Environmental Remediation of Contaminated Sites

Prof. Bhanu Prakash Vellanki
Department of Civil Engineering
Department of Civil Engineering – IIT Roorkee

Lecture 03
Course Outline

Hello everyone, welcome back to the latest lecture session. In the last couple of sessions we have been looking at a couple of examples that would help you understand where the course content would be relevant or how the aspects that you are going to learn during this particular course are going to fit in with respect to the relevant applications. I think we looked at one particular example in Ghaziabad, where I think the groundwater was contaminated by chromium and we looked at how they were pumping the water out and then treating it.

And I believe then we looked at another example where we had relatively more data available in the public domain, and then we looked at the relevant aspects. I think we looked at, if I am not wrong, risk assessment as in site characterization, data collection, and risk assessment. And then coming up with relevant remedial alternatives; as in that obviously as I mentioned earlier is going to be what we are going to talk about in great detail or technical detail, but we have not discussed that in great detail obviously during that particular example.

And then we looked at how different aspects come into play when choosing one of these alternatives as the one that needs to be followed through. So then, we started looking at the course outline in greater detail. So, today we are going wrap up looking at that particular course outline as and I am going to give you a brief overview of each of these aspects that we are going to discuss during this particular course, and then we are going to move onto the relevant aspects.

So coming back to the course outlined here, as mentioned yesterday, we are going to look at some of the laws here that are going to be relevant in the Indian context.

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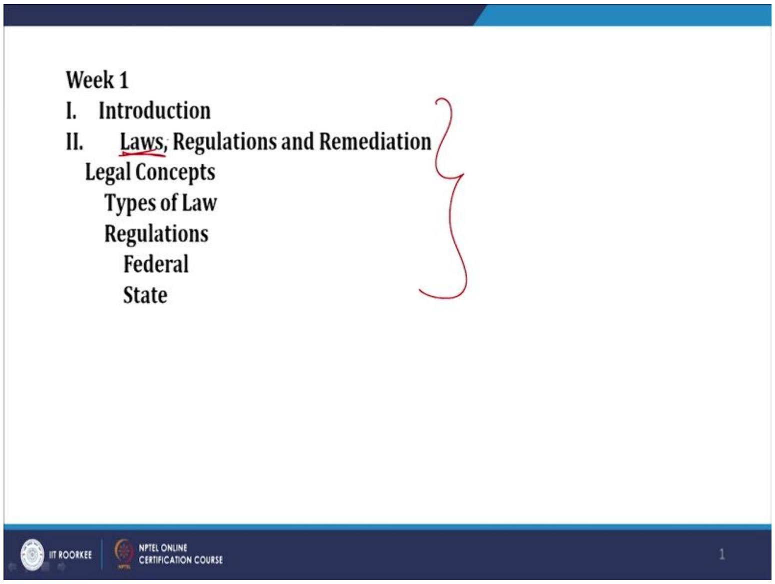

So, with respect to the laws and regulations, we are going to look at that briefly may be today itself and then move on to risk assessment and then come back to laws and regulations in greater detail.

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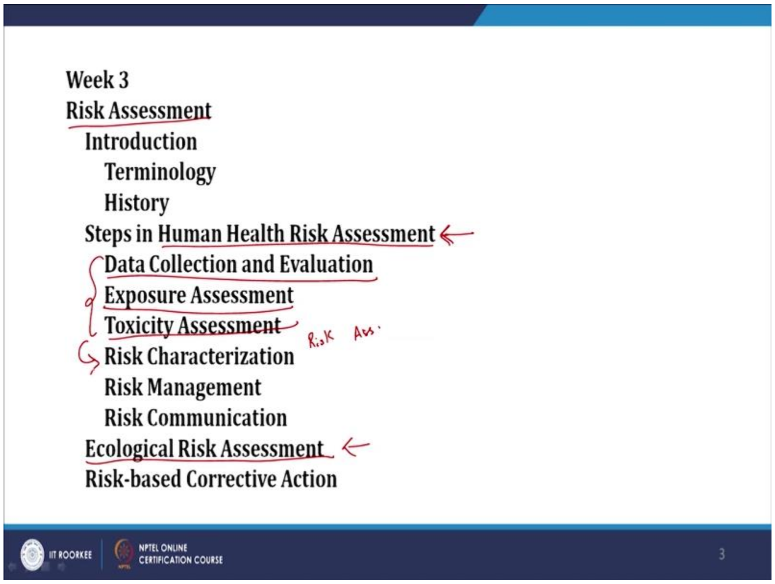

So, again as we talked about in risk assessment we usually have two kinds of risk assessment, they are human health risk assessment and ecological or environmental risk assessment. Typically, what we usually look at is human health risk assessment and as I mentioned earlier the ecological risk assessment is much more time and resource intensive.

And also obviously depending upon the type of contamination or extent of contamination and the relevant remediation required, we are going to either go for or not go for ecological risk assessment, but certainly we are going to look at the human health risk assessment. In that particular aspect, we usually have four major aspects to consider, obviously data collection and evaluation and we are going to discuss this in detail. And then exposure assessment, toxicity assessment, and then risk assessment.

And all these four aspects come into play when one looks at risk characterization and more or less we look at the holistic picture. And then obviously risk management as in what aspects need to be looked at or followed through to be able to bring down the risk to acceptable levels, what are the relevant aspects required, and communicating the risk to either the public or the relevant authorities over there. Again, these are the different aspects out there, so we are going to discuss this in great detail.

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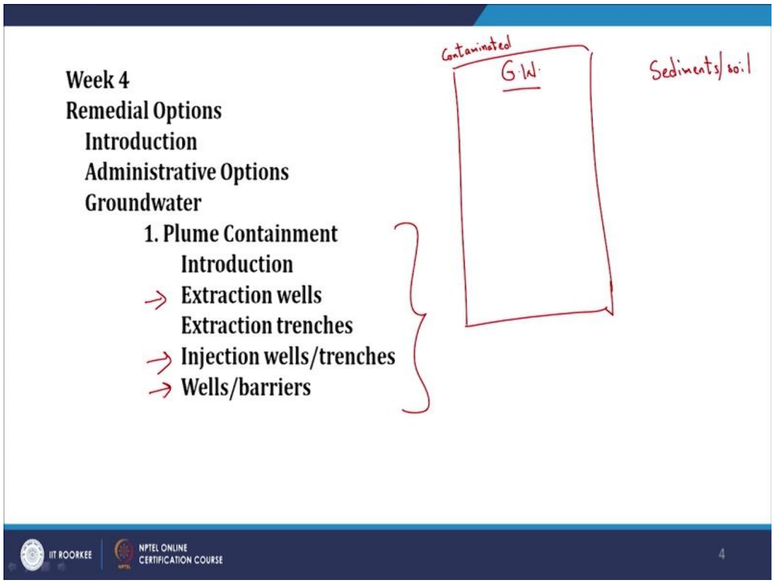

Then we will move on to the next major aspects, which would be contaminated groundwater, and we are also going to look at contaminated sediments or soil. So this particular aspect would make up major chunk of our particular course; this as in, remediating contaminated groundwater. The second major chunk would be with respect to looking at the relevant aspects about remediating contaminated sediments or soil.

So in this particular aspect, we have obviously plume containment, where in we dig extraction wells, injection and extraction wells or just barriers. As the name indicates here, it is plume containment. So, here we are not trying to treat the contaminant or such, we are only trying to contain the plume so that we avoid the spread of the contaminant over a much larger area and thus potentially affecting larger populace. So that is the particular aspect here, we are going to look at the relevant aspects, the types of materials, the hydraulic conductivities here that we need to look at and these aspects out here.

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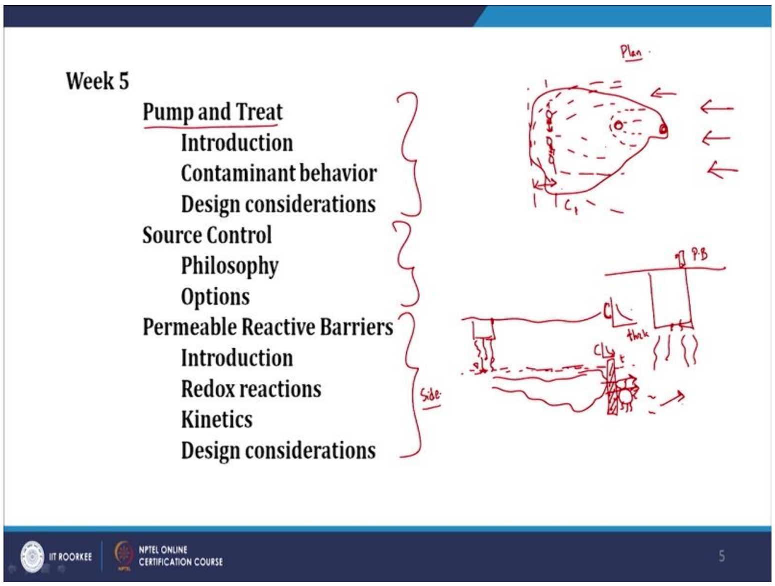

So moving on though we are going to look at pump and treat next again with respect to or in the context of remediation of groundwater or contaminated groundwater. So obviously we looked at one example out there in Ghaziabad, where they were pumping out the particular chromium contaminated ground water. So, obviously again we are going to look at the relevant aspects as in where do I need to place the pump.

As in if this is the plan view and this is my contaminated plume, this is the plan view, and this is the source of contamination and groundwater flow is in this direction. And after certain time, this is the boundary of the contaminated groundwater at a particular concentration and now I need to be able to pump out this particular water. Obviously, if I have the pump out here and the groundwater flow being in this particular direction, will it be able to capture the entire plume?, Not really.

So here we are going to have to be able to come up with a scientific explanation or you know an explanation based on science that would help us to try to capture the plume here. So in that context, we are going to look at the number of wells in the first case that are required, the distance between the wells required, and then the distance between the top edge of the plume and the center line of the wells. And then we are going to look at the capture of the plume here, based on the capture lines or flow lines here.

So, these are the aspects we are going to look at and in general we are going to look at the **Javendel et.al.** design. Based on those aspects, we are going to come up with that. Obviously, the relevant aspects such as the maximum allowable drawdown and such, we are going to consider that; confined and unconfined aquifer; and so on, so those aspects we are going to look at there. And once obviously we look at that particular aspect, we are going to have to move on to understand in which cases is there is going to be relevant or feasible and in which cases will this not be feasible.

So in that context, an example would be let us say, here we are pumping out the groundwater, so obviously a compound that's hydrophilic or would you want to stay in the aqueous phase would be you know or pump and treat would be better in such cases. But if the compound is hydrophobic, let us say it is a chlorinated solvent, or chlorinated organic, or a hydrocarbon. As in you have this petrol and diesel stored in underground storage tanks beneath your petrol bunks, typically you know they are great sources of pollution, but maybe not of great concern as of now in India because I guess people have other priorities, other pressing or more important priorities, but again that is of great concern worldwide and certainly in India too, I guess. Right now, probably we are unable to spare time or money to look at these aspects. Again, coming back to what we are discussing, we have leak of this underground storage tank. So let us say, we have this underground storage tank and this is the petrol bunk out here. Please excuse my poor drawing skills, I guess. This is my underground storage tank, so typically they develop leaks and then we are going to have leak of particular hydrocarbon.

So, as we know, the hydrocarbons and again chlorinated organics in the case of industrial solvents are hydrophobic. So, if we look at the equilibrium between the organic phase and, organic phase as in the organic fraction in the soil and the groundwater or the aqueous phase where would the compound want to stay? I should not use the term stay, where would the concentration be relatively higher. The concentration would be relatively higher or the compound would prefer to be adsorbed onto the organic fraction in the soil rather than be present in the groundwater.

So, thus if you are just trying to use pump and treat in this particular scenario as in, if I have soil out here and my hydrocarbons adsorbed onto this particular soil particle and this is the water surrounding it and the number of moles in the groundwater are relatively less. So, if I keep trying to pump out this particular groundwater, so there are going to be considerable issues that are going to come into play.

As in let us say, you are going to have tailing and rebound and again the time required for your particular pumping out the relevant contaminant in this context, because there is going to be desorption from the soil. As in because the compound is adsorbed onto the soil, preferentially adsorbed; so as you pump water out, and water at relatively less concentration or water with less concentration of this contaminant comes in contact with the soil, again you are going to have desorption, but again this takes time and the soil acts as a reservoir of contaminants, so these aspects need to be considered obviously. So again those aspects in pump and treat and then source control; if you are able to detect the spill within a limited or relatively little period of time, so then you can look at options to control it at the source itself rather than let it contaminate a wider pool of groundwater.

So then we can move on to permeable reactive barriers, so again the name is relatively self-explanatory, it is permeable reactive barrier. So, let us just look at a quick example here and some of the advantages in the context here. So, here, let us say, is the soil surface and this is the groundwater level and this is the side view, obviously this is the side view, there has been a spill here and it has reached the groundwater and the plume is spreading in this direction.

So different options out there, but obviously you know, again people tried to look at cost and convenience, and obviously effectiveness to go along with that. So, obviously passive techniques such as permeable reactive barriers are relevant here. How do I go about that? I am going to build a permeable reactive barrier, so it is going to be relatively porous obviously; why porous because you would want the groundwater or the contaminated plume to flow through the barrier and not around the barrier.

For example, if the porosity of the barrier is lesser than the porosity of or if the hydraulic conductivity of the barrier is less than the hydraulic conductivity of the surrounding aquifer, the plume would obviously want to flow around it rather than through this particular barrier; again path of least resistance if I may say so. So again, I am going to design the barrier in such a way that obviously the plume would prefer to flow through that and for this, what do I need?

I need to know the shape of the plume, extent of or the distribution of the plume and so on and more importantly I need to know what are the contaminants present in this particular plume. So, if it is an oxidized contaminant, I am going to have reactive barrier made of reducing agents. So, as the groundwater or contaminated groundwater passes through the barrier and then leaves the barrier, the kinetics and such, if this is C versus T, let us say, thickness of the barrier if I can say so or length.

It is going to be now plug flow reactor obviously. So, again, the concentration is going to decrease as the contaminant moves through the barrier. So again, there are obvious advantages here as in you do not need continuous operation and maintenance here, you do need some monitoring wells and obviously being subsurface, you know, obviously depending on different kinds of techniques, the amount of area required is going to be less. And this is relevant in the Indian context, why? Because obviously the cost of land is pretty high, I mean the demands on the land are pretty high and thus the land costs are pretty high and in that context, the PRBs are pretty good option, but obviously depends upon site conditions, is it feasible or not, what is the depth of the particular plume and such. Again, we are going to go in detail with respect to the PRBs later on.

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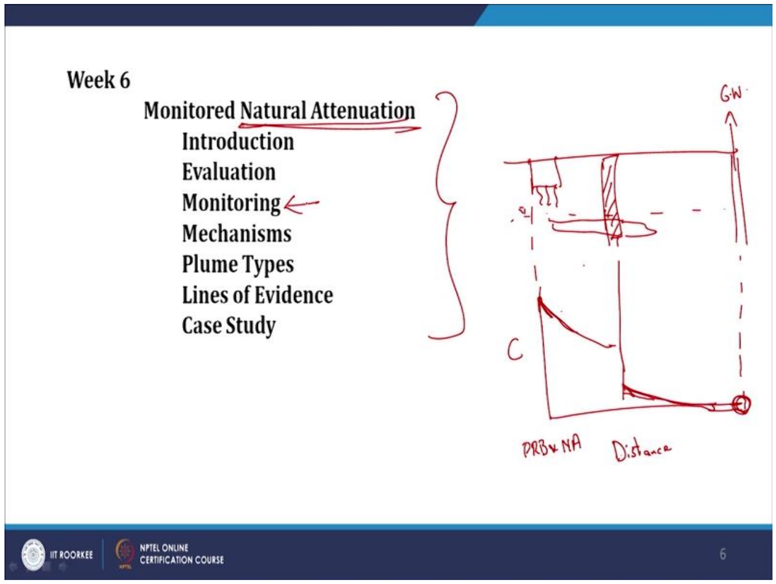

Moving on, so again one major aspect as in natural attenuation or you know monitored natural attenuation, I guess you know this is more widely used out there abroad too or in western world, but certainly has relevance in the Indian context too. why again; we have microbes out there, like us, they want to thrive too and so they look for different sources of energy. So if the conditions suit them, as in you have an electron acceptor and an electron donor, and if you can create the relevant conditions for either the microbes or for the native population of microbes, you can have natural attenuation of the relevant contaminant. Again, when we talked about natural attenuation rather than just degradation by microbes, you also talk about or need to take into account effects of dilution, as the contaminant is dispersed. You know, we are going to look at effects of dilution there and again obviously advection too. So, again different aspects and we need to look at these particular aspects in greater detail usually natural attenuation in conjunction with other treatment techniques is looked at.

For example, this is the side view again, this is the groundwater level, and this is my contaminant here and the contaminant is plume is out here and if I draw the particular graph here as in concentration and with distance starting from here, so what do I see? Let us say initially the concentration is very high, maybe way too high such that it is toxic for the microbes too, so what I can do, I can construct may be a PRB here.

So, if I construct a permeable reactive barrier here and design it in such a way that you know at the end of this particular, I guess it's not to scale pardon me, so by the time it reaches the PRB then it is going to be a considerable drop and then let the microbes do the job. As in here, we have the extraction wells where people are drawing the groundwater from and so by the time it reaches this particular point, we are going to design it in such a way in conjunction with both the PRB and natural attenuation.

Such that you know by the time it reaches the receptor well, you know the concentration would be within the threshold levels or the relevant regulatory levels. So, again natural attenuation; different aspects obviously and one major aspect though is that monitoring is a key aspect here, as in you need to be able to establish a wide network of monitoring wells to understand that your underlying assumptions are valid over time too.

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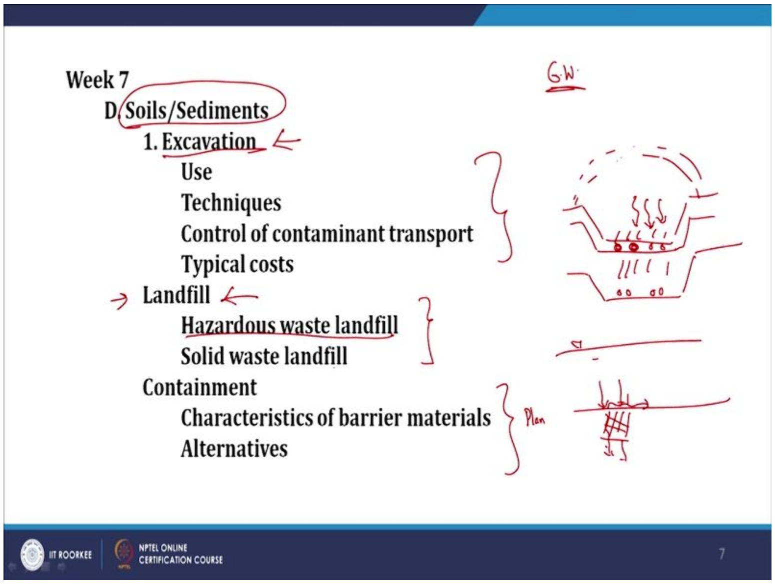

Moving on, so again as we talked about we have looked at various options: typically looked at when remediating contaminated groundwater; so the next major chunk would be with respect to soils and sediments. So you have contaminated soil and how do I go about it. It might be the case that groundwater has been contaminated or probably not has been contaminated and it is just the soil that is contaminated, what are the aspects over there, so obviously, the one that most people in India look at is excavation.

So, they tried to excavate the soil and then you know dispose it in a hazardous waste landfill, but what are the issues here, the cost, I mean if the extent of contamination is relatively high or you know the area is relatively huge, what is the issue here, obviously the cost and we are going to do some math here in that context as in just look at some of the values out there that take into account the cost of hiring, let us say the relevant transport and also cost for fuel and transportation and so on. And see that depending upon the location of the TSDF, the hazardous waste, landfills in our country, it is typically not feasible if we look at certain areas or volumes of soil.

So again, typically what do people do? They excavate the soil and you know take it to the landfill and dump it there, but again that in my opinion is not sustainable in the long-term especially in a country like India as in we are not degrading the contaminant, we are only removing the problem from one particular place to you know concentrating it another relatively contained area.

Again excavation, so again we are going to look at the relevant cost and then with respect to landfill, we are going to look at, in relatively greater detail, with respect to the two kinds of landfill that we have over there, so one would be the TSDF hazardous waste landfills. TSDF is the term given to the hazardous waste landfills in the Indian context and obviously the solid waste or municipal solid waste landfill and we are going to give greater emphasis to the designs required with respect to the hazardous waste landfill.

Typically you need two impermeable HDPE membranes, as in you want to arrest the leachate reaching the groundwater. As in you know, a very generic figure here please; if this is my landfill and obviously there are going to be different cases with respect to the cover; so here again, what do we need, we are going to have to have two HDPE membranes here and obviously leachate collection layer and clay layer and so on.

And such that the leachate that we generate from the landfill does not reach the groundwater table or level here or does not reach the groundwater. We are going to capture it above the first impermeable layer and if let us say, overtime, you know some amount of leachate reaches the second layer we are going to have to try to capture that too, but I guess, I came to know that CPCB has sometimes been insisting on three layers of impermeable liners too, again I think as an extra level of safety.

Again, different aspects here in this case or different scientific or technical aspects, we are going to discuss them. And then again containment; let us say, we have contaminated soil here, this is the soil surface and this is again the plan view, we have contaminated soil here. So, if there is rainfall, again you are going to have contaminated run off or you can have leachate again, so how I do I contain this particular contaminated soil in situ or at the site.

So, I need to look at barriers, so what kind of barriers? Barriers can be synthetic barriers or can be made of bentonite clay too. Again, bentonite clay: the hydraulic conductivity is remarkably less too. So again, different aspects in that context.

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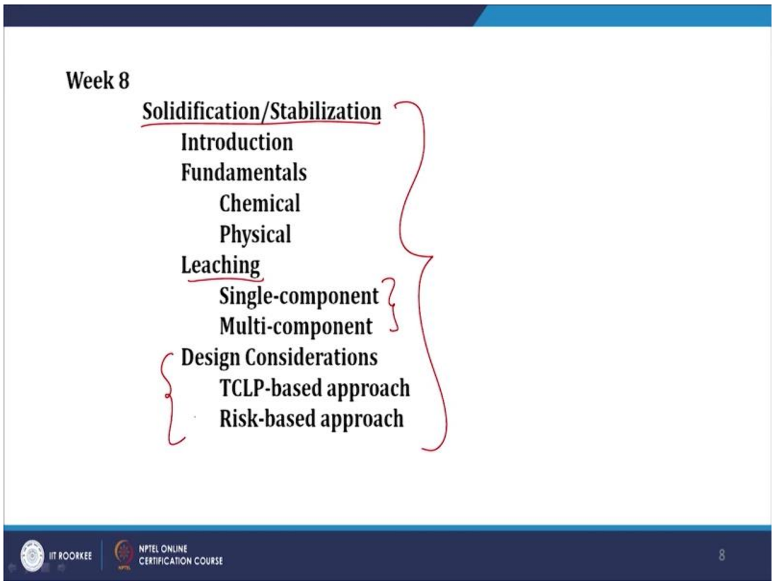

And then we are going to look at solidification/stabilization, and we are going to spend as you can see, considerable time in this context. So solidification/stabilization, I guess is self explanatory, slightly self explanatory anyway, so what is that about now. So you have soil or let us say slurry that is contaminated now, so what do you need to do, you need to solidify that or improve the physical characteristics of that particular slurry or contaminated soil or sediments in the first case and then you are going to stabilize that.

What do you mean by stabilize, I am trying to immobilize the contaminant such that even if water or acid comes in contact with this particular contaminant, it is not going to leach in to the or you know equilibrate into the acid or the water that comes in contact. So there are two aspects involved, one would be obviously improving the physical characteristics of that particular waste, if required, and the second one would be to immobilize the relevant contaminant. And this I think is the second most widely used remediation technique for contaminated soils out there, especially in the western world, and certainly I believe it is catching up or if it is not, it is time to catch up in the Indian context too.

So, in this context obviously we are going to look at two different models, single component and multicomponent leaching models and how that works. And in general in this context, we are going to look at the design approach as in one design would be to pass the test or the TCLP test. TCLP test is the one that people use out there or the regulations define that you need to look at the TCLP test to see if a particular waste is toxic or no.

So anyway, we are going to look at that in greater detail, but anyway TCLP based approach is like you know, you are trying to prepare for an exam, only to pass the exam and then risk based approach is to you know, looks at site specific scenarios and tries to limit the or increase the effectiveness of your remediation such that you know the actual risk at the site is minimized. And this I guess, the corollary is that you learn the material because you like to learn the material and not just for sake of passing the exam, which is similar to the TCLP based approach.

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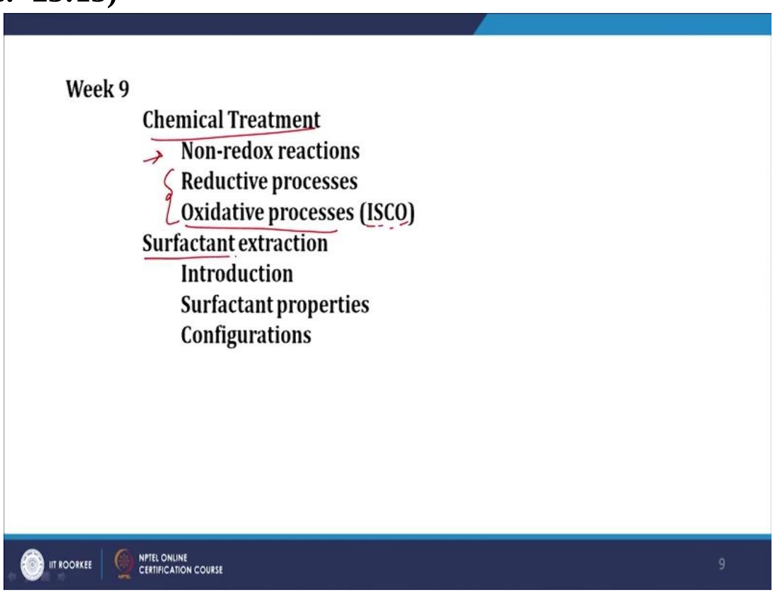

So again, moving on and then obviously we have chemical treatment of the soil, obviously you know, if depending upon site conditions, each of these techniques or remediation techniques that we have looked at until now have their own limitations and such. Again, depending on scenario though if we can either have non redox reactions actions or redox reactions. So, oxidative process, in situ chemical oxidation, something that is widely used.

And again obviously you are going to put an oxidizing agent depending upon porosity; may be ozone, or permanganate and so on and we are going to look at the relevant aspects involved here and again we are going to look at surfactant extraction. As in, your compound is hydrophobic, it does not want to stay in the water, it only wants to adsorb onto the organic fraction in the soil. So, how do I get that out, so similar to let us say, may be if you think there is grease or oil on your particular hand, how do you get that off. You use soap to wash it out or you know it is surfactant more or less.

We are going to look at micelle formation, partitioning of these particular contaminants from the organic fraction in the soil into the micelles. So, earlier they were adsorbed onto the soil, so after adding the surfactant and forming the micelle, we are going to discuss what it is or they are, later on. The contaminant is now going to change phase into the micelle, and then you know again because surface tension is relatively less, we can pump this surfactant out and then treat it and so on. So, that is something again that is widely used again depending on the kind of scenario that you are facing.

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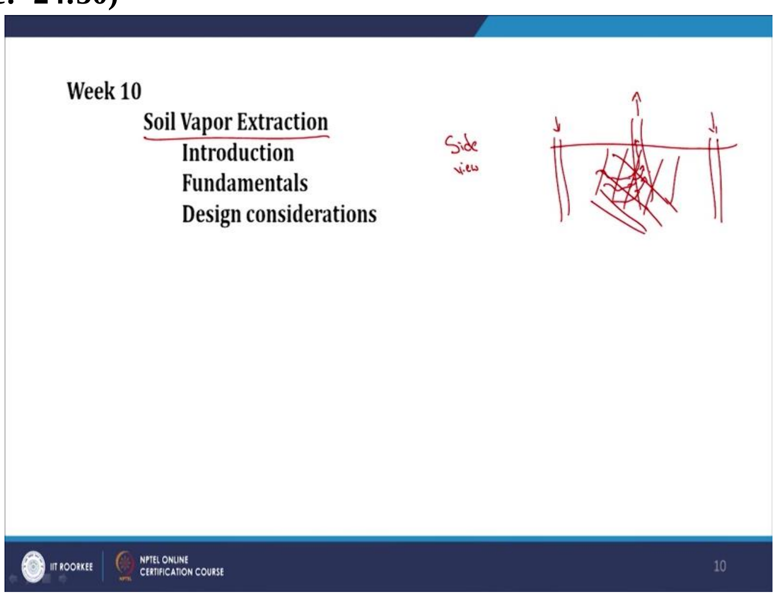

So, again moving on soil vapor extraction, again it is self explanatory, right, again depends on site conditions, depending upon the porosity too and interconnectivity of the pores, so soil vapor, I guess. So either I create vacuum conditions as in this is the side view now and let us say this is my ground surface and below the surface, this is my contaminated soil, so what can I have now. I need to have injection wells for the air or I can have extraction wells or vacuum wells here.

Depending upon type of scenario, you can either inject or push air through or have vacuum wells and so on and then depending upon pores, and interconnectivity of the pores, you are going to have or extract the soil vapor. Obviously in which particular scenario would this, you know workout or be feasible though. Obviously, when the contaminant is relatively volatile as in let us say hydrocarbons. As you know, petrol and diesel, they are volatile. They would rather, you know, change phase into the gaseous phase rather than stay as a liquid or be adsorbed onto soil, I guess. Certainly, they do not want to stay in the aqueous form, certainly anyway.

So in that context, if your soil is contaminated with hydrocarbons, so depending upon the temperature, you can look at soil vapor extraction to extract the relevant contaminated or contaminants and then treat the air again obviously. So that is one particular aspect here and we are going to look at the relevant designs and such in this context.

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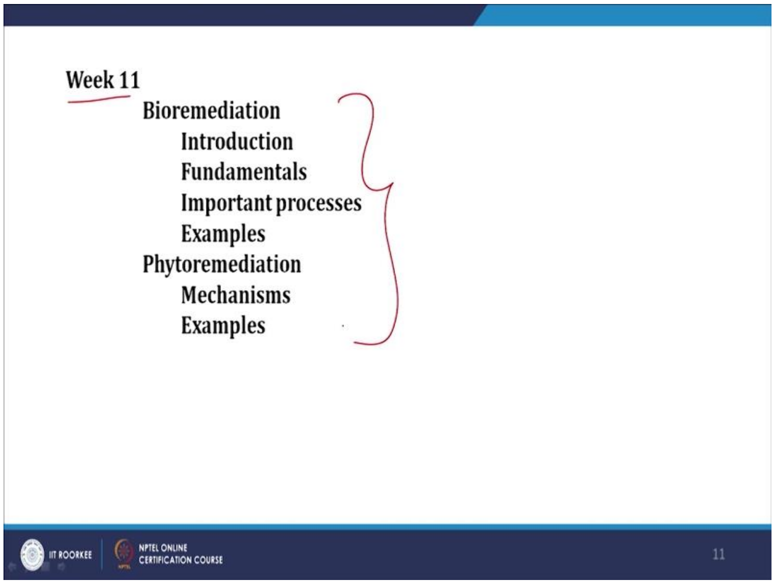

So again moving, similar to groundwater remediation, obviously, we have bioremediation and phytoremediation remediation here. So again, people usually come up with phytoremediation or bioremediation as cure for all kinds of contaminants, but that is not the case. In general, if a compound is not being degraded at a particular site, there are certain…, nature dictates most of what goes on.

And if a particular contaminated site is not being degraded over time, it means that the conditions at that particular site are not suitable for you know the propagation of the microbes that can degrade these contaminants. So you can try to introduce some species or colonies of microbes, you know that you isolated from some other place into this particular locality, which is a contaminated site, but then it depends upon different aspects: as in temperature, availability of electron acceptor and donor and so on.

Sometimes the native microbes can feed off these particular substrate that is required for these engineered microbes or non-native species. As in I am introducing some species, which are not native to that particular site because I think they can degrade the contaminant at a faster rate, but then again it is rule of survival of the fittest. So in general, engineered species have not had a great deal of success, but may be if you were able to isolate specifies from conditions where you know the microbes have thrived under such stressful conditions and brought them in here may be yes, the chances are that it can work out.

But there are other aspects that need to be considered and we are going to look at those aspects. As in what are the conditions required for you know propagating bioremediation and also we are going to look at phytoremediation and again look at the relevant aspects and maybe, maybe, try to disperse some myths about it. Again, we will move on, so week twelve, I believe this is the last particular set of topics we are going to discuss in general; so one obviously is the thermal process in general again; slightly costly, obviously because you have energy demands and such. But obviously when, depending upon the site conditions and the extent of contamination, yes that can be looked at.

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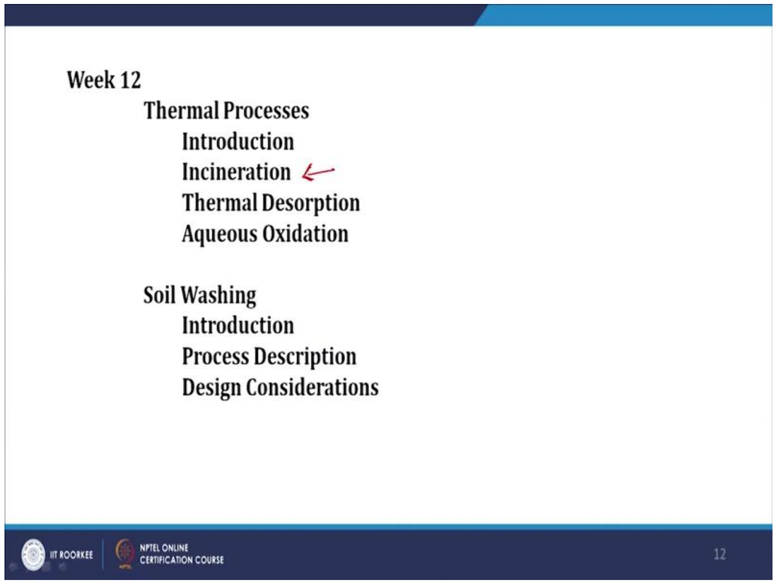

So, incineration obviously, last resort again if nothing else is feasible, obviously incineration, yes and thermal desorption, increase the temperature, again look at delta G values and such and change with temperature and such. You want to increase desorption. And then lastly soil washing. As the name indicates, it is soil washing as in you literally wash the soil. You know, we are going to look at that particular design.

I guess with this particular session, you should have an overview right now about what it is we are going to discuss in greater detail. So, I am going to end my session for today and from next session, I am going to start looking at the law that is relevant to the hazardous waste. I think it was promulgated in 2016 if I am not wrong. So, we are going to look at that briefly and then move onto the risk assessment related aspects and then move onto or come back to laws in greater detail and with that I am done for today and thank you.