temperatures above the atmospheric boiling points.

As with flammable materials, if a leak occurs, whether large or small, the mass flow rate through a hole of a given size is far greater for a liquid than for a gas. Release of a flashing liquid will result in higher level of exposure then the release of a sub-cooled liquid or a gas.

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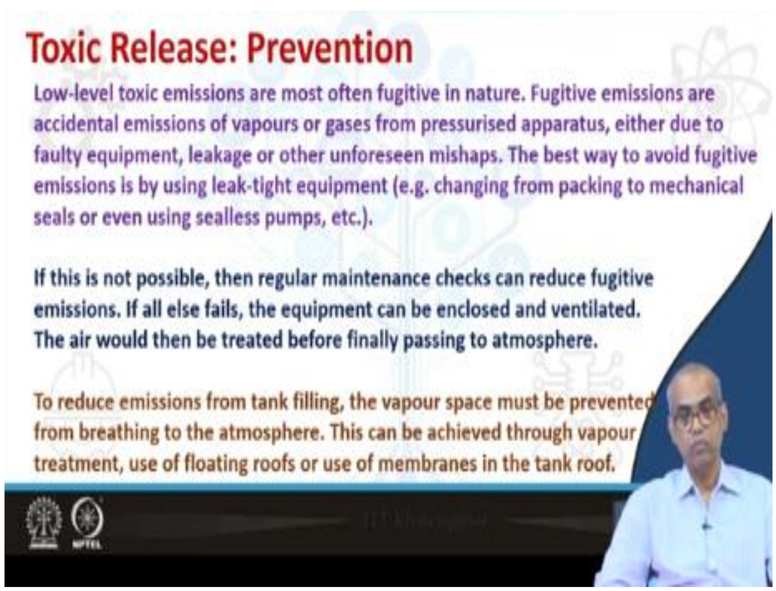

Low level toxic emissions are most often fugitive in nature. Fugitive emissions are accidental emissions of vapors or gases from pressurised apparatus, either due to faulty equipment, leakage or other unforeseen mishaps. The best way to avoid such fugitive emissions is by using leak type equipment. For example, we change from packing to mechanical seals or even we can use sealless pumps so that the leakage is completely avoided.

If this is not possible, then regular maintenance checks should be in place and regular maintenance checks can reduce fugitive emissions. If all else fails, the equipment can be enclosed and ventilated, but before ventilation the air should be treated. To reduce emissions from tank filling, the vapour space must be prevented from breathing into the atmosphere. This can be achieved through vapour treatment, use of floating roofs or use of membranes in the tank roof.

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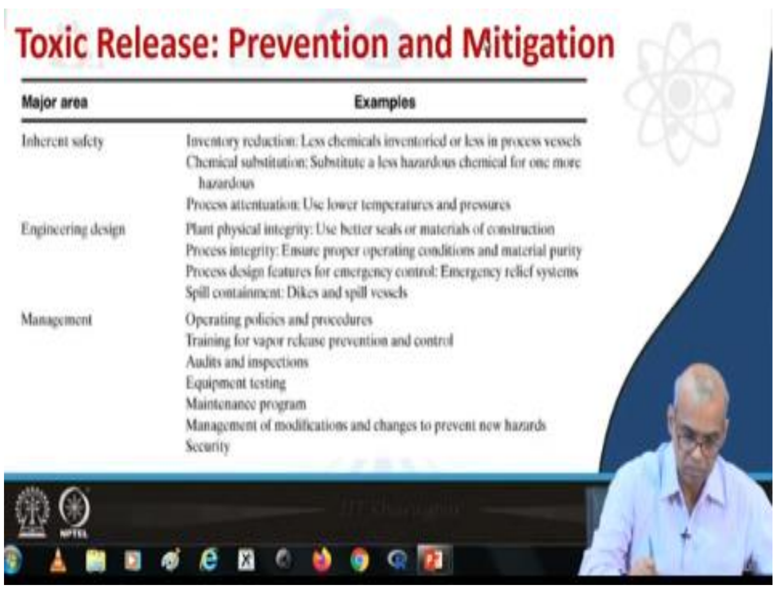

So here certain prevention and mitigation measures for release of toxic materials. We should reduce our inventory, so let us chemicals should be stored, we should use less hazardous chemicals, that means design processes such that we can avoid use of more hazardous material. So if it is possible, we should substitute less hazardous chemicals for one more hazardous chemical. During the design state we should come up with processes such that we do not have to use extreme temperatures, extreme high temperatures we should not use.

Management has a major role to play, there should be training for vapour release prevention and control, audits and inspections should be held, regular equipment tests should be done, maintenance programs should be followed religiously.

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Early vapour detection and warning should be in place. There should be water sprays, water curtains, steam curtains and air curtains, there should be emergency response. If anything happens, emergency shutdown equipment and procedures should be in place, sight evacuation strategies should be in place, there should be arrangement for immediate medical treatment, management should arrange for one side emergency plans, training and reels regularly.

All workers should use personal protective equipment. So, such steps should be followed which will prevent and mitigate the toxic release to a large extent.

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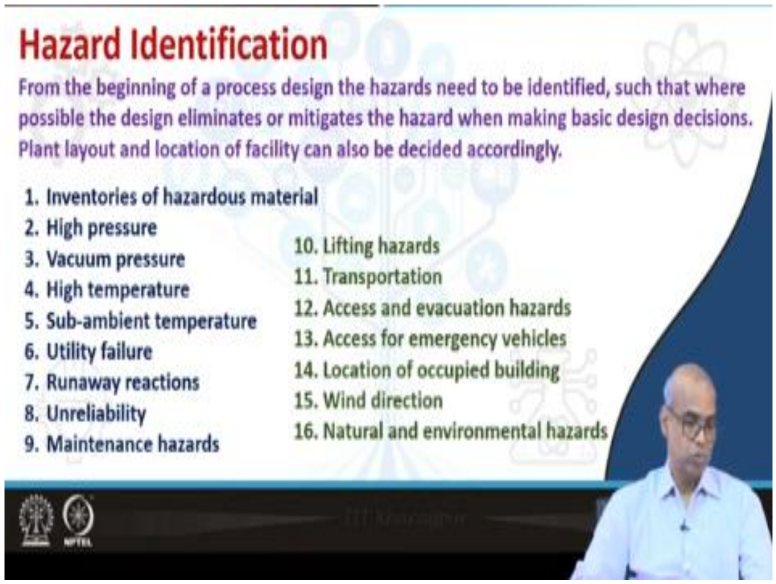

Now will briefly talk about hazard identification. From the beginning of a process design the hazards are to be identified. And we need to identify hazards such that wherever possible the design can eliminate or mitigate the hazard while taking basic design decisions. This should also apply to plant layout design as well as deciding on the location of the facility. So, these are the list of hazard identification, inventories of hazardous material, high pressure, vacuum pressure, high temperature, sub ambient temperature, utility failure, runaway reactions.

Unreliability, maintenance hazards, lifting hazards, transportation, access and evacuation hazards, access for emergency vehicles, location of occupied buildings, wind direction, natural and environmental hazards. So many hazards are related to inventories of hazardous materials and extreme operating conditions. So these must be identified and taken care of during the design stage. Among these, let us talk about the runaway reactions. Let us consider an exothermic reaction.

So, to control the temperature inside the reactor, there will be a cooling jacket around the reactor, so cooling water will be flowing through the jacket and there will be a control system which will sense the temperature of the reactor and accordingly change the coolant conditions, the flow rate of the coolant and will control the temperature of the reactor. Imagine the coolant fails, meaning let us say, the pump suddenly stopped working, the cooling system fails. What will happen? The temperature will start increasing.

Now, you know that the heat of reactions and the temperature relationships are exponentially in nature. So the rate of heat generation relations with the temperature will also be exponential in nature whereas the rate of cooling follows a linear relationship. So, when the cooling is inappropriate at neighbors temperature of the reactor exceeds, then it will start increasing very rapidly and when the temperature starts increasing rapidly, a large amount of the reactant can be vaporized and over pressurization of the reactor can take place.

There are reactions that will lead to over pressurization of the reactor leading to a very serious safety concern. So during the design stage, the designer must consider such utility failures and the runaway reaction issues.

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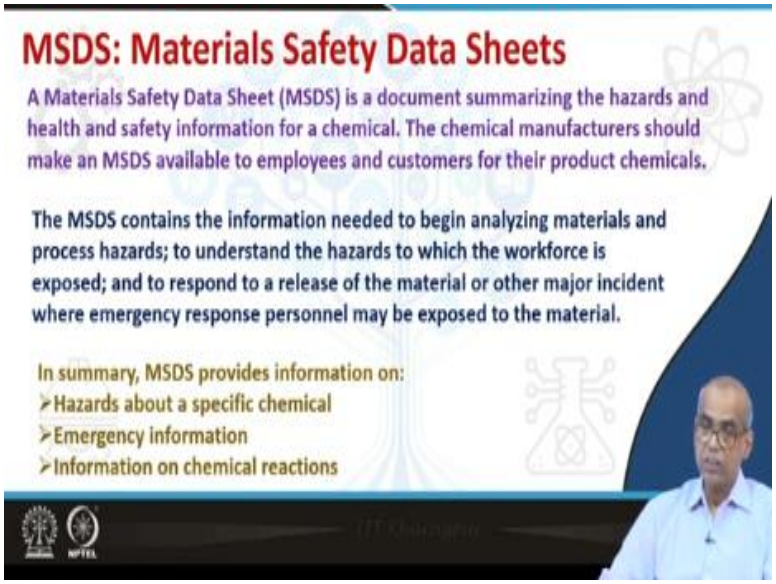

Finally, we will talk about material safety and data sheets. This is commonly known as MSDS. A material safety data sheet or MSDS is the document summarizing the hazards and health and safety information for a chemical. The chemical manufacturers should make an MSDS available to employees and customers for all the chemicals they produce are all the chemicals they sell. In fact, it is mandatory in several countries for the manufacturers of chemicals to make the MSDS available to all employees as well as customers for their product.

The MSDS contains the information needed to begin analyzing materials and process hazards; to understand the hazards to which the workforce is exposed and to respond to a release of the material or other major incident where emergency response personnel may be exposed to the material. MSDS is basically a very important piece of document and wherever we work with chemicals, we first look at the MSDS for the chemical.

Whether you are working in industry with chemicals or whether we are working at our lab, let us say your research lab or the lab you are doing experiments may be the lab for your course work and if you are using chemicals, we should first rate the MSDS. MSDS for chemicals can be easily downloaded from the net and I suggest that whenever you work with chemicals and if you please read MSDS. MSDS is an important document to summarize the hazards and the health and the safety information for that particular chemical.

In summary, MSDS provides information on hazards about a specific chemical, information on chemical reactions as well as emergency information. With this we stop our discussion.