Environmental Remediation of Contaminated Sites

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Lecture – 35
Different Types of Fluxes in a Containment Barrier

Hello everyone, welcome back to the latest lecture session again as is customary let us have a quick recap of what we have been up to so we had been discussing I believe remediation of contaminated soils or sediments right and that context we looked at what is the excavation and then looking at a landfill what are the different competence in a landfill and so on and so forth and some of the ways in which let us say a landfill can fail.

And I think we looked at a few of the practical aspects right and we also obviously looked at the different layers within a scientific landfill and why we need right so we looked at those aspects and then we moved on to another particular aspect in this context which is containment right. So so obviously here we are only talking about containing the relevant contaminant from being transported to a wider area let us say or area from the source right.

So again the key is that its containment we are only trying to contain the relevant contaminant so obviously here we are talking about restricting the transport of the contaminant right so how does a particular contaminant what do you say transport or how is it going to be transported in the subsurface now right two pathways one either due to diffusion or one due to advection right. Advection as in when we have a net flow of fluid in one direction.

As in groundwater flowing in a particular direction this particular contaminant can what do we say that is adsorbed on the soil let us say can reach equilibrium or dissolve into the groundwater and then be transported right by that particular groundwater are obviously because let us say you are going to have a concentration difference let us say or gradient pardon me as and let us say the source locations you have very high concentration of your contaminant.

And a few meters away the concentration is relatively low right so diffusion obviously right to the other mode of transport of contaminants in our particular context is going to let us say see dude that you know the system ends up like this right as in you are going to try to see to it that the concentration or the contaminant is transported from a location where the concentration is relatively high to a location where the concentration is relatively low.

Right that is what it tries to do more or less that if you let enough time what do we say are you flood the system how enough time well see that more or less the concentration will be relatively the same throughout the particular system again that is one of the driving forces for diffusion alright right.

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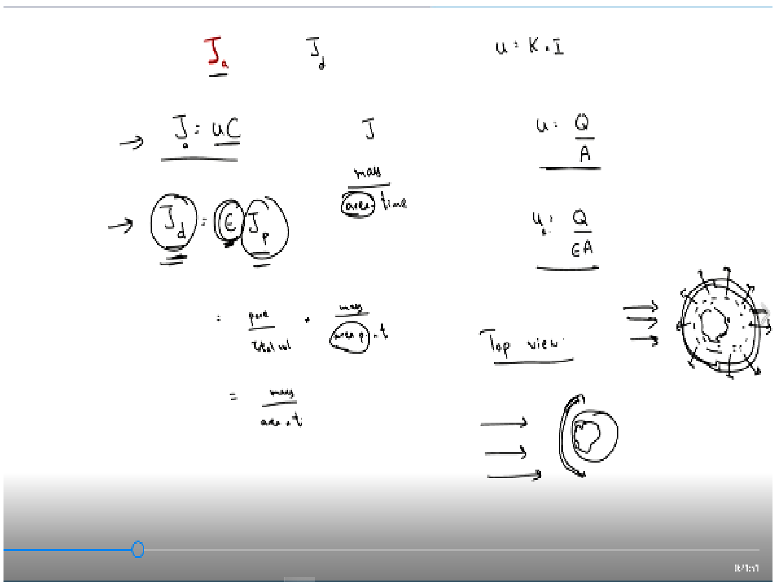

So let us just look at what we have here so we have flux due to a direction right and we also have flux due to diffusion right flux new to diffusion so due to advection obviously we mentioned that it is going to be depend upon the Darcy’s velocity right *times concentration right so again Darcy’s frosty that is going to be equal to the hydraulic conductivity*the gradient right so that is something that we have again Darcy’s velocity.

Let us say how can I understand that in practical terms let us say I can say that its also =let us say u= the floor rate/the total cross sectional area right so more or less though as you understand this if I at least I can use lay mans terms what you say it is like the normalized what do we say velocity as an there the cross sectional area through which the ground water is flowing right obviously the groundwater does not have this much area to flow through right.

It has relatively lesser area why is that obviously because there is cross sectional area let us say if I take length out then this volume is filled with soil right and some pore spaces filled with your water here right. So we are only concerned with that particular pore space right so obviously porosity needs to be taken into account and the ground water as you know can only move through that particular area that is available in the form of a pore space.

Let us say right or free air space I mean here its not there because you have ground water obviously out there. So but we are looking at Darcy's velocity or the total what do we say area right across the entire area so the actual velocity or the seepage velocity through these pores is obviously going to be higher right so that is something that you can look at so if I say U=Q/porosity times A so this U will now be = to the seepage velocity.

Right that is something to keep in mind anyway flux due to advection right this is how we can calculate that and flux due to diffusion right again if I look at the normalized and so on and so forth right its porosity times flux due to the pores and again not due to the pores flux through the pores and what is flux again what are the units now it is like mass of the contaminant per area per time right.

So here this is for the pore space area and this is total area right so obviously thus I need to multiply this particular flux through the pores by the porosity to be able to end up with the flux total flux let us say right not flux then normalize flux or the entire area let us say right and let us just check that I guess right if that is true then porosity= let us say pore volume let us say/total area let us say or total volume pardon me total volume right.

And to let us say this will be called the mass per area of the pore let us see*time so either pore volume I can multiply that by length and such to right and then transform that so yes that will end up being something like mass per total area let us say or area*time earlier it was area of the pores let us say if I can say that right and then here this is how we end up with so that is way obviously we need to use porosity out here.

So in this context let us look at one particular example let us say think of a system where let us say this is the top view now the top view you have the top view right and let us say you have a spill here your soil is contaminated with this particular what do we see TCE let us see and you how ground water flowing in this direction and you want to contain this particular way such that its not transported over you know a wider area right.

So what can you do you can put in a containment barrier here let us say all right or obviously it can have a in this manner or you know obviously cover it entirely or such but typically you know you see such shapes right? So again here you have this and here is your waste and you have your containment barrier here this is the top view obviously right. So here let us say a we can use bentonite clay and so on and so forth.

So obviously what are the ways that you know the contaminant can still be transported let us say if I have this entirely here let us see wait so through diffusion let us see if let us see now let us assume for the sake of ease let us say that this entire room is filled with that contaminant now so because the concentration of contaminants on this side of the barrier is less than the concentration of the contaminant on the other side of the barrier.

Due to diffusion the contaminant well want to be transported okay and this will yes so that is something that is always going to be there and if there is still some groundwater flowing through as in you are going to decrease the groundwater flow or the transport due to advection it cannot be 0 right you know so let us say the you are still going to how some advection let us say let me use this kind of an arrow mark advection right.

So you are still going to have some advection let us say right so let us see how these particular fluxes due to advection and diffusion compare let us say then we use bentonite clay or such right.
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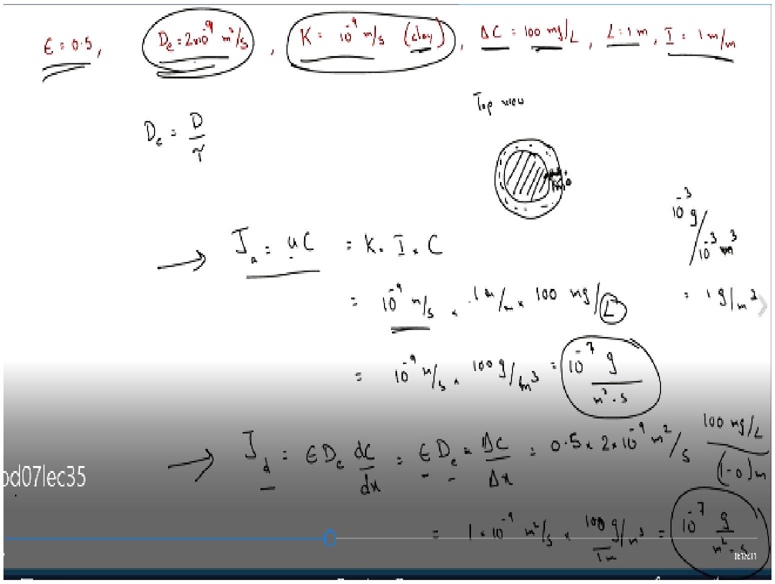

Let us go to the relevant aspects I have so let us say here I have some data so porosity of 0.5 effective diffusion coefficient that includes both dispersion and diffusion let us say I guess 2* 10 power -9 so if you remember how did we end up with this De= the diffusion coefficient/tau right and tau gives us an idea about the tortuosity of this particular system let us say the tortuosity factor right.

Because as you increase the tau right that means that what does that mean that you know the path is more torturous now anyway that is something you see out here and hydraulic conductivity delta c let us say as an as for example I have the top view right and if my containment is within this particular area and this is my barrier let us say and the barrier of thicknesses let us say 1 meter.

So delta c is you know the concentration here or inside the barrier at this point - the concentration at this point so that is delta c here and L delta is 1 1 meter here 1 meter right and energy gradient is 1 meter per meter I guess right so that is what we have here so we will now try to calculate the 1 due to or the flux due to advection that you know is u time C U is K*I*C right. So let us have that here K is 10 power-9 meters per second.

Again as I mentioned this is for clay typically for Bentonite clay you do have such a level of hydraulic conductivity and gradient is 1 meter per meter times concentration here let us say so for the sake of ease of calculation assume that it is 0 here and that is it is 100 here *c is then 100 right 100 milligram per litre right. So I can then calculate that let us see and J due to or flux due to diffusion; pardon me is what is it now its porosity times effective diffusion coefficient.

Let us say times dc/dx is nothing but how is C changing with x or in this case I will say *delta C /delta X right so that is equal to porosity is 0.5 we have that out here right effective diffusion coefficient or dispersion coefficient let us say is 2*10 power -9 meters square per second right that is what we have out here and delta c is the change in concentration is 100 milligram per litre that is what we see here it is 100 milligram per litre here it is 0.

So delta c is 100-c is 0 100 milligram per litre per delta L as or this change in length so that is =1-0 meters right so we have this out here right so what do I have here obviously units need to be looked at meter, meter cancel out so this is obviously in litres right so we have 10 power-9 meter per second *1 meter per meter right and * 100 milligram weight so milligram is 10 power -3 gram I guess right by 10 power -3 meter cube right.

Because 1 meter cube is 1000 litre right so that is going to be 100 gram per litre*100 gram per litre so how what is the what are the units not literal pardon me units are meter cube right this is =1 gram per meter cube 1 milligram per litre =1 gram per meter cube that is what we have here so I ended up at 10 power-9 grams of that particular contaminant per meter square area per second so this is what we end up with for advection.

And for diffusion let us see what we have 0.5*2 so that is 1*10 power -9 meters squared per second into 100 milligram per litre is again 100 gram per meter cube as we discussed earlier divided by 1 meter/1 meter so again the units and such cancel out and if I look at it obviously it is=10 power-7 grams per meter squared per second right again. So we now calculate the flux due to advection and flux due to diffusion.

And this kind of scenario and keep in mind that this is for bentonite clay you know these factors are typically for bentonite clay and I believed the diffusion coefficient is for a chlorinated solvent right the example here is for chlorinated solvent I believe the diffusion coefficient or dispersion coefficient through clean up. So again what do we have here let us just look at what we have so for what do we say bentonite clay.

Let us see the example that we looked at you see that you know you still have advection right or you know there is some transport due to advection but it is so low that you know the flux due to advection and flux due to diffusion or more or less same typically as you know the flux due to advection is far higher than the flux due to diffusion but if you have relatively well constructed containment barrier.

You are going to bring down the advection to such an extent right that you know it is so low that it is you know in the same order of as if flux due to diffusion pardon me right so that is what we have here so what does this tell us that 10 power -7 grams of the relevant contaminant will be transported through a meter square of the relevant area of the barrier per second right that is what you have here.

So for example let us say I think some people sometimes how issues in understanding what flux is maybe I should have discussed this in maybe a bit more detail what do we say earlier but think of this let us say the door here is open and you know wind is blowing dustier right so I want to get an idea about how much mass is coming through that door per time right. So what is that it is nothing but flux right.

How much mass of the dust is coming through that door to that particular door or that particular area per time right that is flux you know that is going to obviously give an idea about the transport let us say and that is what we see out here right.

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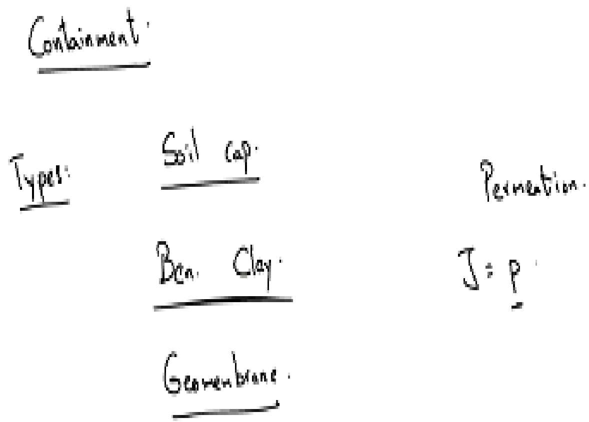

So we are talking about containment okay and that context we looked at the characteristics of barriers right that is what we looked at. So obviously what do we need to look at we need to look at let us say the transport you to advection transport due to diffusion and so on and so forth typically bentonite clay itself as a pretty good way or you know a containment barrier. But obviously it depends upon how you construct or compact that particular layer and such right.

And there are some issues with respect to optimum moisture containment so on and so forth but again it boils down to how much or how well you are restricting the advective transport and the diffuser transport right so what are the different types let us see so we can have just a soil cap okay for example this is typically use let us say if you have relatively remote locations let us say and you know the chances of not contamination.

Let us see ingestion or the rest to a particular person or the locality is relatively let us say but still you do not want the containment to be spread over a wide area let us say or the costs are too high you know different ways or not different ways different scenarios let us say when you do not want to put in a lot of money cleaning up the scenario what can you do you can put a soil cap over that such that we know there is rain fall let us say.

At least you know there is not going to be this contaminant transport so soil cap is one way and obviously people look at bentonite clay or clay barriers right clay barriers so obviously the location is it above beside underneath vaguely underneath or around this particular source or such depends upon the site conditions and way in which let us say the ground water or you know surface water runoff is going to be available right.

So we have those and typically we can also have a Geo membrane right we can also have that so there are different types of these particular caps and such are the containment barriers let us say or containment layers so for in some cases obviously it is not going to be diffusion is going to be permeation let us say or permeability or permeation then the flux= J times the permeation co efficient if I can call that times delta c right.

So that is one particular aspect that you need to be you know aware of anyway right so again containment you know these are the aspects that we look at and sometimes used right. So then we will move on to another aspect let us say which would be which is one of the most widely used methods for treating or you know remediating contaminated soils and sediments that solidification and stabilization right. What do we have here?

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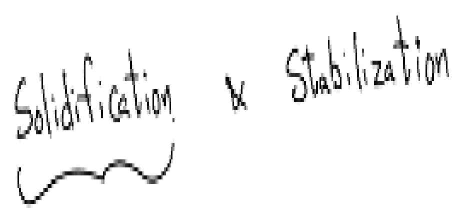

We have solidification and so what do we have here we have a particular method which goes by or which we refer to as solidification and stabilization right. So we look at it in a bit more detail in a few minutes but let us just try to understand what it is that we have out here. So they are slightly self-explanatory so there are two aspects obviously so you are solidifying it and then stabilizing it right.

So when you are talking about solidifying a particular a mixture or such you know what are we trying to do we are trying to improve the physical properties or the characteristics of that particular mixture now we are solidifying it right we are improving the or affecting the physical characteristics or such as a strength and such typically unconfined comparison strength and so on so typically we look at physical characteristics.

Or improving the physical characteristics of strength of the mixture through solidification. So stabilization is more or less you know making the relevant contaminant either less toxic or immobile right so the first aspect is you are certifying it right giving it or imparting it more strength second aspect is you are trying to see to it that the contaminant within this particular mixture is or becomes either less toxic.

Or it becomes immobile or is not free to let us say be transported right or is less mobile obviously right. So I believe we have few slides here let us look at what I have here so again what we have here.

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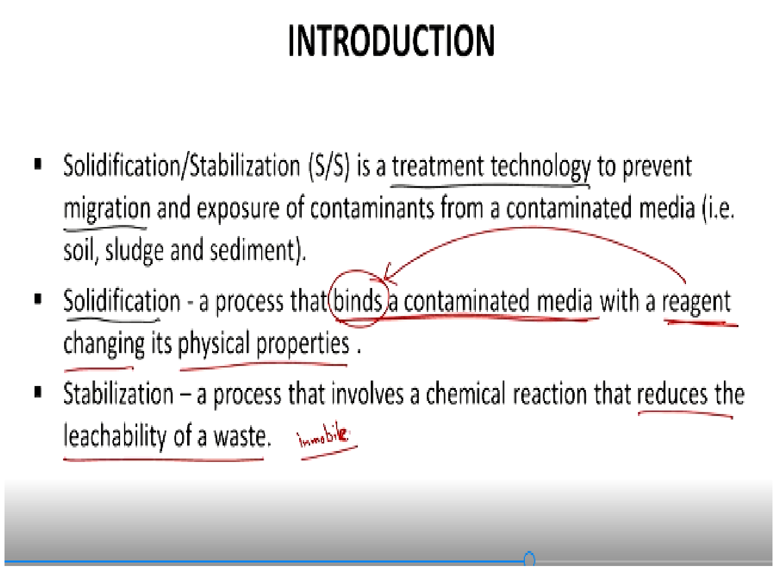

So typically most widely used again so here we used to prevent migration let us say from contaminated media that is something that we obviously discussed yes as I mentioned here solidification typically for the fiscal strength right for fiscal strength and again how does that work binds a contaminated media pardon me with the reagent right we look at what reagents we typically use.

So here again the key is that we are talking about bind right we are binding the contaminated media with a reagent we look at what they are but obviously the key is that we are trying to bind the media here right and thus increasing on the increasing typically improving the physical properties and as we discussed stabilization that reduces the leachability of a waste leachability as in we are making it more immobile right.

For example, how do you define let us say whether a particular waste is a toxic or not toxic right for example when we looked at the relevant laws let us say we saw that you know we have a at least in India let us say a hazardous waste management and other rules and such right I think 2016 or such they are obviously how do you classify between let us say for waste can be disposed in a municipal landfill.

Or you know needs to be followed by the relevant regulations and needs to be dumped in a hazardous waste landfill or such how do I go about that right. So obviously let us say if I am not sure I need to conduct the TCLP test right the toxicity characteristic leaching procedure test right so what is this about it will refresh your memory so for example this tries to or this test tries to mimic the worst case scenario that can happen to a particular waste let us say.

And the worst case scenario is that your particular waste ends up in a dump or a municipal dump let us say or municipal landfill I will use the term dump for now and during the anaerobic decomposition of this particular dump you are going to have acids form let us say and that acid is going to let us say so in this anaerobic dump where your waste turned up in the hazardous waste you have acids being formed and acids come in contact with your relevant waste.

And now you know typically let us say we are talking about heavy metals let us say your contaminants are going to change phase from let us say is the soil phase to the acquiesce phase right typically because the PH is low because of your acids that are formed and then this leachate let us say is now going to contaminate the groundwater and then we transport to wide area so that is the worst case scenario that this TCLP test tries to limit let us say.

So what do we do out there if you remember we break down the relevant what do we say mixture into I think a size 9 mm or less right less than 9 mm particle size right and I think we take the 1 gram to 20 ml right 1 gram of the relevant compound right or your waste to 20 ml of the particular (()) (22:21) acid based mixture are leeching leachate here right and what do we do we put them in a particular box and this particular ratio right?

And then end over and mixing end over as in you know as this and over and mixing for 24 hours and then we test the relevant concentration of the relevant compounds in that leachate and if the concentration of the relevant compounds in the leachate is higher than the prescribed limits then we describe that particular waste or mixture as hazardous waste right. So that is some background here regarding the TCLP test right.

So why is that that we are looking at or why have we looked at TCLP test because the key is that you know how do we classify the waste as hazardous waste by connecting the TCLP test and what does the TCLP test do it tries to see to it that you know the contaminant changes phase let us say from being absorbed onto the relevant what is it solids or such into the leachate right you are trying to improve the what do we say.

If I can say are trying to make the contaminant more mobile so here the stabilization in a way you know tries to work against that by decreasing the reachability of waste or making the waste more immobile right. So in solidification stabilization there are different ways but one way is obviously such that you maintain the conditions in such a way that even if you conduct the TCLP test on this particular solidified and stabilize waste.

It will not be classified as a hazardous waste again different aspects well come back to that again right so let us look at what else we have here primarily used for hazardous waste sites yes there are some aspects as in a radioactive waste obviously are not classified as hazardous waste in our Indian context is a separate law or you know different kinds of regulations but solidification and stabilization yes is a good way to again look at.

Let us say a radio act two or remediating sites contaminated with radioactive material and such but typically used for at or you know remediating sites contaminated with hazardous waste right. So let us move on right here.

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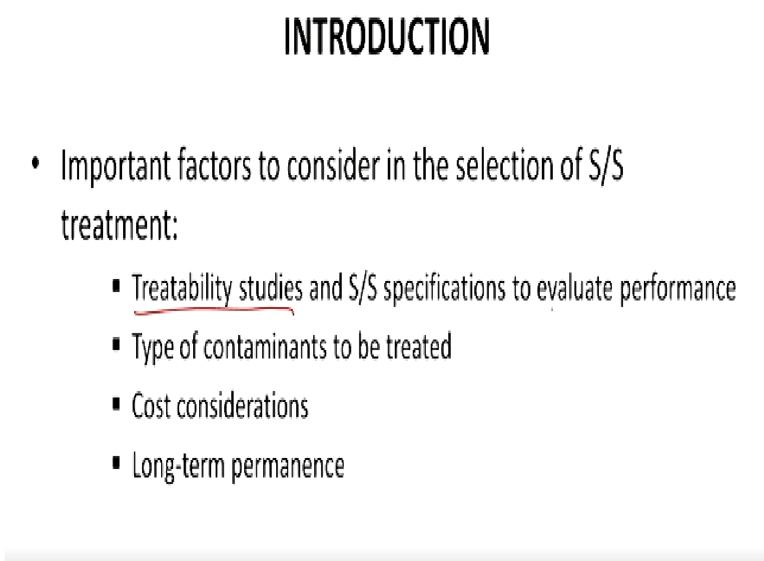

So what are the different aspects obviously so first obviously we need to conduct the treatability studies or the bench care studies and then look at the relevant performance that is obvious I guess late so not all type of contaminants can be treated by what do we say this particular solidification in stabilization right so think of which contaminants let us see are easier to be bindered and also easier to make them more immobile.

And which contaminants are not typically we look at heavy metals easy to let you bind them or let us say at least make them immobile by raising the PH and precepting them out our sites or adsorption onto the relevant matrix or such well come back to those later right. So again type of contaminants is an issue for example typically organic contaminants are hydrocarbons and such obviously not a good way but for some organics yes you can do that

But typically for heavy metals are in organic solidification stabilization is a pretty good technique now right obviously cost considerations depending upon the site against site considerations the amount of binder that needs to be used right and these are aspects so we look at the long term performance right. Our permanents in this context does not how stable is it in the long-term right.

Is it unchanged or such is that more or less permanent or can I think of this solution as a being a permanent solution or a short term fix or such those aspects obviously I can or should look at right? So typically again now aspects are a type of contaminants and then long-term permanency let us say right these are the aspects we need to look at so let us move on.

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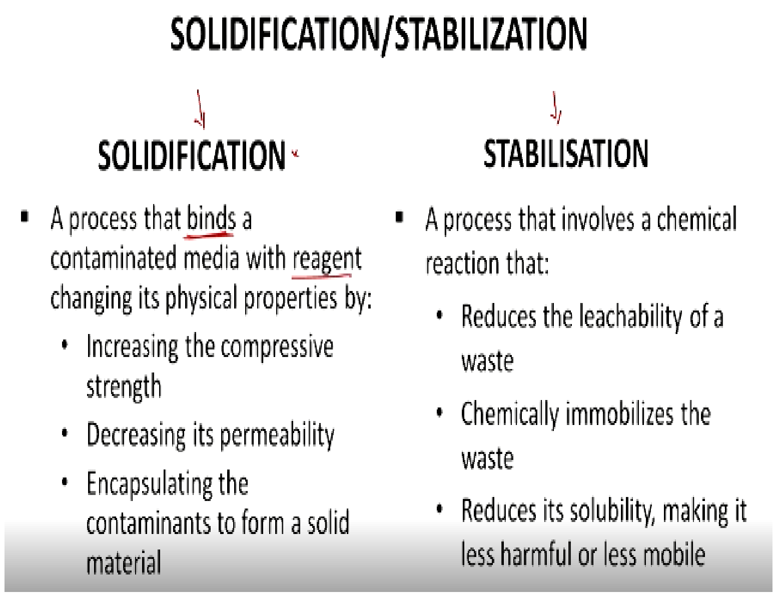

Typically, again as we looked at their two aspects sometimes you need not look at solidification let us say you have the physical characteristics of the relevant waste are pretty good right but typically you will go for board solidification and stabilization right they go hand in hand. So let us look at what we have what we have here so its again that you bind the containment media with the reagent right and what do we do.

We increase the typically the unconfined compressive strength right the compressive strength anyway right we tried to increase the compressive strength we increase its not increased pardon me we decrease its permeability right why is that an issue for example of the mixture or your particular a waste is where to permeable. Obviously than you what do we say our ground water or any other leachate let us say that you know can permeate through this particular mixture right.

So there will be a greater chances of what do you say contaminant transport from that particular mixture into your particular leachate now right. So thus you want to decrease your permeability right you want to decrease the let us say the ability of that particular fluid to flow through or permeate through your particular mixture here. So we are going to try to decrease the permeability right.

And also such that and this process of solidification we also tried to encapsulate the contaminant to form a solid material right you are trying to let us see if I can use Layman's terms to capture or hold them in place them as in the contaminants in place so that is one aspect. So then stabilization as we looked at right you know these are typically chemical reactions right solidification.

We are looking at the physical properties stabilization what are we looking at typically the chemical properties by trying to make the contaminant either less mobile or immobile or reducing the toxicity waste right. So again as we discussed you know making it less mobile or immobile or reducing the leachability of waste right. So again as I mentioned these two go hand in hand as an chemically immobilize waste right.

For example, you have a heavy metal let us say right and you raise the PH high enough it is going to precipitate it out right or precipitate into a solid phase and once you precipitate tend to a solid phase and again carry out solidification let us say you are going to maybe encapsulate it right or you can have absorption onto the relevant matrix the cement matrix or such right so that is something well come back to that again.

So again also decrease its solubility right that is something again all these three aspects go hand in hand out right. So other than this obviously we can add some admixtures that you know also have relevant reactions such that they can decrease the toxicity but that depends obviously on the type of contaminant right. So I guess with that am what do we say I am running out of time so we will look at this in greater detail in the next session.

But again this is one particular remediation techniques that is the most widely used technique all over the world but certainly I have not come across a lot of cases or at least very few cases in India but that is typically because of less what do we say awareness if I may say. So right there should be some technology transfer and such so I am assuming that the people looking at this we do at least can look at relevant sites.

And see if solidification and stabilization is something that is applicable or such right again I will continue this session and you know the relevant aspects in the next session and thank you