Geoenvironmental Engineering (Environmental Geotechnology): Landfills, Slurry Ponds & Contaminated Sites

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Lecture – 29
Control and Remedial Measures at Contaminated Sites – Part 1

Good day to all of you, today we begin the new topic control and remedial measures at contaminated sites. So, if a site has become contaminated either by waste dumps or slurry ponds on top of it, but in many cases by several other causes then what do we do at these sites? This will be the topic of discussion for the next two lectures and remember we will only focus on the role of geo technical engineering because you know control and remediation of contaminated sites requires an understanding of the contaminants how they can be removed, now these may be issues of chemistry or chemical reactions or bio chemistry or bio chemical reactions.

So, we definitively need an interdisciplinary approach to solve these problems, but we have to help all the chemistry and the chemical engineers and the biochemical engineers reach the soil reach the ground water, and then you know then undertake the processes of clean up. So, let us see what we are going to do today.

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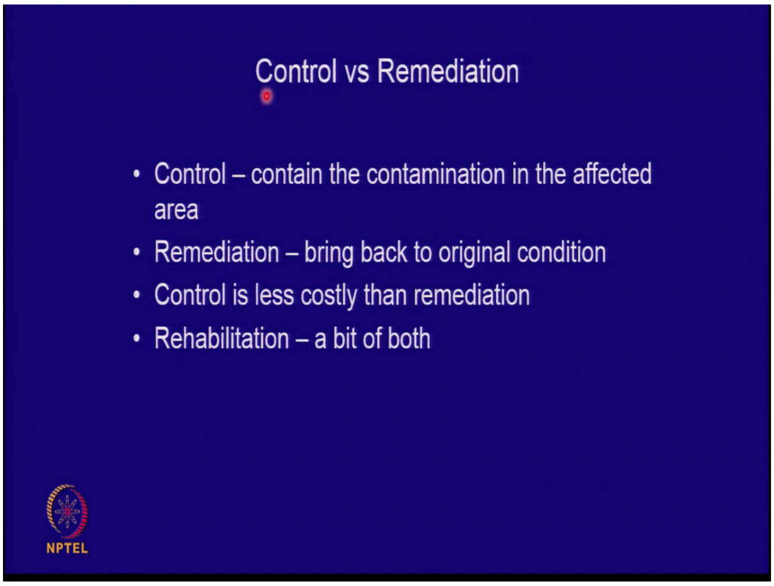

So, we just quickly recall that there are two words we are using control and remediation, control is containing the contamination means we stop the further spreading of the contamination. At a site when you reach there would be a source of contamination and there is uncontrolled release. So, we control we undertake control measures to prevent further spread of contamination in the affected area. Remediation of course, is that we bring back that site to it is original condition that is before the source of contamination was placed on that side.

Control is less costly then remediation, control is usually the first step, I mean immediately after you recognize that a site is contaminated you would like to take control measures very early so that there is no further spreading by the time, you come up with a remediation plan. The word rehabilitation is sometimes used as reflecting remediation, sometimes it is used reflecting control or a bit of both. We will be using the words control and remediation in the next two lectures.

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When you have a site which is ah reported to be contaminated, and since it is all subsurface contamination you will get some either some visual reports or you will get some ground water contamination problems from a receptor. Then the question which comes to our mind is the site not contaminated, is it probably contaminated or is it definitely contaminated. Suppose you start getting contaminated ground water in your hand pump. So, it is not that the adjacent soil will be contaminated, it is possible that the soil or the source is far away and the contaminants are leaching from that source into the ground water and in the ground water there will be high permeability zones and low permeability zones, and may be the contaminated ground water is travelling in the high permeability zone.

So, once you have a reported incidence, you have to first check is this site contaminated is it not contaminated or is it probably contaminated. You see it is its seems very simple that I can go and say that site a is contaminated; first question is to what extent is it contaminated in plan and to what extent is it contaminated in depth. So, that requires very detailed investigation. Before you attempt to quantify whether it is completely contaminated in a particular zone, you have to do preliminary testing to establish whether the site is not contaminated or probably contaminated.

So, today in India three classifications exists, you may get a report site may not be contaminated, you may get a report and you from the preliminary data you may say it is probably contaminated, and then after doing detailed studies you can call it a contaminated site. When you want to call a site contaminated you need some standards to measure the contaminant levels. So, each country has national standards for permissible limits on concentration of contaminants, whether it is heavy metals, whether it is dioxins whether it is a pesticides.

So, all countries have national standards for permissible limits, and you have to compare the existing levels of the contaminant with respect to the permissible limits. India does not have soil standards today and the process of coming up with national standards for soil contaminants is currently underway in the ministry of environment and forest, but we have other country standards. So, if you do not have data from India, you can look at standards of other countries. However, if a contaminant level is high, does not necessarily mean the site is contaminated it is possible that the back ground levels in that region are high any ways.

So, what you have to compare is suppose there is a doubt in your mind that there is lot of high level of arsenic being reported, is it something which has been artificially introduced into the ground, or is it that this is an area which had geologically some source of arsenic which cause the arsenic levels to be high. Therefore, the first step whenever you get a contaminated site input is to look at background concentrations.

Move away from that site, move 20 kilometers away from that site, and go and pick up some samples from all around. So, our first establish the background concentrations of that particular contaminant of concern, if you find that the background concentrations are low and if you find that they are higher than the permissible limits of the standards, then you have to go to a screening stage; that means, you can say that it is higher than the screening level therefore I need detailed investigations to look at the action that we have to take. And if the concentrations are beyond response level; that means, it is mandatory to take action.

So, you have a soil standard which says that x milligram per liter is the permitted concentration you find that you have got a value y the value y which you have got may match the background concentration; that means, there is nothing in that site which has induced it to become higher, it may not match the background concentration and it may be higher than you have to see whether it is higher than the screening level. If y is higher than x; that means, we have to now establish in what area is the why greater than x is it a local one or two sample reading or is it that over 100 meters by 100 meters to 3 meters depth you have got some problem.

So, you do further investigations after your level of contaminant exceeds the background and the screening levels and if the level is very high; that means, you do detailed investigation and you get high even higher values, then these are called response level; that means, you have to take action to bring the contamination levels down. So, you have a background concentration or screening level and a response level. So, in a country standard you may have two levels reported to you screening and response.

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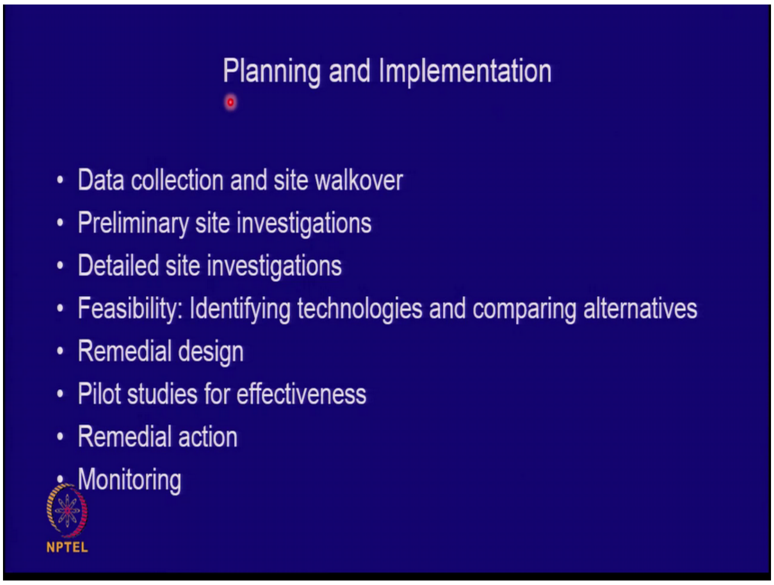

So, typically when a when you get some information from any site either telephonically or through an email or through a letter, you have to do a site walkover and data collection; you have to find out the history of that site what all may have been dumped on it, and then you may do some preliminary site investigations. Preliminary site investigations may be a you know picking up samples from a local well a hand pump a tube well and picking up a few shallow soil samples using hand augers.

So, to just get an idea what is happening at the service and at the nearby wells. If you find that the levels are elevated then you will go for detailed investigations. Now detailed investigations means as I have said earlier that you been report you have got a report that this is the point in which there is a high level of a contaminant, you have to first establish the boundaries in plan and depth this is in plan let me say.

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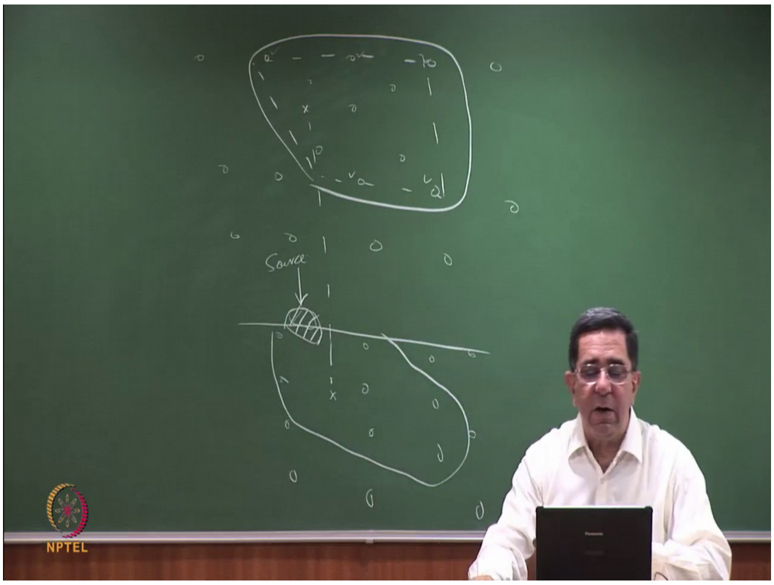

So, I need to first do a coarse grid investigation as to how far are the background levels elevated. And when I can found out that it is elevated here it is elevated here, here and here and here then you feel that this is the area requiring further investigation

So, now you may use a finer grid to be able to (Refer Time: 11:19) what is happening. So, you may do more tests to identify, and you will have to continue to do it till you get a no contaminants around it. So, you need to have no contaminants far away so that. So, this way I may be able to say that this is one is contaminated in plan, then the next issue is to what depth is it contaminated, then this person had reported you that the hand pump was picking up water from this place. So, once you have identified these the locations then you might pick up samples from various depths and then you may be able to say that my plume is something like that. So, you need to be able to do detailed investigations to be able to quantify the amount of contamination.

Once you know is it the is it contaminated at the top few meters, is the ground water contaminated down to 25 meters, then your strategies for solving the problem will come. So detailed site investigation will tell you how far the contamination is spread. You have to then do feasibility studies as to how you can remediate the problem and you know remediation technologies are not standardized, there are a few which we will discuss, but they are being developed every ever so often and remediation technology will be contaminant dependent. So, you may have thousands of contaminants. So, for a particular contaminant, you may need oxidation you may need neutralization for another one you may need volatilization for another one. So, you may have depending on the type of contaminate different technologies.

So, at this stage after detailed site investigation, you look at the technologies which are useful for that contaminant, you have to compare the alternatives, some of these may not even being proven because this may be a new soil condition. So, you have to after comparing the alternatives look at the cost options, and with the cost options you select the technology. Once you have selected the technology then you will have to do remedial design, suppose your technology is at I will extract the ground water and treat it, then how many wells what is the spacing what is the depth of wells that is a what you will do in remedial design. So, that you can work out exactly what you have to install and when the water comes out, what is the type of treatment plant am I going to use reverse osmosis? am I going to use a biological processes? That is remedial design and because soil is so, different from one place to another, you first have to do a pilot study many of these technologies are on the cutting edge, you have to do pilot studies is what you have chosen effective.

So, you will first do pilot studies on a small plot of land, apply or solution there and see if it is effective. Once you find that it is effective then you go for remedial action; that means, now you do a full scale application of the technology, and look at the remediation and because it is a contaminated site monitoring will be done right from the very beginning, all through remedial action and post remedial action as well; that means, you have this is going to be totally instrumented site, were data what were the levels before what was the levels one month after, one year after, 5 years after, 10 years after what are the contaminant levels that will have to be monitored.

So, this is the full planning and implementation methodology and do remember that no single solution is there, which I can handout over to you and say this can be adapted.

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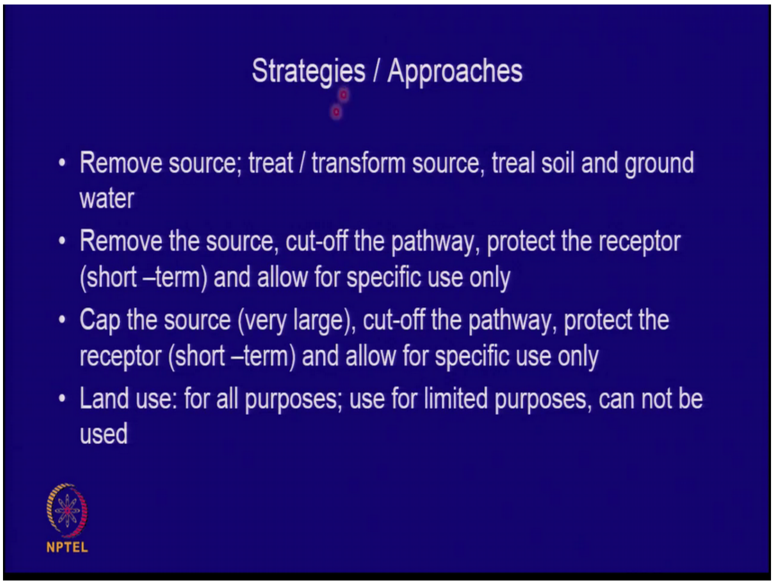

Starting is a simple if the source is small and if you have been available to identify. It remove the source because first is what is causing the contamination. You have removed it where does it go you dig it out, but where does it go well either it will go to a landfill a hazardous waste landfill or whatever it appropriate or you will have to treat and transform the source then along with the source the soil and ground water will also have to be treated. So, suppose the source was somewhere, here or maybe it was partly below the ground partly above the ground. So, this has to be tackled and all these zone has to be tackled. So, is it an issue of tackling the liquid phase, is it an issue of tackling the solid phase or is it an issue of tackling the 3 phase because there may be a Vadose zone in between as well.

So, you will remove the source, treat the source or encapsulate it or transform it, you will treat the soil and you treat the ground water. This is easy for very small site contaminations and believe me a there are several small sites, you know in industrial areas you will find that somebody has gone and placed some chromium sludge. On a open plot of land the plot of land may be only 200 square meters plot of land may only be 15 meters by 15 meters, and the contamination may have go down. So, you may have to remove that sludge which is on the top, you will have to see how many meters is the soil has got the chromium has traveled down to you may have to you can actually you might want to remove the soil, it may not have reached the ground water yet and if it has reached the ground water you might want to do pump and treat.

That is if it is small, suppose it is big you can try and remove the source means let me say suppose the source is not very big, but the contamination spread is big. Then you must still be able to remove the source, but now since the contamination is very big you cannot dig up the soil and treat the soil, you cannot dig up the water and treat the water it may take months and years to extract the ground water and treat it. So, then what you do is you know that you cannot treat such a large mass. So, you remove the source, you cut of the passes you might make a vertical barrier around it, and protect the receptor, you may say that no ground water wells can be placed in this zone and if there are ground water wells you may seal them so that nobody can use them. And allow that land only for specific use; that means, you have ground water supply will now come over surface water you can use the ground surface, but you cannot use anything from below the ground.

So, strategy one remove source, treat source, treat soil, treat ground water for small size. Strategy 2 source is small remove it, but the spread is large cut off the pathways nothing further should reach. In that zone say nobody is allowed nothing can be done protect the receptor and allow for specific use only. If the source is very large like if you have a hazardous waste dump, and let us say hazardous waste dump is 300 meters by 300 meters, now you got a problem. You can remove the source eventually you have to put it in a landfill right. So, you have to construct a new landfill either at the same area or nearby and you have to take the whole source away, but till you can do that because it may take some time, you might want to cap the source. So, that further release of contaminants is reduced. So, when this source is large cap the source and do everything else do the cutoffs protect the receptor and allow specific use only.

So, it is a graded response depending on the kind of problem that you have, and as far as the land use is concerned you have some 2 or 3 options, land use can continue to be used as original or it can be used for limited purposes only or it cannot be used at all. So, it is very simple to say you cannot use this land, but if it is a large tract of land to certainly tell all the industries around it and the villages around it, that look you cannot use this land may be incorrect, but you can specifically say no groundwater wells here no digging here, you cannot remove any soil from here of a purpose of making something else, but you can use the top of the surface we are monitoring that there are no gaseous emissions and volatile organic compounds coming out. So, that may be for limited purpose and of course, to allow it be use for all purpose you have to have complete remediation.

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Complete remediation is a very very expensive exercise it takes a lot of time. So, many people look at intermediate solutions. So, just you recollect we have done this before your source contamination can be the solid waste dumps which we have done a lot about, people may have buried their waste in trenches or put drums at a site and buried it, the sludge coming out of ah small effluent treatment plant of a factory, may have been applied on land or it may have been filled in low lying areas, you may have a liquid waste pond which is just leaking or reservoir. You may have a factory discharging it is effluent in a no mans land adjacent to the wall, you may have buried drums of liquid waste, here we are talking of buried drums of solid waste or buried banks which are leaking like petrol tanks we may have leaking pipelines. In the past some industries were injecting their waste water in to the ground now it is not, allowed there may be some accidental spills and there may be agricultural applications of pesticides and other compounds.

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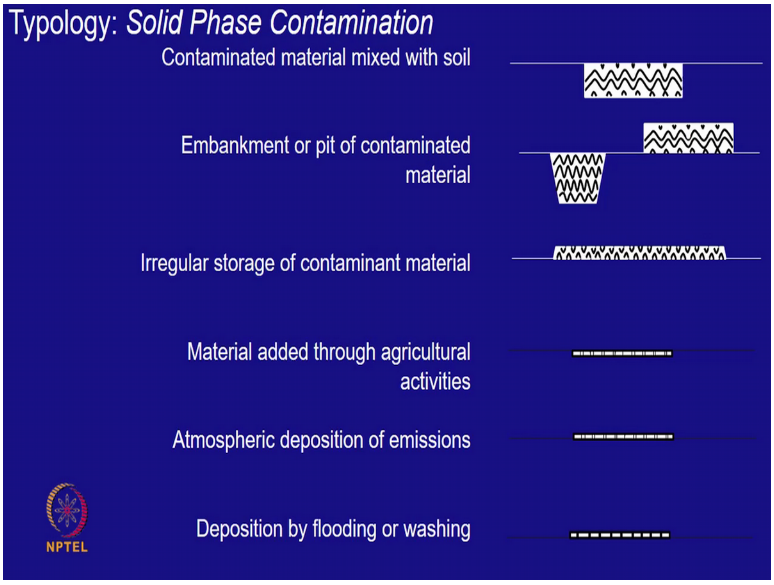

So, these are all the sources and if you look through literature, you have to prepare a typology diagram. The typology diagram must state what you understand is the source is it a solid phase contamination. So, was the source originally solid or liquid that is what you must say. If it is solid one of the ways it is contaminated it is being mixed with the local soil; that means, you add undulating ground you add some sludge, you came and mixed it and covered it so that nobody would find out. And that is called that is given a symbol like this and it is called contaminated material mixed with soil.

Sometimes it is very well defined I mean people big actually make big trenches and pits and they put their waste in it or you may have a mound at the top, these are well defined. So, still it is soil phase; that means the original contaminant is coming from the solid phase. So, you may have an embankment you may have a small heap a mound or a pit which may have been covered with soil, but the boundaries are now well defined. You can also have irregular storage of contaminant material you have a plot of land, a football field or half of football field, one day somebody threw the waste at one end another day somebody throw an another waste at another end it may be an irregular storage and this kind of symbol is used.

Material added through agricultural activities you are always doing some modifications at the top, we are using pesticides and other kinds of pest control chemicals, they may be excessive. So, they will get mixed at the very top layer of the soil very very thin top level of the soil. You may have atmospheric deposition of emissions you have a waste to energy plant, and you have got a thermal power plant the ash is coming out of it, and the ash is settling with time you will find a thin layer. So, you may have some atmospheric deposition of missions or you may even have site wash out. You have a slurry pond embankment brakes the entire ash comes out and sludge your fields. So, basically the contamination is coming from the solid phase and these are some of the standard diagrams which are used in the contaminated sites program. If it is there is one more solid phase which is actually under water. See all the solid wastes were solids on soil solids on soil solids on soil, but there is underwater deposition. So, most of the canals most of the surface water drains eventually you will have thick black deposited material.

Worldwide it is known that it contains the maximum number of contaminants the water is passing by all the total suspended solids or others are falling. These sediments or sludges are either treated after excavation or they are putting hazardous waste landfile. So, and it is also solid phase contamination, but it is underwater.

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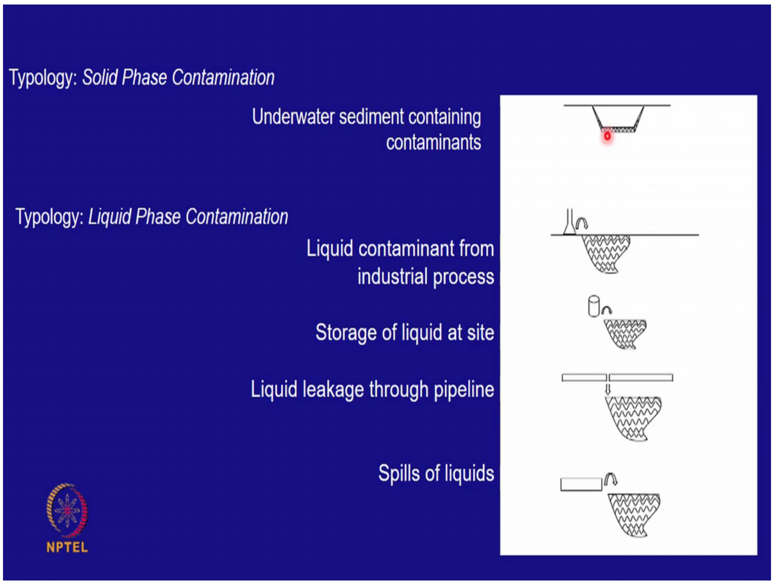

So, you have underwater sediment containing contaminants. So, you will have this kind of contaminant. The other typology is liquid phase right, you may have be having some liquid coming out of some industrial processes, which is leaking I (Refer Time: 25:59) at the site itself or you have stored the liquid either in a reservoir or in drums or in underground buried tanks or your liquid has leaked through pipelines or you have had accident spills. So, these are the standard diagrams which are used for defining the typology.

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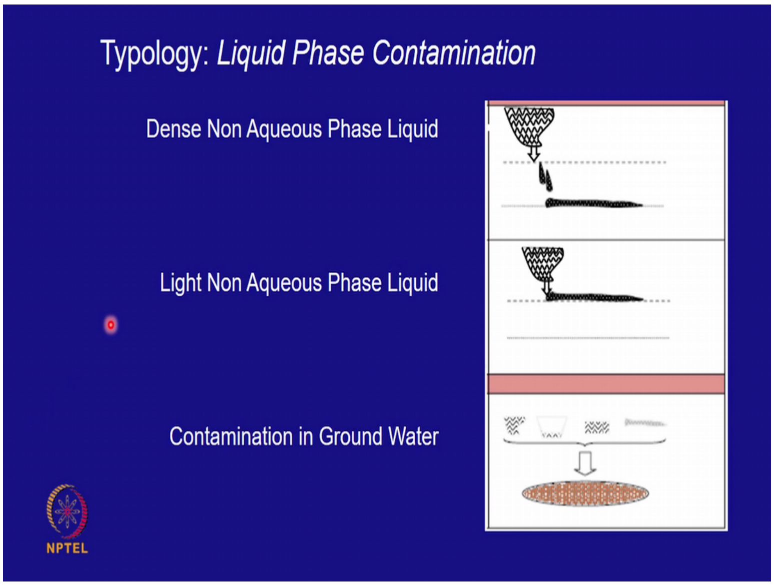

Sometimes you are having non aqueous liquids like in petrol stations and there are lot of them. So, you may have DNAPL dense non aqueous phase liquid; that means, this will come into the ground, this is the ground water table level it will go and sit at the bottom of the ground water table level or you may have LNAPL that is something which is lighter than water than that will float it would not mix with the water it is immiscible, but will float. So, it is l DNAPL and LNAPL are the ones which are observed at various hydrocarbon processing stations or the petroleum stations and finally, you may have many sources contributing to contamination in the ground water.

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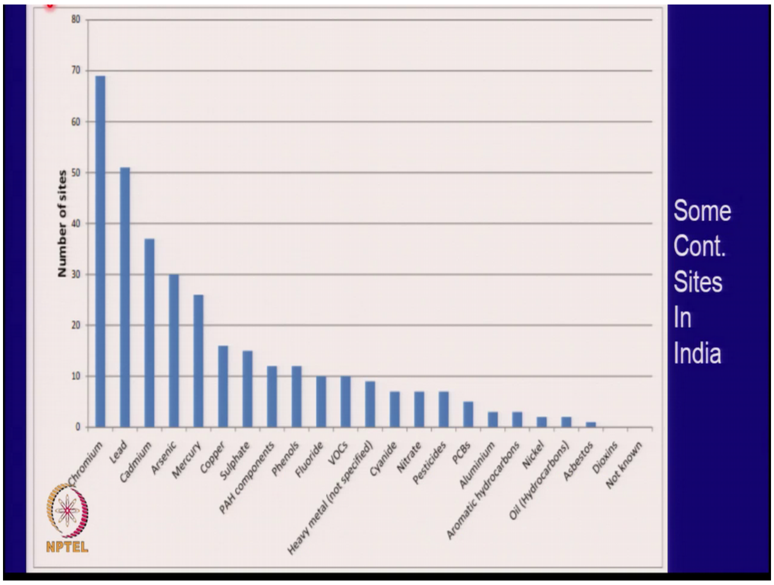

So, this is the typology which is now universally recognized for the sources of contamination. The first results of a World Bank edit project are coming out now, it is 300 probable contaminated sites have been identified in India; these number is lightly to become much bigger. But the results from the three hundred probably contaminated sites in India and these are not including the big municipal solid waste dumps and the hazardous waste dumps which are also contaminated sites, but what you find what kind of contamination are is being reported in India 70 sites have chromium, 50 have excessive lead some have excessive cadmium, arsenic, mercury and so on and so forth fluorides VOCs heavy metals not specified, pesticides, PCBs, nickel, asbestos and so on and so forth. So, these are 300 probable contaminated sites in India, the list is ever expanding and some of these will become contaminated after detail studies and some of them will be classified as not contaminated because they are below the background levels.

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So, what do we do? Are we said we can either do control or we can do remediation. Control comes back and brings us back to a very similar situation that we had you can covers or caps, we can have vertical barriers, you can have combinations of covers and caps with vertical barriers base sealing is expensive can be done, but is usually not adapted, and sometime these may be in conjunction with pump and treat. This is where geo tech engineers have a lot of role to play. If I if one goes for remediation it is a different problem all together, you have to treat the source, you have to treat the soil, you have to treat the pore gas the gas and the post phase, you have to treat the pore fluid and you have to treat the ground water. Pore fluid may not be ground water it can be some other fluid and this treatment can be done after excavation or extraction that is called ix ex situ or you might want to do the treatment in situ will look at these two separately.

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So, let us first come to control. So, control is very similar to the covers that we have done, we can have local soil cover, you can have municipal solid waste cover, you can have hazardous cover you have paving over geo members and others. The most often adapted cover is the hazardous waste cover. The most often adapted cover as a solution is the hazardous waste cover. Sometimes you will also put a paving over geo membrane, but the tendency is to cover it in a manner that further release is reduced. If you cannot remove the source you have to cover it in a manner that the further release reduced.

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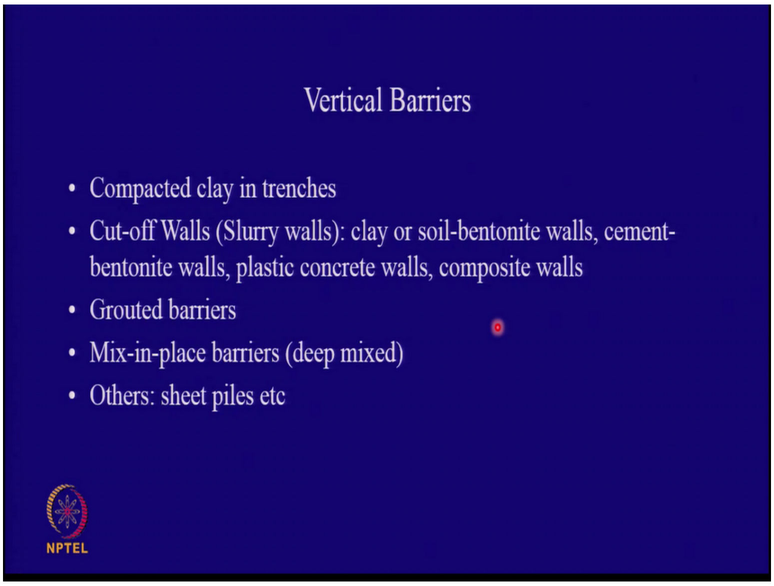

So, there we do not have much to do, but the new thing that we are now addressing are vertical barriers, and lets go back to design of dams there you know we were preventing seepage from the base of a dam. So, if I am constructing a dam here and that is my bed rock.

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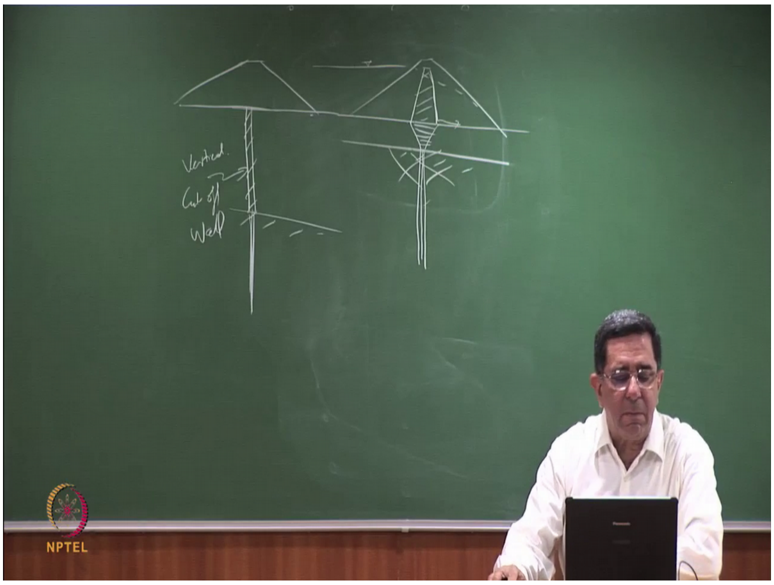

So, I am bothered about seepage through the dam and also seepage beneath it if this is pervious. So, in the dam to prevent seepage I put a core a clay core right, and this line disappears it comes here now.

So, we been dealing with this. So, many years what do we do below the dam if it is got a pervious bed, how do we prevent the seepage from going from beneath the dam.

Student: Cut off walls.

Well first choice is not cutoff wall, first choice is a cutoff trench making cut of walls is difficult. jJst see a dam is sitting on boldary strata to and you want to make a vertical wall in a boldary strata it is a expensive exercise. So, first we say is (Refer Time: 31:22) can I excavate. It if I can excavate can I do open excavation, and can I come back in layers and put clay in it. So, this is the standard traditional cut off trench, the cut off trench may be a few meters deep, 0 3 5 7 you have to cut it at slope, you have to have the available width at the top. Water may still seep through this or no is this rock going to be impermeable, soil lightly to be underlaned by impermeable rock or more fractured and disintegrated and then later on competent rock. So, most of the interfaces between soil and rock are not hard rock, they all have joints and fissures and they are pretty permeable. So, you will have a some kind of a jointing pattern and then this will be competent rock at the bottom. So, if I stopped the water here, and if I stop the water here, water still wants to go through the rock. So, what do we do what do we do when we want to make a impervious barrier in rock.

Student: Grouting

You do grouting cement grouting; why do not we do grouting in the soil?

Student: Sir grout will flow (Refer Time: 00:00) defined.

No no no no grout will also flow in the fissures of the rock? If they are cases then you put grout in the rock and it will come out one kilometer downstream, your pumping grout here it is coming out one kilometer on the other side because all connected at the bottom.

Student: Thank you sir to find (Refer Time: 33:01).

So, in soil it is difficult to pump in cement grout, unless it is pure gravel and sand. If that has any fines the pumping is difficult. In rock pumping is simpler because the fissures are tend to be interconnected and the grout goes in the direction of flow which is possible. In soil if you have silt no grout can travel cement grout cannot travel, if we have silty sands cement grout will not travel, only when you have coarse sand and gravel will cement grout travel.

So, what they what we do in dams we make a grout curtain, and grout curtain may be 3 rows of grout holes. Now I have an impervious barrier. So, the first thing that you see here is of course, when this is when the location of the rock is deep below, when the location of the instead of this situation suppose my situation was this is the base of the dam and my rock is here. Now make a c20 meter deep cut off trench is very difficult right. You have the option of grouting or I have the option of making a vertical die from wall a vertical cut off wall.

So, when the rock is deep below and my dam is way up there, then I have a tendency to put a vertical cut off wall. I do not do grouting installed because not simple to do grouting in soil, I might want to grout something vertically it may not get grouted vertically and the grout may not penetrate into this. So, I will make a vertical cut off wall and then below that may be grout curtain. What is the vertical cut off wall made of? Cement concrete, soil, plastic concrete, PVC, vertical cut off wall is not a diaphragm wall which is returning earth behind it like for Calcutta metro. So, it is not an typically not an RCC wall, it will be a plastic concrete wall or it will be a soil cement clay mix wall, it is an impervious wall it is not a structure remember. So, we will see this as we go along.

So, vertical barriers are compacted clay in trenches when the thickness to the impervious strata is low, it can be cut off walls now the word that you are going to come again and again is slurry walls. They call them slurry walls, ever body seems to think that they are made of slurry they are not made of slurry they are only stabilized with bentonite slurry. So, please do not think that a slurry wall is made of slurry. So, you are going to have cut off walls made of clay or soil bentonite or soil cement bentonite or cement bentonite or plastic concrete or composite.

So, because concrete is often attacked by sulphates, you do not tend to use concrete walls unless you can preclude that none of the chemicals in the waste in the contaminated site will affect the concrete, you want flexible walls. So, you typically tend to use a soil wall clay or soil wall plus bentonite or bentonite plus cement or soil plus bentonite and cement. We can have grouted barriers and we can have deep mixed barriers and we can also put sheet piles, but cut off walls are the first and most cost effective solutions.

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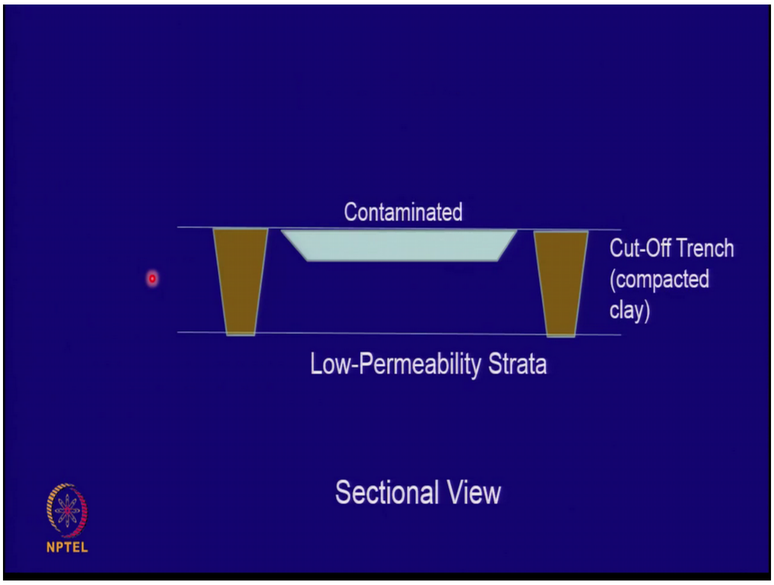

So, this is the contaminated site you have shallow contamination, you have low permeability strata at shallow depth. If this depth is 0 to 5 meters it is a good enough way of isolating the contaminated site.

So, this is the cut off trench of you are you will have to send the roller in or a the compaction device into this, and make the cut off trench rarely you get very shallow ah low permeability strata at very shallow depth, but never the less this is one of the solutions which exist.

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When you starting to make cut off wall which they call slurry walls, the wall can be made of clay it can be if clay is available locally it will be made of clay on nearby. If it is not available then you come back to what we were doing for amended soil barriers, soil plus Bentonite or it may be made of soil plus Bentonite plus cement, you might want to give some strength additional strength. So, the wall we will do an example or it can be made of soil plus Bentonite and you may want a double assurance that nothing is going to go past you might put a geo membrane inside that and walls there may be special sheet pile walls.

There is another word here reactive permeable walls or reactive permeable barriers; this is something on which I want a self study by you, what are reactive permeable walls or reactive permeable barriers. These are not barriers these are pervious walls and let me give you the thought is very simple in all the walls we are trying to keep the contaminated water within the walls right in reactive barrier, you are making the wall of a material which has a chemical which will react with that contaminant, and allow only treated water to go through. It is a very specific solution for a very specific type of contaminant, you cannot have a magical chemical which you will put in a wall on one side is contaminated water on the other side is drinking water, but if you have one type which you may be in your one page right up. So, I want to your one page right up to be one diagram of half a page, and one paragraph on where is this kind of solution used. | Half a page diagram will just tell you what the how the wall is made, but we are going to look at this clay and soil and Bentonite and soil and Bentonite and cement walls. So, let us say this is the contaminated site in plan ok.

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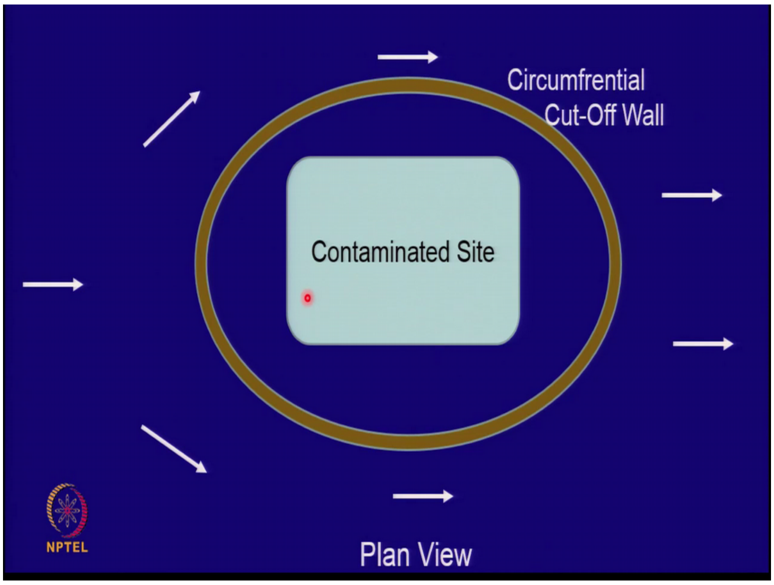

So, the philosophy is can I put a wall or an impervious wall around it so that the water can be bypassed it. And my ground water flow in this direction, can I get the ground water to bypassed the wall. So, this is the contaminated site, and this is a circumferential cut off wall assume it to made of low permeability material.

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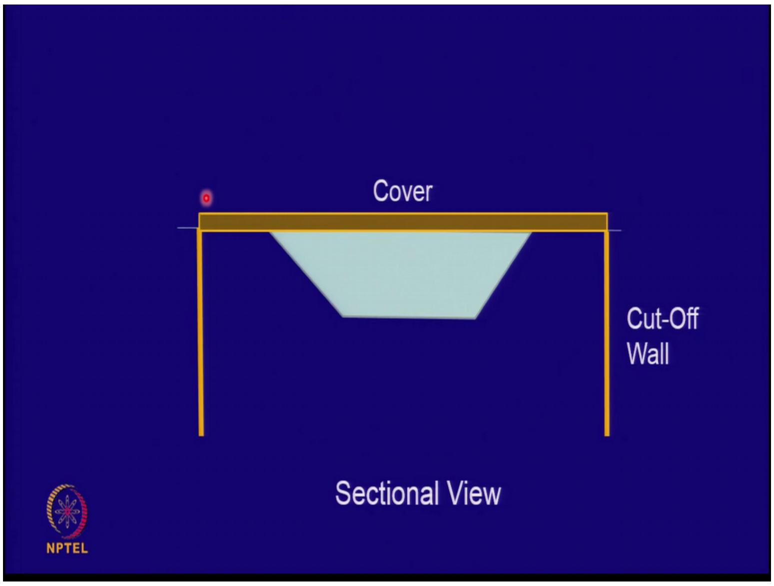

In section this is already look like it; will have a cover at the top. So, that no more more release of contaminants cannot take place and it will have vertically cutoff walls. Now how deep do they go theoretically they should go to an impermeable strata, those are called key in cut off wall you keyed them in, but suppose the impervious strata is 100 meters deep, then you make a hanging wall. Still remember you would have made a wall all around it, and it is pretty deep and the fresh ground water is passing by and not reaching the top.

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So, this is what is done you excavate a trench 0.5 to 1.5 meter wide, how do you excavate you normally use an excavator a backhoe? You will you seen this device, what is a backhoe? You can excavate to the backhoe and typically backhoes can have extended arms from 10 to 12 meters deep. So, they can dig very deep, this strench is stabilized with Bentonite slurry, imported clay or soil mixed with Bentonite are made in the form of high slump material. You remember high slump concrete yeah the idea is you should be able to put this material in the trench, and it should be able to slump and spread by itself. So, you have to add enough water to your clay or to the mix of Bentonite with the excavated soil and make a high slumped mixture; back fill this into the trench and the slurry will come out. Keyed in wall reaches the low permeability stratum, but hanging wall does not and it is used in conjunction with pump and treat.

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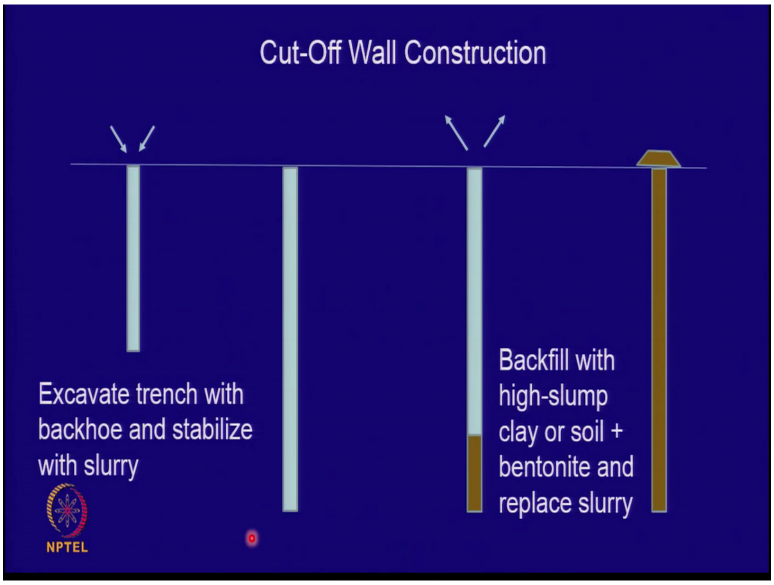

So, you excavate a trench, using an excavator fully excavated trench and it is stabilize with Bentonite slurry 5 percent Bentonite, and then you start sending in your high slumped material, how do I send it will come become apparent? This slurry keeps on coming out now and that is your final wall.

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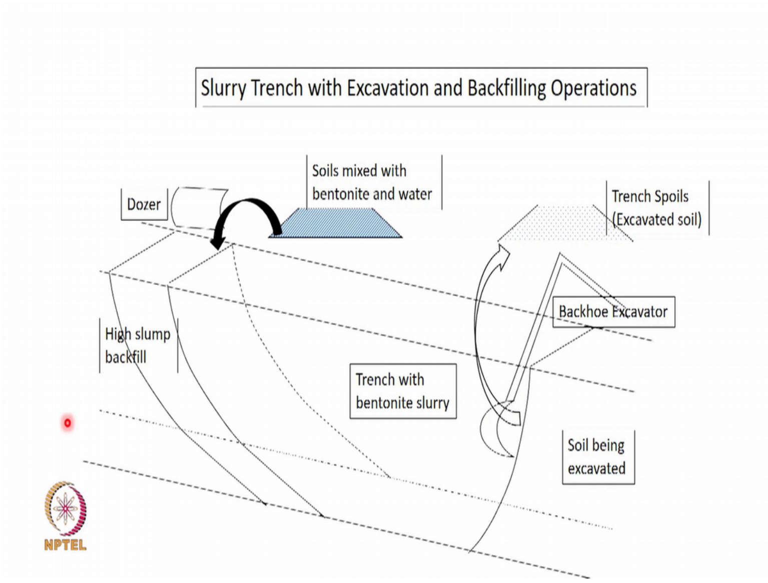

This is the way the operation goes, this is the cut off wall being constructed, this is the unexcavated soil you are a back wise is making this strench alright. This spoils are coming here, if you are getting clay from outside you bring the clay and slump it forward from the sides. These high slump material, if you do not have enough clay you take this trench spoils and mix it with Bentonite 5 to 10 percent Bentonite, and deposited the slurry keeps on coming out.

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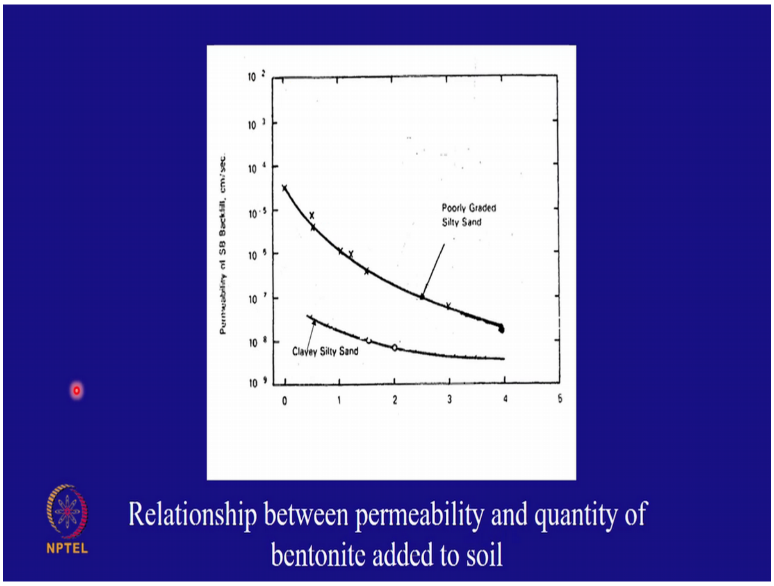

So, the trench is excavated and proceeds in this direction, and you can see that normally typically we will get 10 to the power of minus 7 centimeters per second with about 5 percent Bentonite, we have done this before.

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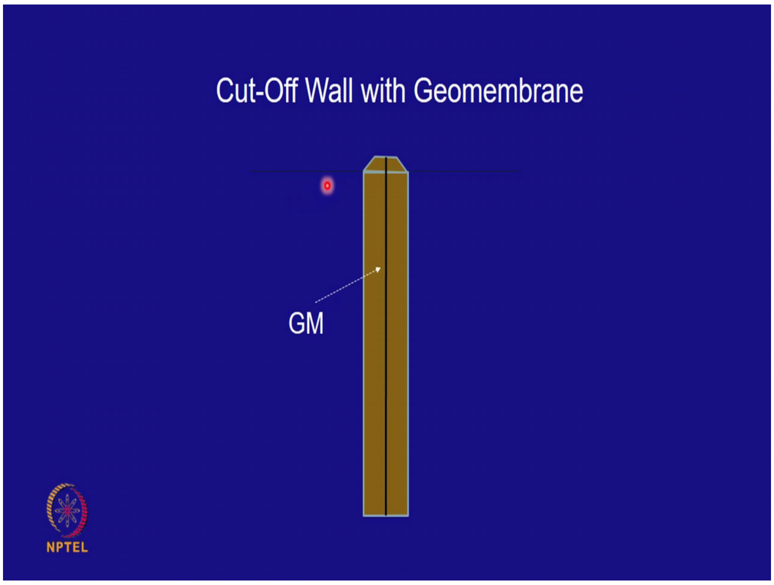

Sometimes we want even higher impermeability then in your volume might put a geo membrane, and there are these Geomembrane sheets which can their special arrangements by which the machine can make them make vertically into the Bentonite into the soil wall or the soil plus Bentonite wall.

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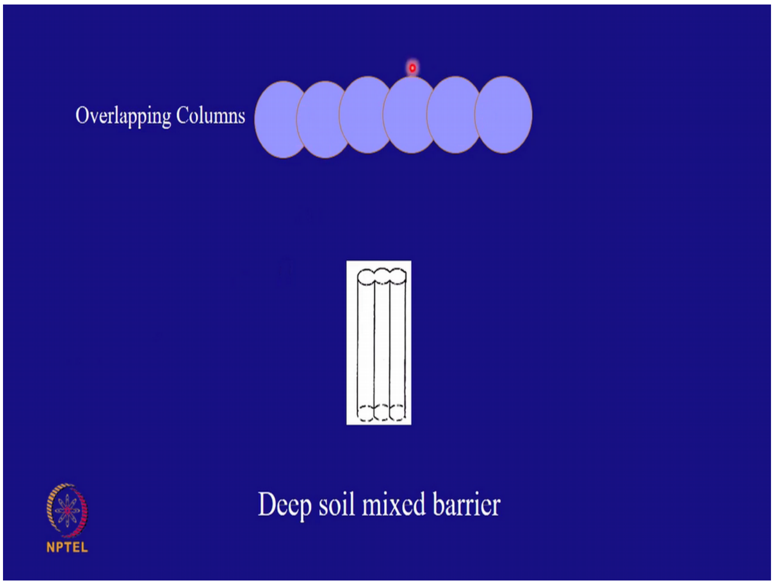

You can also make overlapping cement columns, deep mixed columns we have had one this in ground improvement again rarely used, but if you want a wall made of over lapping columns, then you can have deep mixed augers, they are 3 augers which you operating and they can over lap and make a deep mixed vertical wall.

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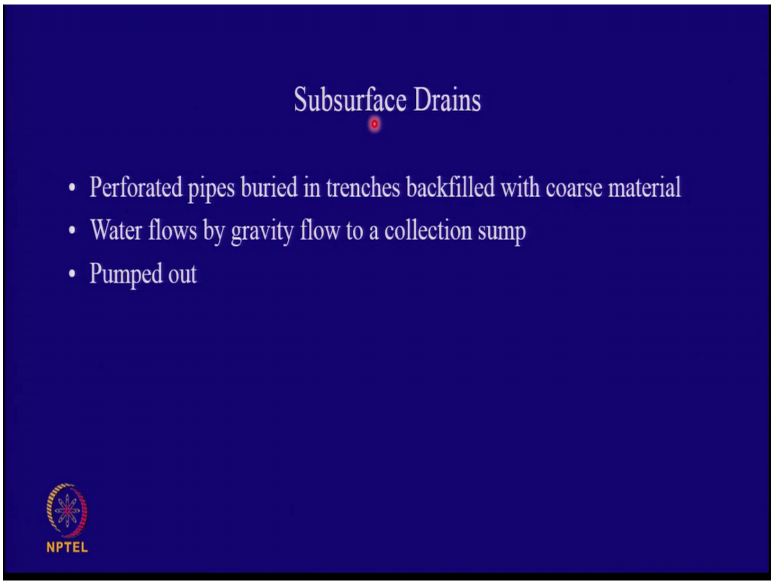

But by and large the wall which is used very often is the clay wall or the soil plus Bentonite wall. You might want to put a subsurface drain in conjunction with this, a subsurface drain is something in which perforated pipes are buried in trenches and backfilled with coarse material, water flows by gravity to the collection sump and is pumped out.

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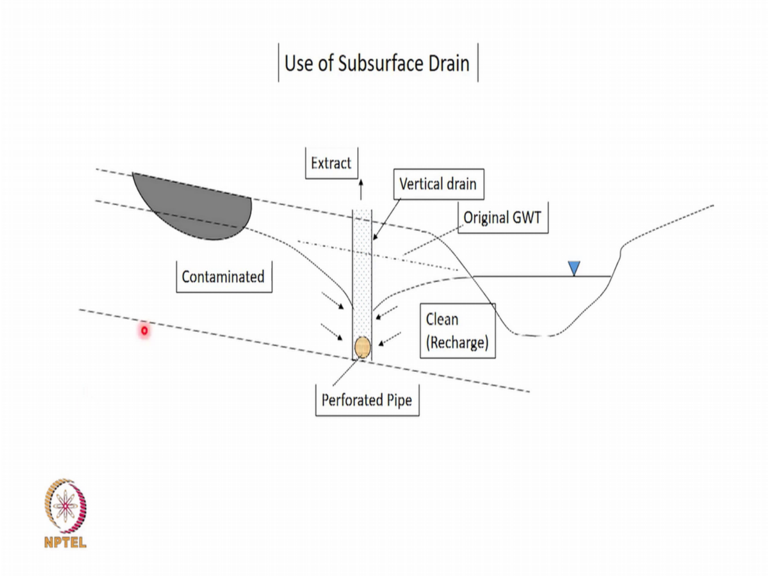

So, instead of making an impermeable wall, I make a pervious wall. If is the plume is coming I put a perforated pipe at the bottom, water will flow into this I have to continuously pump it out at some sump. So, sometimes you can use subsurface drains to augment your barrier walls to reduce the depth of water table.

So, far we have seen how to contain, but we have to actually solve the problem of bringing it back to it is original condition that means, we have to treat now.

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You to treat the source, we have treat the soil, we have to treat the pore gas, you have to treat the pore fluid and we have to treat the ground water. And we can do it ex situ or in situ and we will take it up in our next class, but the first action that we take always is control. One control is cheaper, two controls can be effected relatively quickly and at least you are at peace that the thing that the further spread of contamination is not taking place. So, apart from the covers that we have done the major role geo technical engineers is to make a vertical wall, and in the next lecture I will try and give you a case study example as to how we put a proposed a cut off wall around a tailings pond.

So, we will stop here and if you have any questions on vertical barriers, specially how to construct it the most important thing is how do you construct barriers. Now suppose you want to make a vertical cut off wall 30 meters deep, and you have a excavator whose arm can only go 12 meters of it, how are you going to make a vertical cutoff wall 30 meters deep? We need trench cutters this is you have to use the same equipment by which we make die from walls, if you remember last time I had told you that trench cutters look like this, these are devices.

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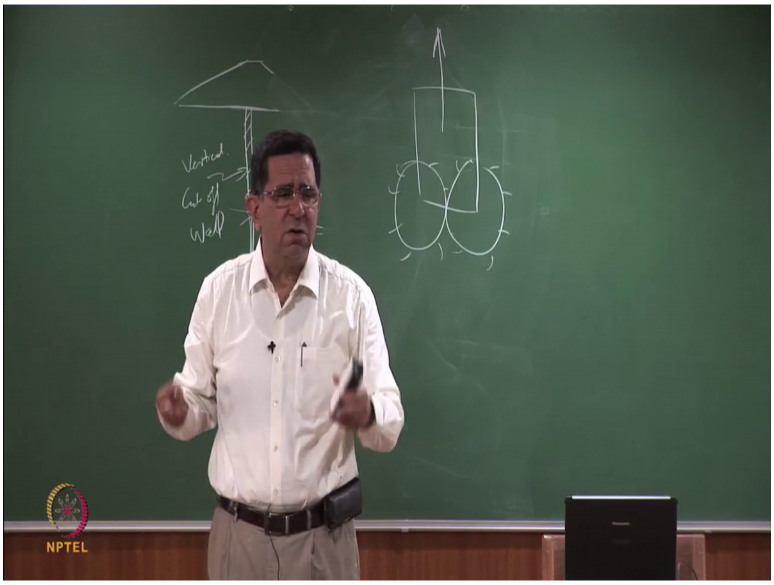

Where these rotate and they cut a trench, and you are using reverse mud circulation instead of putting in the slurry as they cut you are sending the slurry up the pipe line. So, you have to use trench cutters if you have to make deeper walls then 10 to12 to 15 meters, and these trench cutters are the same that are used for making diaphragm walls for underground construction like in metros and other underground openings, any other questions?

Student: Sir in slide sir we have a barrier and then we have (Refer Time: 47:12) there we are pumping out the water sir contaminated.

Subsurface drainage right.

Student: On this side we have sir let us.

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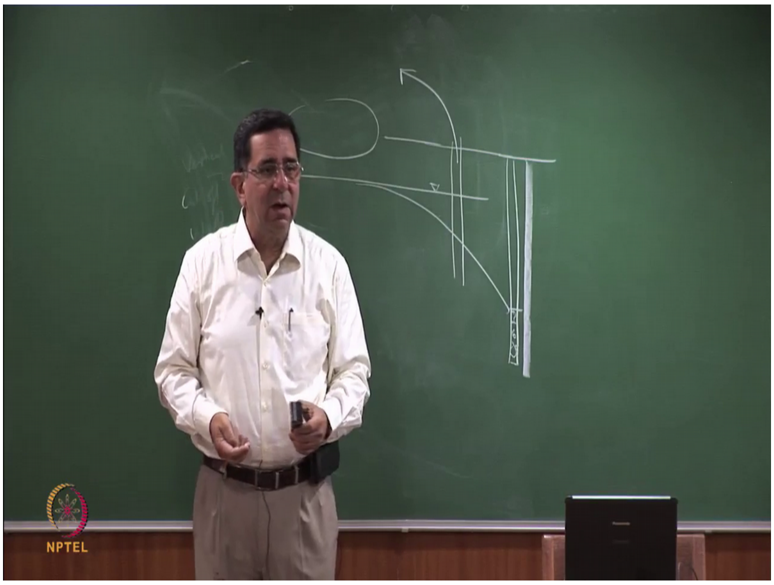

So, there is a waste there is a contaminated plume, my traditional solution is let me put a cut off wall here. We have to do something to this contaminated water I can do two things, I can do pump and treat or I can make a continuous pervious trench around it. If you put and treat you have to put the pumps at very close locations in plan say a few meters away, you can take out the water treat it and re inject it. So, the diagram which was shown was it was having a subsurface drain here is this the one you are talking of.

Student: Yes sir.

So, the idea is still that this water must get caught pumped out and treated.

Student: Sir I am more concerned about the settlement sir what will be the settlement and if we have cap it with between.

You are worried about the settlement of the surface yes, because of these cuts that we are making.

No sir you when the water will go down.

So, the design is not only of draw down it is also of injection wells. So, when you do the design the question that is being asked is that when we all these pump and treat or when we do the subsurface drainage, the water is taken out then because of increase in effective stressors settlements will occur at the surface. Answer is yes they will occur.

The question is do we do very massive drawdowns? The answer is no we do limited drawdowns; however, in the next lecture we will see we also put injection wells simultaneously; that means, water is being extracted treat it and inject it back. So, you try to keep the level of the ground water table about the same as what it was originally or the draw down may be very limited. So, it is a mix of taking out and injecting. So, even if you are putting a subsurface drain, what is not going to come out till you take it out from a sump? You when you take it out then you have to put in that much of water back into the system. So, we will stop here and look at remediation in the next lecture.

Thank you have a good day.