Environmental Geotechnics
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Lecture - 29
Geomaterial characterization – 9 (Pore solution studies – II)

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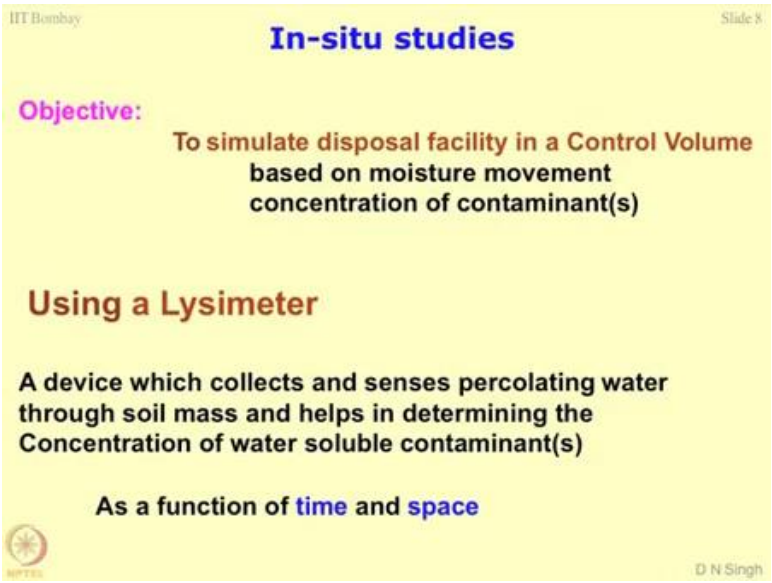

So, this is where actually lysimeter studies become very useful or the pore solution sampling becomes very useful.

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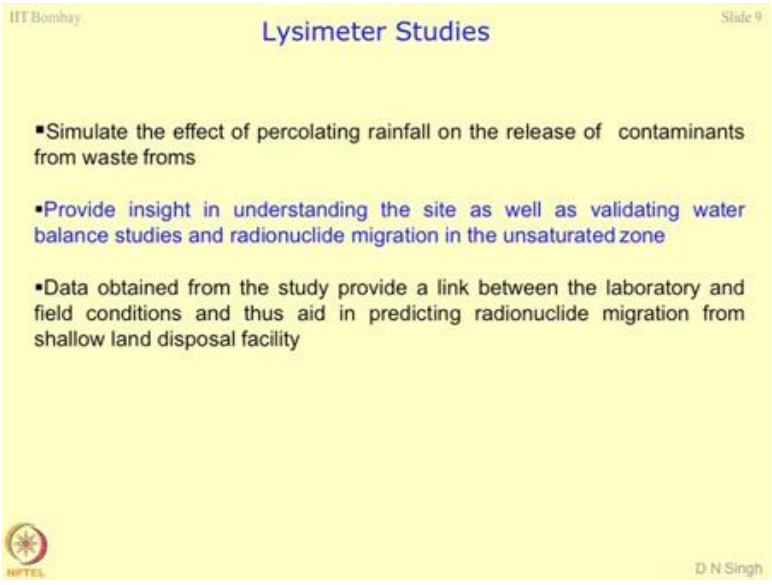

A bit more about the lysimeter studies; they will simulate the effect of percolating rainfall on the release of contaminants from the waste forms. Waste forms are nothing, but different types of waste which are either stored on the ground or dumped in the soil mass.

Lysimetric studies will provide insight in understanding the sight as well as validating water balance studies and radionuclide migration in the unsaturated zones. This is where our profession matches very well with hydrogeologist, is it not. They also do the same thing, but then their perception is mostly on ground water flow our perception is mostly on the what is happening to the soil mass, all right. So, these are two different perceptions for the same problem. For us porous media becomes more important for them following water becomes more important.

So, data obtained from the study provide link between the laboratory and field conditions and thus aid in predicting radionuclide migration from shallow land disposal facilities. I have used the word radionuclide migration; it could be any hazardous toxic waste for that matter.

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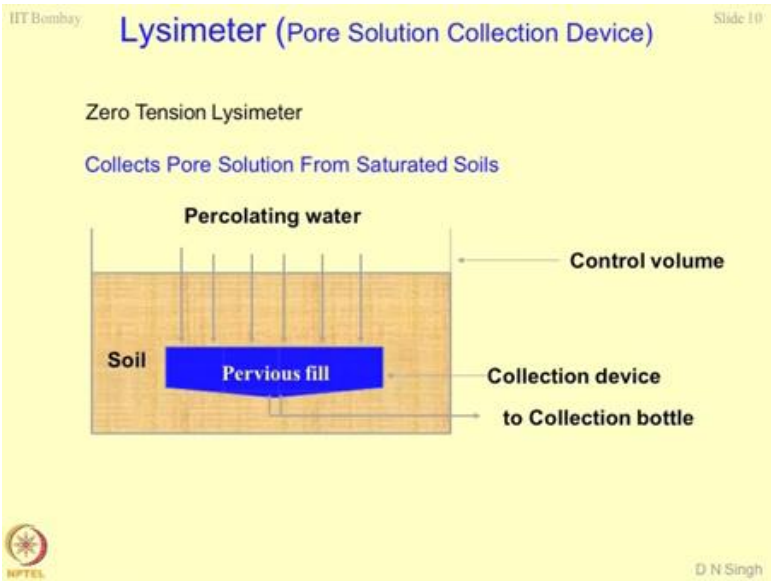

So, lysimeters are nothing, but pore solution collection devices. Zero tension lysimeters, they collect pore solution from saturated soils. So, there is no suction pressure in the soil mass. This is a typical conceptual figure which shows what is meant by a lysimeter.

Now, this is a control volume which has been created in the in-situ conditions. Now, this is a soil which is back filled and then you insert something sort of a pervious material like gypsum block. Yes please.

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Contaminant length.

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Testing means.

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Yeah. So, again there is a same thing. You can you can check the concentration at the source itself and downstream. Is this the what you are asking.

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In which? In this one.

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Ok. I think, yeah, I will try to answer your point here. So, first thing is you install a control volume in the ground and then you insert something which is pervious, it could be a sand layer, it could be a gravel mixed with sand, it could be a perforated pipe, it could be of gypsum block or whatever and then you refill the native soil, clear. But what has happened in the process of refilling we have destroyed the matrix of the soil. So, that is one of the limitations of these studies.

Second thing is there could be preferential flow from the sides of the control volume, the same thing as it happens in your falling head test, there is a preferential flow between the sample and the container. Now, coming back to your point either I can dump the waste over here or I can bury the waste over in the soil mass and then start saturating it that means, percolating water.

So, if the waste is lying on this system the moment it come in contact with water the leachates will be moving into the soil mass and they will be collected from this pervious fill to a collection bottle, is this correct. Even if you bury it inside what is going to

happen? This percolating water will subsequently percolate into the soil mass first, then it will interact with the waste, whatever leachates out, leachates are they will be collected into pervious fill and this fill can be used to suck out the sample. Is this part clear to your question, this is what you are asking?

Ha, sir permittivity will be changing in a concentration which is going out or more may be due to some reason that would be waste solid would be it becomes more or becomes less.

Jain you should understand one thing we are civil engineers; we always talk in terms of factors safety of two and three. What is the meaning of this? We always going to get an answer within 30 percent limits clear. So, these are very indicative test and again the bottom line is something is better than nothing, but yes you can get an answer to a real-life problem within a bracket of uncertainty. So, the biggest question is even if you get some answer within some uncertainty limits there is no harm and you can refine it further. So, subsequently you will see that there are methodologies which have been developed which will cater to your needs very well and you need not disturb the soil mass.

So, it is very good that you have raised this issue all these lysimeters you know they had been in practice since 1940s, but over the years what has happened is because of good electronics, because of mode sophisticated instrumentation the practices are improved a lot. And now we are in a situation or in a and a stage where the best possible sampling can be done. I will take you through the history you know you may realize that this is the development which is happening.

So, conceptually is this part clear that how a lysimeter will work. So, basically you have a soil mass in which some pervious system is embedded and then this system can be used to suck whatever leachates are coming out of the waste matrix in the best possible manner.

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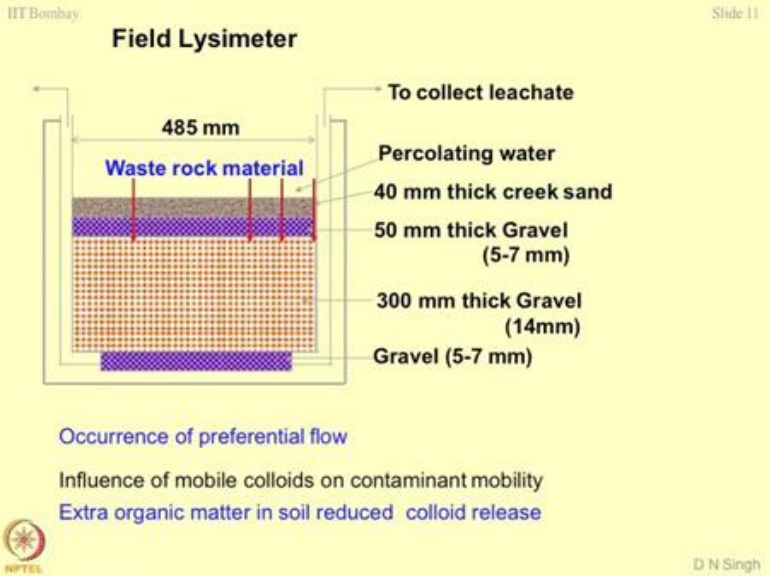

Now, this is another very good example of a field lysimeter which was developed incidentally you designed your land field liners like this. Have you ever seen a land field liner cross section? Some of you must working on landfill liners design, is it not. Vindya you are working.

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Yes. So, your emotions can tell me that you are associated these studies and this reminds you that you have to start studying your topic. So, anyway look at this. You have the gravel at the bottom most point followed by again a thick gravel, followed by again a gravel layer, followed by a sand layer, followed by percolating water and then this is where you can dump the waste material. So, essentially what is doing it is a reverse filter. So, everything which filters out of this gets collected over here, you can provide to suction chambers at the bottom and you can put a motor over here or a pump over here, so that you can pump the leachates on to the ground depending upon the depth of the lysimeter.

So, there are few lysimeter which are instrumented so well that you have pumps submersible pumps also at the bottom of the lysimeters so that you can pump out the leachates quite easily. So, this is another design of a lysimeter, is this ok. But again, you cannot stop preferential flow taking place from this lysimeter. Another thing is if you want to study how many colloids what fraction of colloids is passing out of the fines this

is a good technique. So, influence of mobile colloids on contaminant mobility. Sometimes extra organic materials in the soil can reduce the colloid migration because of the cohesion between the particles. So, fines may not move out.

These types of studies will be very good for identifying the materials, this should be the best candidate materials for designing a liner system. So, that under hydraulic head the fine should not get washed out from the soil mass. I have been talking about from this situation earlier where because of contamination the fines from the soil may get washed out because of eating up of cementing materials.

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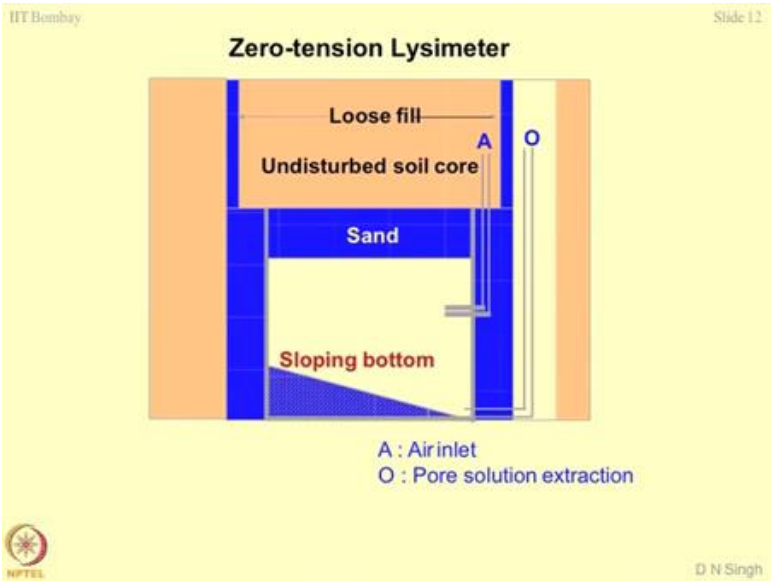

Now, this is also a typical design of a lysimeter where you have a sand cushion below the soil sample, though it is written that this is an undisturbed soil core what normally you have do is you have to go to the field cut out a thick slab of the soil and then place it on the sand bed. And below the sand bed there is a cavity. And what this cavity does?

Everything percolates into this there is a sloping bottom and then the whole idea of providing sloping bottom is so that you can collect the leachates easily from this end and then you have air inlet and a pore solution extraction, alright. Simple design you can design your own lysimeter for that matter, depending upon your requirement. The basic idea is it should be able to collect the pore solution continuously.

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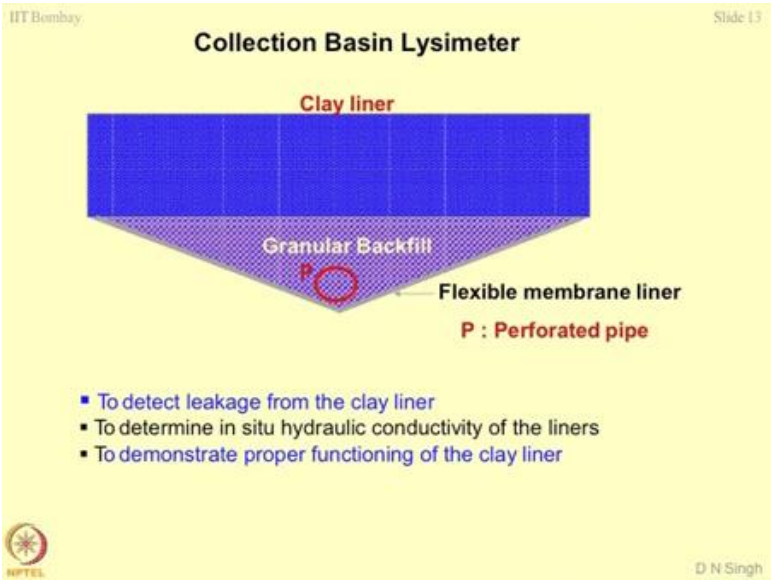

This is a very interesting liner system particularly when you use them below the clay liners. You have a clay liner and there is a granular backfill in which a pipe perforated pipe is buried. What this perforated pipe does? This pipe will simply collect whatever leaching out you attach the system to a pump and you can run out all the leachates from the landfills. So, this is nothing but integral part of landfill leachate collection system, alright.

So, as I said this is basically use for detection of leakage underneath the clay liners. You can device an electronic circuitry and put that electronic systems somewhere here. So, the moment heavy concentration of leachates comes and touches this immediately the circuitry will get completed and this becomes your automatic leachate collection indicator or alarm. So, this type of instrumentation can be done.

The biggest question is how will you do that. So, these systems are developed for testing your design philosophy. So, the whole clay liner philosophy can be tested it is a sort of a performance test. So, you load it with water and then see what type of contaminants are going to percolate through, is this ok. These systems can also be used for determining in-situ hydraulic conductivity of the liners.

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To demonstrate proper functioning of the clay liner whether the clay liners are intact or not, whether the factures have taken place, whether the concentration of ions is passing through it or not.

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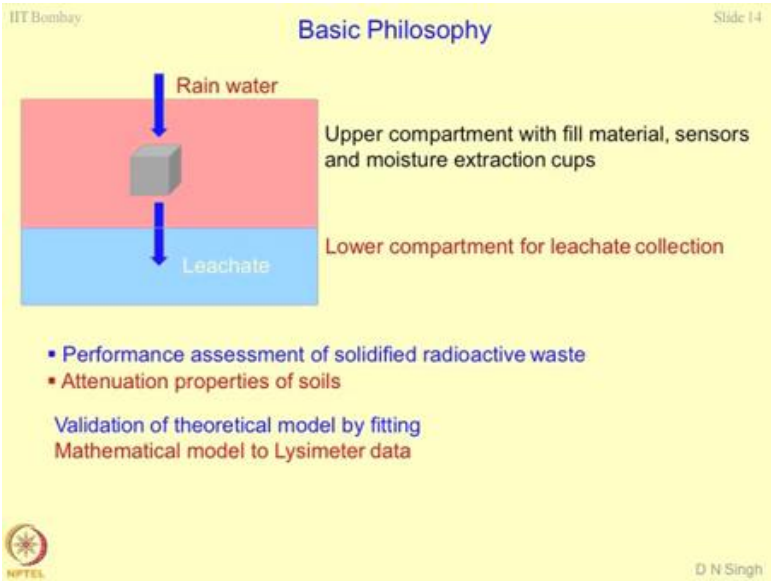

So, all in short the basic philosophy is like this that you have a upper layer which is the fill material, here you can put lot of sensors moisture sensor, temperature sensors, humidity sensors, ok, pH sensors, salinity sensors and so on and then there will be a lower compartment which is going to collect leachates. So, this is the basic design philosophy. How good a design would be depending upon how best possible way you can do it.

So, basically these types of philosophies are used for performance assessment of solidified radioactive waste units or toxic waste units and to study the attenuation properties of the soils. I think Binal you are asking this that I have embedded now here a waste body, ok. And now the rain it is starts interacting with the rain. So, what happens? The leachates will come out, alright.

So, you can collect low leachates because of the influence of the rain water or the ground water even, suppose there could be a ground water, so because of the fluctuation of the water ground water the leaching may start and whatever leachates we are collecting you can find out their concentration to gain validate the theoretical models and you can make

a mathematical model or lysimeter data. So, this is the basic idea about these types of studies, is this clear now. Any doubts? Yes please.

(Refer Time: 13:51).

Yeah.

(Refer Time: 14:06).

Actually, I am unable to follow what is the meaning of giving waste.

Sir, (Refer Time: 14:13).

Just let him complete. See whenever somebody asks a question you let him complete, let him discuss, ok. It is not a very good way to you know desert somebody and start talking. Yes please.

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External substance means some waste. Yes.

Ok.

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Yeah. I mean like your question is basically what I could follow is either this unit will be sitting over here or this unit could be inside the soil mass and slowly and slowly it is going to interact with the water is this your question. Now, you explain what is that you have followed.

Sir, actually he wants to ask that like here we are simulating here giving a contaminant and simulating a situation. Can this be used (Refer Time: 15:15).

We are not giving any contaminant.

(Refer Time: 15:16)

We are not giving any contaminant. The idea is your waste is either setting inside the soil mass here like this or this unit could be piled up over here, now slowly and slowly this unit will interact with the rain water or the ground water and then what happens this unit

will leach out something and that leachate is going to percolate into the soil mass. So, how you are going to capture it, how you are going to tap it so; this is where you are going to collect the leachate. And, once you have collected here you can take it from here by pump or by suction or whatever you can analyze it and you can find out how much is leaching out of this arrangement, is this part clear now ok.

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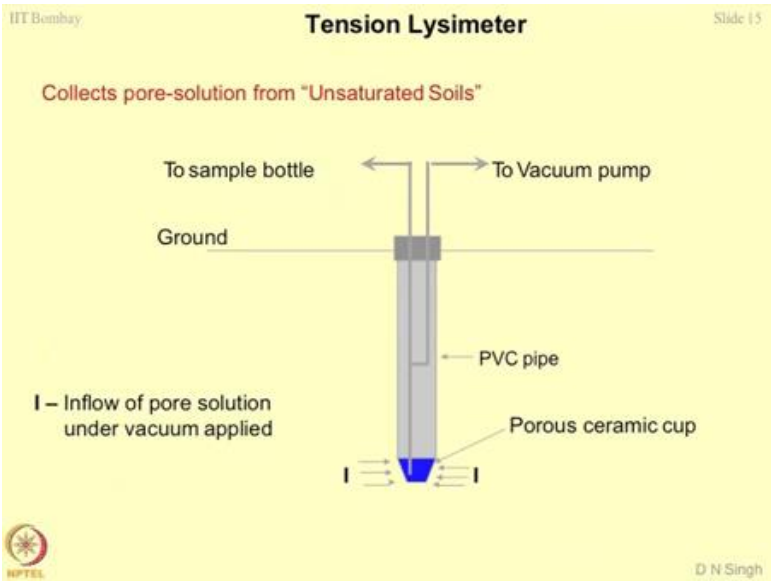

Let us talk a bit about tension lysimeter. So, by now you know that these are the lysimeters which are used for collecting pore solutions from unsaturated soils. This is a simple suction lysimeter or a tension lysimeter which you may call as there is a PVC tube and there is a porous disc at the bottom of this PVC tube insert this in the ground and then apply some vacuum.

So, because of this application of vacuum what will happen? The leachate will rush towards the porous disc and then it gets filled up into the PVC pipe. You can lift it up with the help of the pump collect it in a sample bottle and do the analysis. This I had shown you when you are visited my lab some of the slides I will show you today again to recreate, it this is ok. So, this is one advancement you may say since 1940 or 1930s, alright. So, here the disturbance to the soil mass is minimal, not minimum minimal very less.

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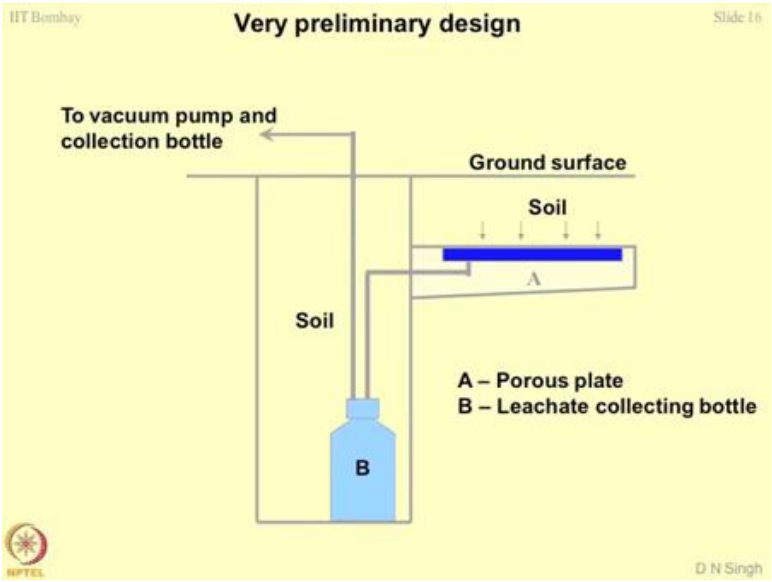

This another type of a system which was design quite in back in history 1940s I suppose. Very preliminary design the same thing we have only difference is they used to keep a bottle in a ditch and then there used to be perforated plate below the soil mass, but again you are disturbing the entire soil. So, conceptually this is from where people started working on you know tension lysimeters. But then the state of the art has improved a lot and you did not do this type of studies. So, whatever soil sample is leaching can be collected in a porous plate which goes into the bottle and ultimately you can lift from the bottle with the help of a vacuum pump.

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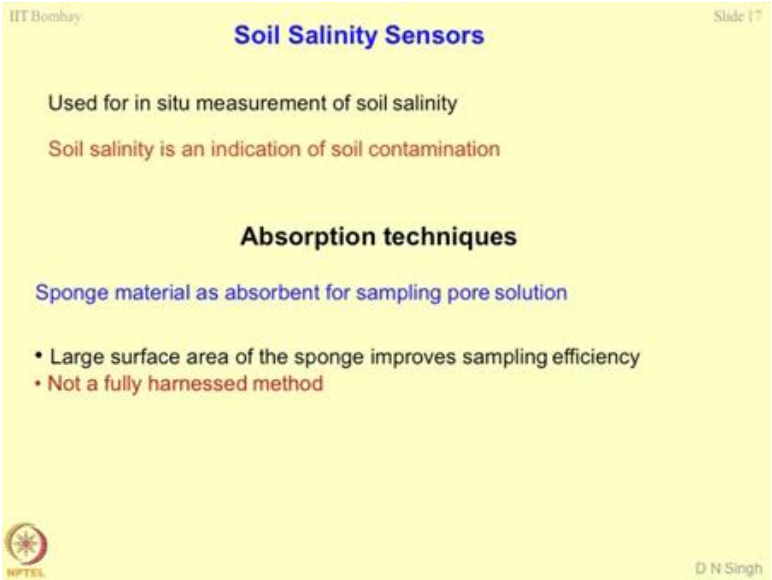

Soil salinity sensors these are used for in-situ measurement of soil salinity, but this is a very blind term. I hope you will appreciate salinity is a very blind term because you cannot be specific of the species of ions which are present you agree. Binal, you got this point? So, you can always say yes, there is something leaching out of the facility, but you cannot be sure what is this species of the contaminant which is leaching out. So, there you have to go for pore sampling and then check the species of the cations with the help of ICP-MS, ICP or atomic absorption.

Absorption techniques, some sort of a sponge material can be used as an absorbent or sampling the pore solution. It is a very primitive way and it requires large surface area of the sponge which will improve the efficiency, but then the biggest problem is not a fully harnessed method. It is not a very well-developed method. Of course, some people tried in the earlier days.

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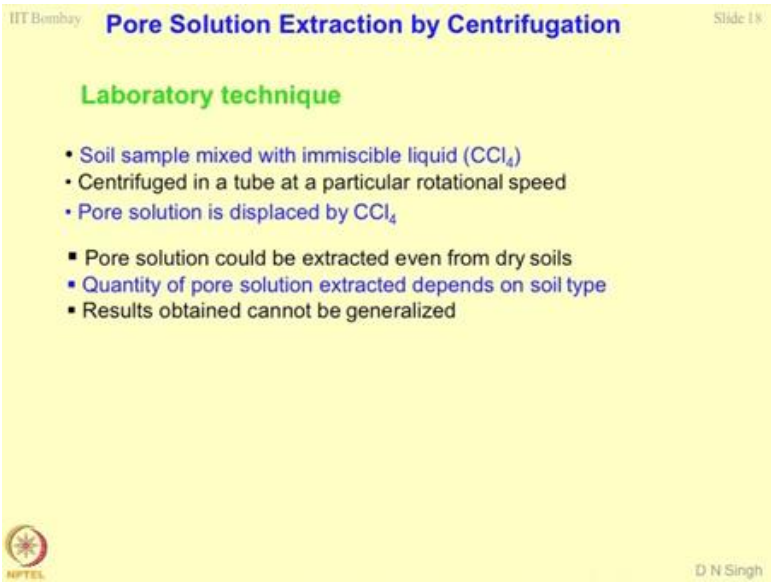

Now, let me move on to the pore solution extraction by centrifugation. This is a laboratory technique, centrifuge the sample. And with the help of the centrifugal force you can displace some amount of pore fluid. If that is not sufficient enough then what you should do? Soil is mixed with CCl_4. What is CCl_4?

Carbon tetrachloride (Refer Time: 19:23).

Carbon tetrachloride or chloroform and then you centrifuge it in a tube.

(Refer Time: 19:30).

Yeah sorry.

(Refer Time: 19:34).

Is this carbon tetrachloride. Somebody said chloroform I said yes.

CCl

CCl: so, carbon tetrachloride. So, when you mix it with the CCl_4 and then centrifuge it then what happens? CCl_4 will displace the pore plate. So, CCl_4 goes into the soil mass and the pore solution comes out, you can collect it and you can analyze and you can find out what is the concentration of the contaminants. This is the best technique for even doing with the dry soils because the pores get filled out with the carbon tetrachloride and whatever pore solution comes out this can be the concentration of the pores.

However, the biggest limitation of this technique is that the type of solution which is coming out will depend upon the soil type, alright. So, it is very difficult to centrifuge clays it is very difficult to remove pore solution from the clay by this method. However, if you have sandy silty type of soils it is very easy. And that is the reason that the results which you obtained from centrifuge cannot be generalize because there is an effect of the external forces which are acting.

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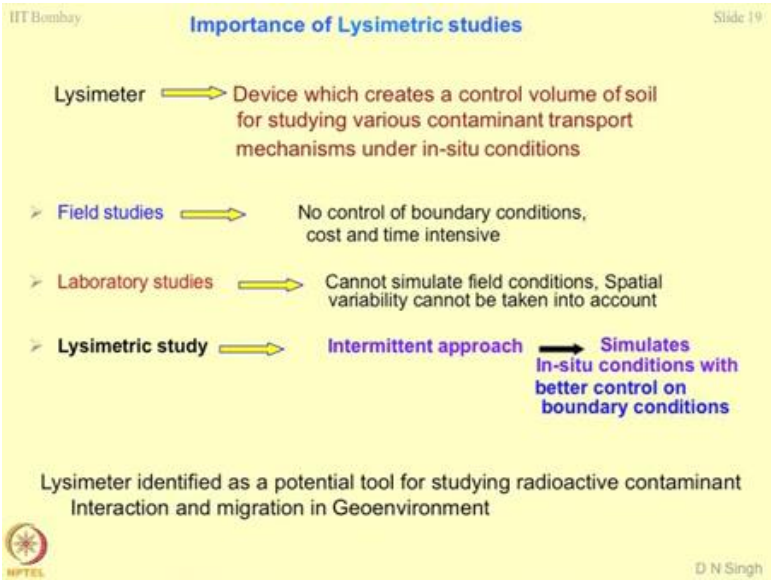

Now, this is where I will try to give you some more idea about the lysimetric studies. Till now I think we must be clear about what is meant by lysimeter; a device which creates a control volume of the soil for studying various contaminant transport mechanisms under in-situ conditions. Now, when you do field studies unfortunately you do not have any control on the boundary conditions and they are very expensive both in terms of financially as well as time wise.

If you match them with laboratory studies you notice that laboratory studies cannot simulate field conditions spatial variability cannot be taken into account, and this is where lysimetric studies become very important. So, this is the intermittent approach between the field test and the laboratory test. And, what I mean to say by intermittent approach is that this simulates the in-situ conditions with better control on boundary conditions. And, this technique has been identified as one of the best techniques to study the interaction and migration of contaminants in the geoenvironment.

I will show you the efforts which are made by micro in installing a lysimeter at one of the sites at waste disposal sites at BARC for the real radioactive waste.

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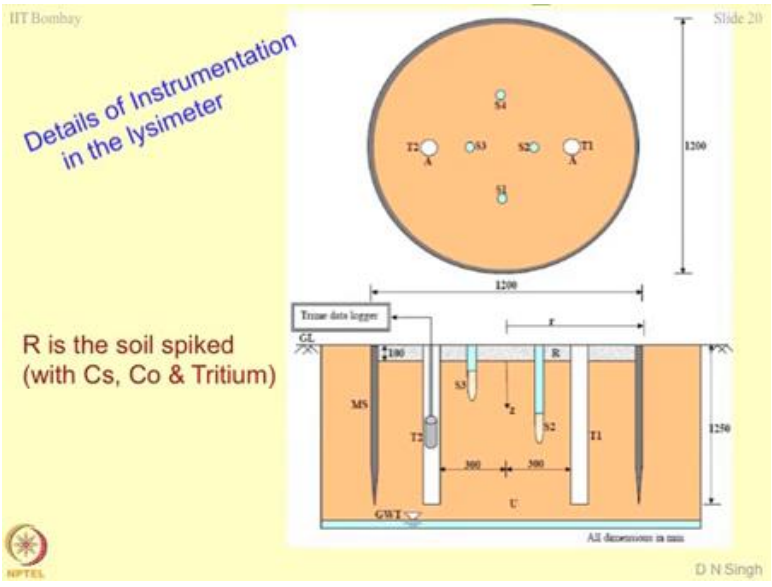

So, this is the facility which was installed you have a ring of a stainless steel 1.2 m in diameter which was embedded into the ground and then we embedded two tubes for measuring the moisture content volumetric moisture content with the help of TDR

probes: Time Domain Reflectometry probes. You can see S_1, S_2, S_3, S_4 as the suction samplers, which were embedded at different depths below the ground surface.

So, what we are speculating here is that we are trying to find out how contaminant migrates if a layer of dozed soil is placed on a natural soil. So, Binal this is how we are again simulating a lysimeter. The top layer happens to be a contaminant a spiked soil and when you reach at with the water either manually or because of the environmental conditions these contaminants have a tendency to migrate into the soil mass. So, we are trying to find out concentration as a function of g, depth and time. So, the moment a concentration front reaches over here the samples get collected in S_3, the moment it reaches over here the samples get collected in S_2, and similarly S_1 and S_4.

Now, these TDR basically give you the value of moisture variation along the depth over a prolonged duration. These experiments are done for 3 to 4 years regularly. And what we did is that this layer we spiked with cesium, cobalt and tritium these are the radioisotopes. And ground water table can also fluctuate within the control volume outside the control volume and so on.

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Now, this is how the whole setup looks like. That these are TDR probes 1, 2, 3 and 4 points are the suction samplers. And these are access tubes which can be used for measuring the moisture content of 1.2 m, 1.5 m soil column which is lying below this.

This top collar which you are seeing the soil was excavated and this was refilled with the spiked material, the spiked sand.

Now, when you are drilling these holes for installing the TDR tubes there will be a cavity formed between the native soil and the TDR probe. So, you have to fill it up with the help of a slurry of the soil, so that there is no preferential flow again taking place between the suction samplers and the TDR probes.

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Now, this is the close view of how suction samplers can be installed, and how can you take out a pore solution from the vial, alright. So, this is the vial which is connected to the suction sampler.

There is a caution because right now you do not find any contaminant over here, but once it has been spiked with radioactive contaminants it was a health hazard to go to near to this place and collect the sample, but then everybody has a limit of exposition for the radioactive you know. So, the moment that limit is over the second person has to go for collecting the samples, you cannot continue collecting samples like this.

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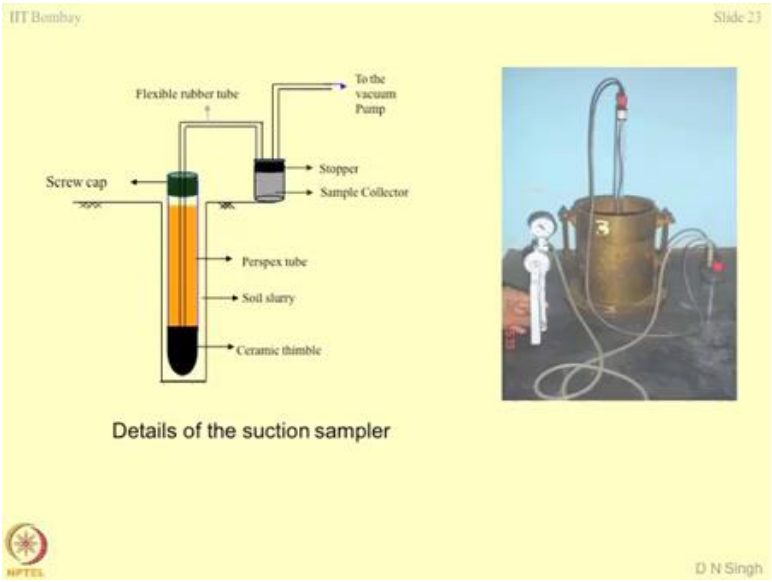

So, you will learn a lot when you are dealing with these types of problems. This is the typical suction sampler which goes inside the ground this is connected to a collection sampler then you can apply vacuum to collect it in the sampler training is done is this type of a CBR mould.

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Now, this is how the instrumentated, instrumented sites look like. You can see lot of wires coming out of the units. This is installation of the TDR probes and the suction samplers and this is how the dosing is been done. You can see the statutory notice over

here that this is not a place for everybody to come close to the vicinity, and then this is how the sampling is dosing is been done of the sand and at the radioactive material. And then this is a strontium which is crimson in color is being spread on the entire soil mass. So, we have to take some safety measures for doing this.

These studies were done by my PhD scholar Dr. Ravi Ranjan Rakesh who is a BARC stalwart right now.

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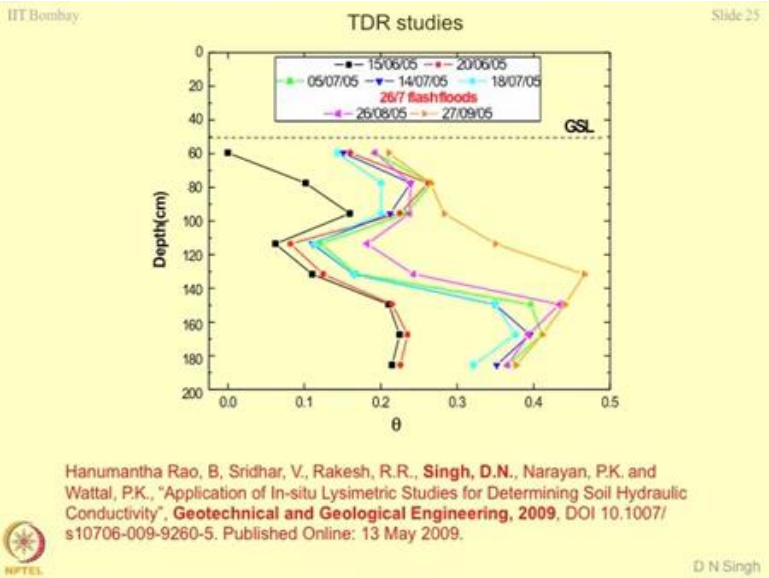

Just to show you what type of TDR results you will get if you do the analysis over depth versus volumetric moisture content and you can notice from here that every month, he use to take the samples. And this was the famous deluge of Bombay you know 26th July which according between and we loss the instrumentation. We could not continue this experiment we have to replace them.

So, incidentally what it gives necessarily is the function of volumetric moisture content up to 2 meter depth. So, this is where we can simulate you know saturated unsaturated flow conditions. And those of who are interested you can check it out this work is published in Geotechnical and Geological Engineering, 2009, very recent publication.

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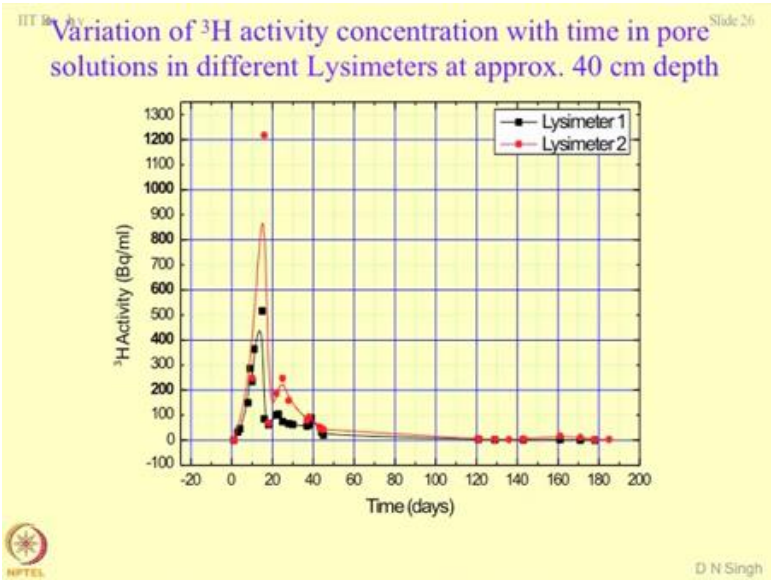

Now, this is the peculiar graph which you can notice. I think you are there you were talking about how activities can be or the concentration can be you know monitored. If you look on the y axis this is the tritium activity in becquerel per millimeter and on the x axis you have time. So, as time increases you will notice there is a spike and after with this spike fades away.

So, this is the maximum activity place where the sample was taken. It is something like the front of contaminant is moving and the moment it crosses over a certain depth of lysimeter there is no sample available to enter into the lysimetric tube and hence you can get only one spike, alright.

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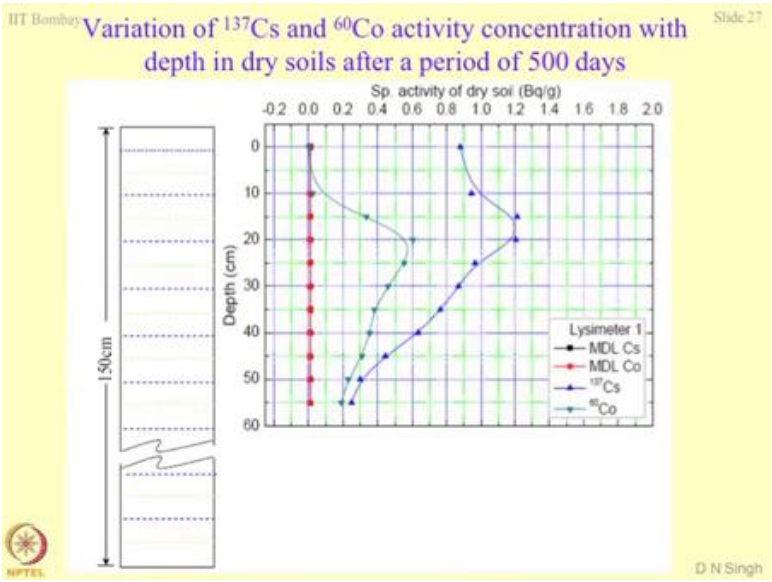

Now, hope you will appreciate this point that over 500 days how these activities changing with respect to depth. So, what we established here is that Cesium and cobalt sorry, their absorption capacities are very high. So, they get absorb within the top layer of the soil. They will not reach even after 500 days beyond 20 centimeter. So, is this something good or bad? Is good. Yes, that mean even if you dispose or something on the ground even after almost more than a year you will not find any trace of this activity in the bottom surface.

So, you need not to be worried about most of the activities which are being taken up by nuclear scientist. So, this was a very good study which tells you how to plan the activities and you need not to spend more money in designing barrier system and containment system and so on. The nature takes care of itself you know; it is a good example.

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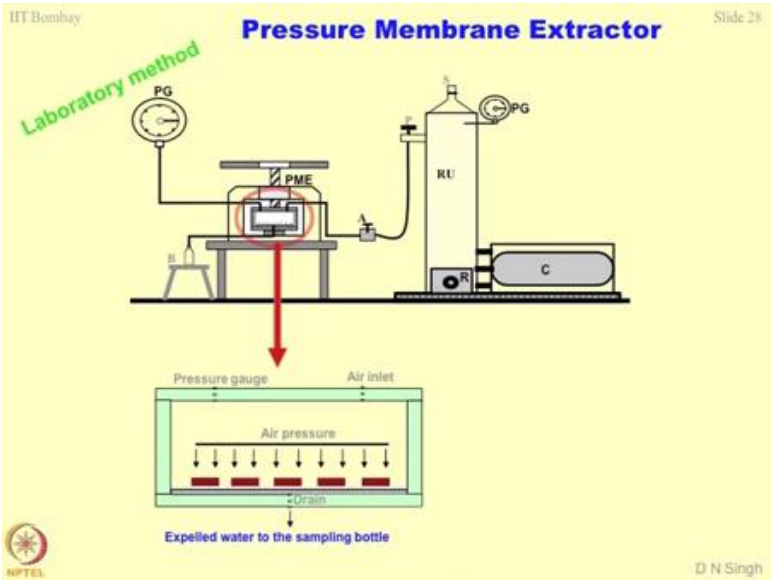

Yes, let us talk about pressure membrane extractor which is a laboratory method. This unit you must have seen in the laboratory where we have a pressure membrane extractor chamber which is connected to a compressor unit, air compressor unit and retainer unit. What happens essentially is that this retainer and compressor unit pushes in compressed air into the chamber, and details of the chamber you can see that looks like this type of arrangement where you have pressure gauge connected to read what is a pressure inside and what is the air inlet keep several discs on a typical membrane which is known as cellulose instead membrane.

This experiment will be shown when you come to our lab for during experimental geotechnics and then because of this application if these containers are having slurries water will come out and then you can check what is a concentration of the contaminants in the draining of water. So, this is connected to the sampling bottle at the bottom of the pressure membrane extractor unit.

Now, these type of studies we have utilize for two purpose, we have differentiated first of all whether a soil contaminated or not, simply by doing the pores analysis pore solution analysis with the help of AAS or ICP. And then second is you can find out the matrix suction of the soil also, because in literal terms what you are doing; you are doing a sort of a triaxial cell in which the cell is buildup with air and then you are trying to

squeeze the water out of the soil sample, alright. So, the amount of pressure which you are reading in the pressure gauge happens to be the suction pressure.

So, this way and if you can measure the moisture content repeatedly alright so, you can get the soil water characteristic. Now, this work is further being continued by Seema. So, whenever you get time you can attend her seminars and you can see what she is doing.