Environmental Geomechanics
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Lecture No. 43
Sorption-desorption characteristics-II

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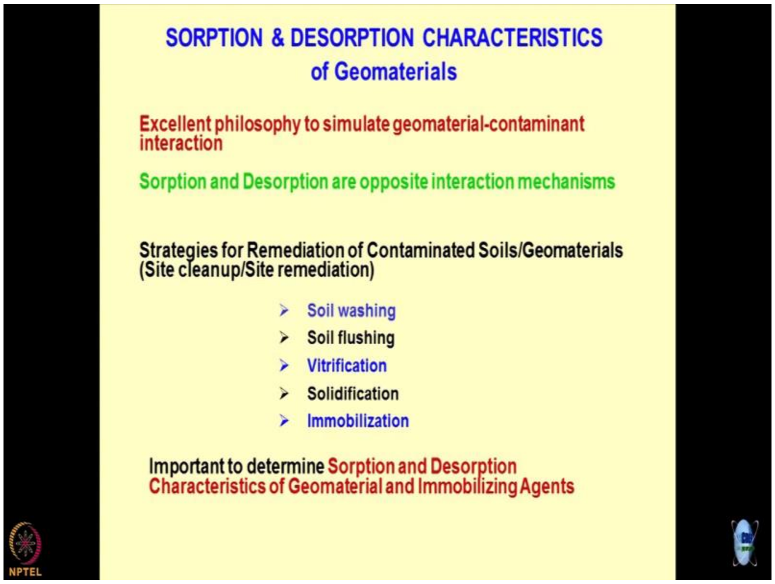

SORPTION & DESORPTION CHARACTERISTICS
of Geomaterials

Excellent philosophy to simulate geomaterial-contaminant interaction

Sorption and Desorption are opposite interaction mechanisms

Strategies for Remediation of Contaminated Soils/Geomaterials (Site cleanup/Site remediation)

- Soil washing
- Soil flushing
- Vitrification
- Solidification
- Immobilization

Important to determine Sorption and Desorption Characteristics of Geomaterial and Immobilizing Agents

What are the basic characteristics of the geomaterials which are required to define sorption and desorption characteristics?. It is an excellent philosophy to simulate geomaterial contaminant interaction as I said, though, they are in opposite mechanisms. These are strategies which are normally used for remediation of contaminated soils and the geomaterials. This comes under the category of site cleanup and site remediation program. And there are several types of strategies for remediation of contaminated soils.

The first one is soil washing. You inject fresh water into the soils which are contaminated, and then we presume that desorption process will occur the contaminants will get released from the substrate they will flush out in the pore fluid, and this pore fluid can be sucked out later on. Is this okay?. This is what you have been asking. So, the more and more water you add to the system, you are diluting things. At the same time, you are creating a situation where desorption initiates. Unfortunately, in today's world, we do not have so much water.

The second question is the amount of sludge which you are going to create that becomes a secondary source of contamination. And then you have to do some special things to take care of this sludge which you have created. And then the question is volume, the question is the intensity of the concentration, and the question is where to store it. How to neutralize it, where to dispose it. Soil flushing, I think similar thing what we were talking about the washing could be flushing. Also, fluids would be different.

Vitrification I think we had talked about sometime back at very high temperature, you take the soils which are contaminated vitrify them. So, you must be coming across this word in the building industry vitrified tiles is it not? What are these vitrified tiles you have taken clay particles, you have heated them at very high temperatures? So, that there is an amalgamation gets formed particles which were discrete have now become more uniform amalgamated vitrified cool it. It gains strength. This is the vitrification process.

So, I can take the contaminated soils; I can use some plasma torches to create very high temperatures. I can vitrify the entire thing as if they melt and they solidify. Lava is a form of a vitrified material which is coming out of the volcanos. That is a vitrification process, and when you cool the system the chances are the surface might have vesicles because of the trapped airs, the trapped gases which are coming out of the volcanic eruption might come out slowly.

And those Vitrification things might have vesicles formation also, but when you do it under controlled circumstances, the vesicular formation would not be. This is the process which is being used by the people or the industries which are producing extremely toxic waste, including nuclear waste. So, one of the ways to get rid of the toxic nuclear waste is vitrified the contaminated soils but very expensive. A lot of research has been done and should be done in the Indian context.

So that these techniques can be adopted, the question is a large amount of soils, the volumes are going to be so huge that how vitrification would be done and how the costs would economized, time, efforts, this is a big question. And then solidification, I might take contaminated soils, I might add a solidifier into it. Sometimes we also call these agents as stabilizers. Immobilizers. Cement is a stabilizer cum immobilizer cum solidifier.

So, if I take contaminated soils and if I mix cement into it, what I have done, I have trapped all the cations, unwanted species which were present in the system, because of the cementation effect. So, all these cations get held chemically in the matrix of the cement. Now, they cannot come out in the environment; you got this point so, a solidification is a good form of immobilizing the waste. Now, this solidification could be achieved by several activities.

So, one example I have given you is adding cementitious materials; another way would be lower down the temperatures and freeze the entire thing. So, if I change the state of the material to a frozen state, what ice does, ice will also interlock all these contaminants in such a manner in its matrix that they cannot come out unless the system melts. Are you getting the point? These are the concepts which you can use for decontamination of or the remediation of the contaminated lands.

Immobilization, I think I have already given you an idea about the mobilization you are immobilizing the movement of the cations in a porous media, it could be a chemical process, it could be a Physico-chemical process, it could be a physical process like lowering down the temperature. What about the pressures, if I enhance it, and if I enhance the pressure, the interlocking is going to be better? So, I can use different techniques to immobilize the waste which is migrating into the porous media. Is this fine. Now under all the circumstances, you have to study the activity of the contaminants and the porous media or the geomaterial and this is where you have to characterize the geomaterials to study their sorption desorption capacities, is this okay. Any question. I have given you a lot of ideas and a lot of thoughts. Sir, in case of the vitrification process, we get all the contaminants on the surface only after completing this. No, this could be in situ.

So, suppose if I know the place where the soil is contaminated, what I have to do is to just maybe insert the plasma torches and the whole system can be vitrified in situ itself. We get all the contaminants on the surface of that particular. Not surface within the matrix also because the whole idea is to do a sort of melting of the sand particles or the clay particles. If contaminants are inside the matrix, so, they get trapped there because of the elevated temperature.

So, plasma torches normally work at the temperature of 1400 to 2000 degrees centigrade. That is what. So, what you have done under in-situ condition itself you have frozen the entire thing this I could have done by injecting cement or some binding material and then waiting for some time to matrix getting formed are you getting this point, after that, that place is immobilized like a concrete floor, is it. Exactly so, when the extent of contamination is too much, the best way would be vitrification, but very expensive. Second would be immobilization or solidification.

Make things immobilize, but you will be surprised to know that not much as much research is being done here. Now, this is a subject which interfaces with metallurgical engineering and material sciences. Why? So, sometimes when you get a chance to go through the nuclear power stations or research station or watch it on you on YouTube. What they do is the glass normally glasses used to vitrified and so, they encapsulate the atomic waste in glass why amorphous glass system impervious, nothing can come out of it, Do you remember the salt domes, which we have talked about.

So, salt domes are these creations of nature best places to dump your atomic waste; nothing will come out it. Sir, in this mobilization we are mobilizing that contaminant, right. We are not actually removing no we are not removing. So, why the reason is concentrations are too high. See, remember even if I take out something from some phase. The next question is what I am going to do with this when I am going to keep it.

So, it is something like cancer cells have been removed from the body. But now the question is what to do with it. So, what hospitals do they incinerate it immediately? They cannot store it. Are you getting my point? So, the more and more you take out the toxicity from a system, you have to handle it, you have to store it, you have to manage it. And still, the question is, what should I do with this? This is what the industry is asking you. I hope now you are getting at the crucks of the problem.

And another question is should we stop the industrial activities. Should we become slaves economically to other nations because each and everything has to be imported then and then also there is a problem because everything will come in rappers and the covers and then ultimately, what you will be doing all these wrappers, covers and the packaging waste would be going in the landfills? So, the cycle is vicious.

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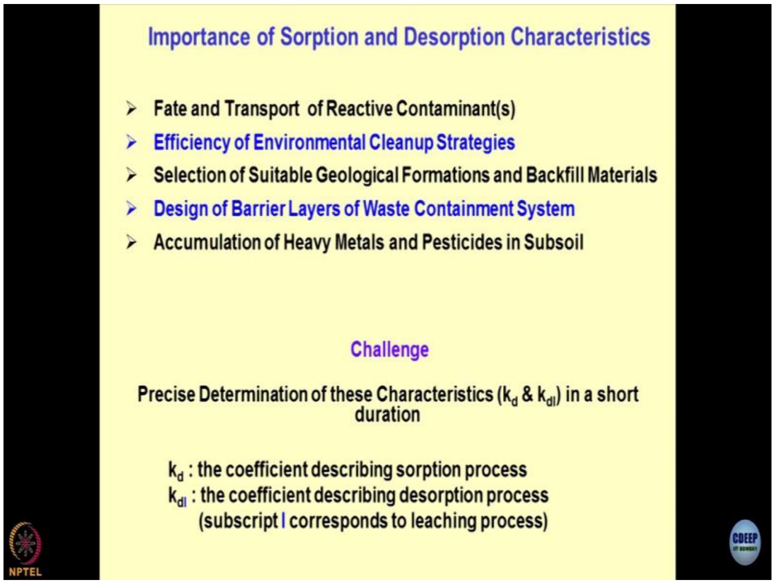

Importance of Sorption and Desorption Characteristics

- Fate and Transport of Reactive Contaminant(s)
- Efficiency of Environmental Cleanup Strategies
- Selection of Suitable Geological Formations and Backfill Materials
- Design of Barrier Layers of Waste Containment System
- Accumulation of Heavy Metals and Pesticides in Subsoil

Challenge

Precise Determination of these Characteristics (k_d & k_{dl}) in a short duration

k_d : the coefficient describing sorption process
k_{dl} : the coefficient describing desorption process
(subscript l corresponds to leaching process)

So, importance in sorption and desorption characteristics in several fields of environmental geomechanics, these concepts are being used. Number one fate and transport contaminants, why contaminant should migrate from one point to another point, I hope now, you can get the issue easily. If sorption capacity is extremely high of the substrates, they will not let cationic species to move from one point to another point.

This could be good at the same time this could be bad also. So, when you are inserting permeable reactive barriers in the ground, you are creating a very activated system which is bound to attract most of the cations and give you freshwater downstream. But in due course of the time, the filter itself is getting contaminated and becomes a big source of contamination. Now, what you are going to do. Take them out, wash them and again insert them or design a system which is going to last for 50 years.

This is the scope of environmental geomechanics. I hope you realize that these are the questions which have been ignored completely not many people have tried to answer these questions. So, these technologies have to be developed in the house we should not be dependent on others. Because these are basic and simple concepts, anybody can design systems efficiency of environmental cleanup strategies. I think now you can understand why sorption desorption mechanisms are important.

If I have to show that after encapsulation nothing moves out from the matrix in the form of cationic suspension or cationic solutions, my immobilization is the best one. So, I have immobilized the waste to an extent where even after it comes in contact with water, nothing leaches out. This is a simple cleanup strategy which you have created. Imagine this is the beauty of these sentences that their implications are so tremendous.

So, you have a landfill and surround the entire landfill with some curtains, which are not cutting of the seepage only, but they are reactive also. So, curtains which were done by grouting were only stopping the seepage. Now, what you are done in the form of reactive barriers, you are treating the contaminant and stopping their movement outside the in the geoenvironment. So, selection of suitable geological formation and backfill materials which can be utilized for going ahead with your disposal programs. So, the government of India requires this type of studies to be done.

In a very vigorous form, because they have to select the sites where the waste should be dumped. Similarly, the backfill material does you remember we were talking about the backfill materials required for stopping the contact between the containers of the waste canisters we have talked about and the environment. So, what type of backfill material should be utilized so that they are the best sorbents. They will not let even any radioactivity to leach out in the environment either in the gaseous form or in the liquid form.

That is the isolation of the waste design or barriers I think we have discussed enough of the waste containment system, accumulation of heavy metals and pesticides in subsoils. So, soils which are heavily contaminated because of fertilization, because of insecticides, which are being used in agricultural practices, they have to be decontaminated. I think I gave you one good example at the beginning of the course in most of the parts of Punjab, Haryana; the soils are heavily contaminated.

So how would you decontaminate them create a strategy? So, you will be the number one consultant in this subject, the soils have become contaminated because of various agricultural activity over-fertilization, and all those chemicals are still remaining in that root zone. So, fertility is lost. And what you have done is you have made them as a secondary, tertiary source of contaminants. So, every time and water interaction takes place in the form of rainfall or flooding.

There is a problem with the groundwater. So, what are the challenges? It is easy to list all these things. The challenges are that precise determination of k_d is itself is a big question mark. We are using this parameter to define the interaction between contaminant and geomaterials. But now what I am saying is that the determination of k_d is tough. The way I have written here k_{dl}, k_{dl} corresponds to k_d parameter associated with the leaching process, desorption process.

So k_d is a sorption process, and k_{dl} is the leaching or the desorption process. Very soon, you will realize that it is quite difficult to measure k_d and k_{dl} precisely. But we should still try, as an engineer, I want some numbers, is it not? Without numbers, I cannot design my systems. I cannot dispose of the waste, particularly toxic waste like nuclear waste. Okay. So, a little bit about the k_d parameter though I gave you the background of what k_d parameter is. It is basically a sort of a distribution taking place in case of geomaterial this could be clay particles.

So, as if the clay particle lying over there and the flow of contaminant was taking place in the fluid phase. And then suddenly something which is of high surface area, high cation exchange capacity, high chemical activity comes and the moment these guys realize what is going to happen all of them will get distributed from the stream, and they will get parked over there. This is the k_d process conceptually. Hope you have understood now.

Now, what you have to do is you have just found out how many fractions of the contaminants have left the mainstream flow and that can be related to the activity of the substrate. So, whatever percentage fraction of the contaminants is getting parked on the substrate divided by whatever is in the fluid phase would be a ratio which is nothing but k_d. So, now let us see how to define this in a copybook manner. So, this also known as a partitioning or distribution coefficient, this is a measure of sorption of contaminants to soils, rocks and admixtures.

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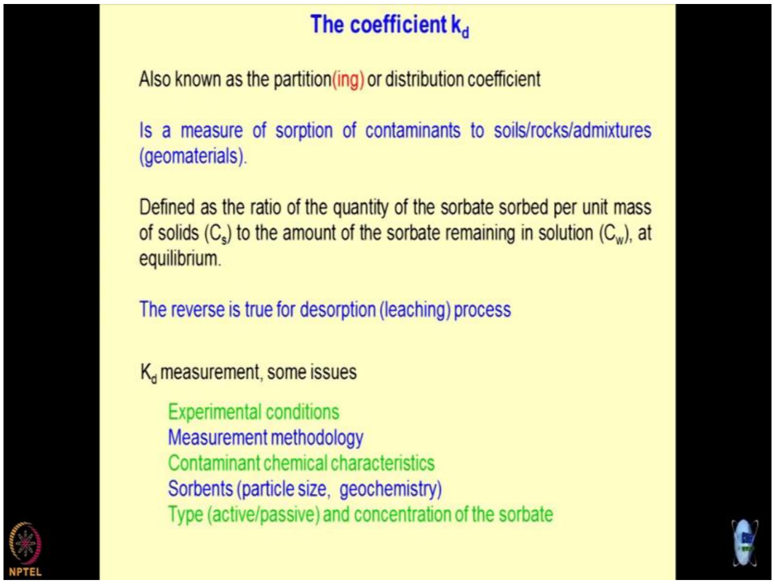

The coefficient k_d

Also known as the partition(ing) or distribution coefficient

Is a measure of sorption of contaminants to soils/rocks/admixtures (geomaterials).

Defined as the ratio of the quantity of the sorbate sorbed per unit mass of solids (C_s) to the amount of the sorbate remaining in solution (C_w), at equilibrium.

The reverse is true for desorption (leaching) process

K_d measurement, some issues

- Experimental conditions
- Measurement methodology
- Contaminant chemical characteristics
- Sorbents (particle size, geochemistry)
- Type (active/passive) and concentration of the sorbate

geomaterials, would you consider bacteria the geomaterial or not. This is a big question, bacteria in the soil matrix is a geomaterial why it provides a surface, and I have shown that what Sashank has done is he has started working on biosorption. So, the sorption which is having because of which is getting induced because of the bioactivities and what are the bioactivities. MICP microbially induced calcite precipitation.

So, inside the soil, you have created a system which is still very active because of the presence of calcium, and you have created a phase at which the interaction with contaminants might occur. So remember my example, multhani mitti, the one which you use for your facials, bentonite, activated clays pour it in suspension, add some sandalwood powder, turmeric powder, all these materials are good substrates, what they are going to adsorb bacteria, sweat, salts from your skin.

So, the moment you have a substrate which is charged active, chemically, mythologically, the species which is getting passed over this is going to create partition phenomena.

You can find out the k_d parameter of your skin and sweat because nowadays everybody is talking about artificial skins. Is this correct or not? So how would you grow skins. If your skin is not contributing to the filtering of the sweats, point to remember? So, suppose if I define the concentration of the contaminants in the solid phase, parked on the solid phase to the liquid phase we normally define this as the ratio of the quantity of the sorbate, sorbed per unit mass of the solids to the amount of the sorbate remaining in the solution and this is what we define this as C_S/C_W.

So, the reverse process is true for the desorption and what are the issues related I will come back to this definition of k_d slightly later. The issues are the experimental conditions have to be controlled temperature and pressure particularly. Because k_d is very susceptible to the pressure-temperature conditions, I think we have discussed this why temperature, because the rheology of the fluid is going to change because of temperature and pressure, is going to affect the bonding between the contaminants and the surface on which the system is going to work.

Measurement methodology itself is a significant factor which contributes to the whole thing. Because there are several techniques of the finding of the k_d parameter, we will discuss some of them and human errors. The type of contaminants that you are using, whether they are active whether they are passive, the concentration itself and so on. The type of sorbent which you are using that is the particle size, or it is geometry because particle size and the geometry and the geochemistry are going to contribute to the mineralogy.

And it's surface area and indirectly cation exchange capacity. So, to me, it appears that k_d parameters are the best way to characterize the clays. Why incorporates into it, the effect of the environment also. Your liquid limit and sensitivity parameters which you have used to characterize clays are not complete because they are not defining or imbibing in them, how the clay particles are going to react with the atmosphere, environment. I think we have discussed this thing type of substrate and type of contaminants and their concentration and all those things.