Environmental Geotechnics
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Lecture – 36
Contaminant transport through porous media -5

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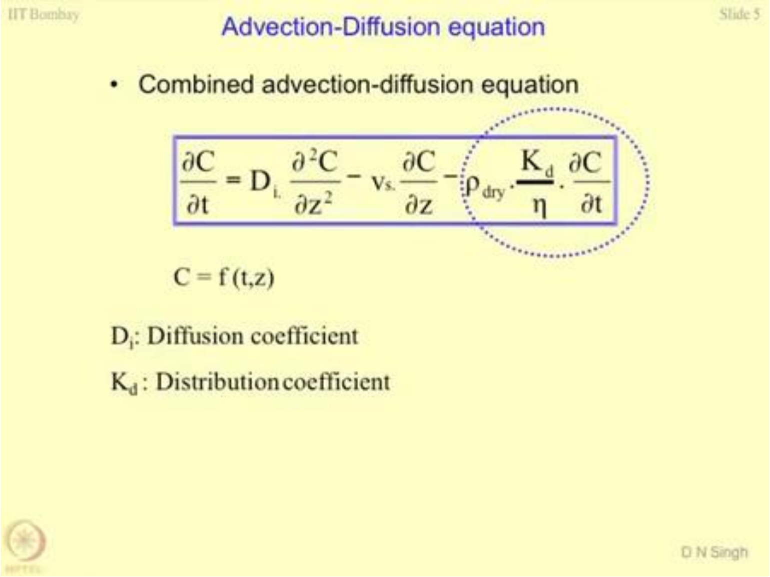

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Slide 5

Advection-Diffusion equation

- Combined advection-diffusion equation

$$\boxed{\frac{\partial C}{\partial t} = D_{i}\frac{\partial^2 C}{\partial z^2} - v_{s}\frac{\partial C}{\partial z} - \rho_{dry}\cdot\frac{K_d}{\eta}\cdot\frac{\partial C}{\partial t}}$$

$C = f(t,z)$

D_i: Diffusion coefficient

K_d: Distribution coefficient

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Now, once you have done all these mechanisms, how you are going to use them? So, what I have shown you was the simplest possible models which were being used, but nature is not so simple, our profession is not so simple and that is where we have to take help from few models which define advective-diffusive contaminant transport in tandem; in tandem means together coupled phenomena.

So, this is the form of the equation. If you do lot of mathematical jugglery, you will end up getting this equation. Can you recognize few terms appearing here? $\Delta C/\Delta t$ is nothing but concentration gradient with respect to time. D_i is diffusion coefficient; $\Delta^2 C/\Delta z^2$ is variation of concentration with respect to distance. What is V_s? Seepage velocity; $\Delta C/\Delta z$ is nothing but again concentration gradient in the distance domain. P_{dry} is the density of the media. What is K_d? K_d is the distribution coefficient divided by porosity of the porous media multiplied by $\Delta C/\Delta t$.

I have not intentionally shown the derivation of this equation which will take lot of time, but I just wanted to show you how these types of equations can be used for simple modeling purpose. So, if I ask you question in broad sense what this parameter corresponds to $D_{i.}$ $\Delta^2C/\Delta z^2$, Srinivas, what would be this term?

Student: (Refer Time: 02:14)

This is diffusive contaminant transport. What about this term, $\Delta C/\Delta z$. V_s advective, contaminant transport. What about this thing which I have encircled? This is the retardation of the porous media. See the flux is moving from one point to another point. What you are trying to find out is the rate of change of concentration. So, rate of see how concentration is moving from one point to another point, it is nothing but primarily because of diffusion. If there is a seepage velocity, the concentration gets reduced. So, you have reduced this much value from this term. So, diffusive contaminant transport minus advective contaminant transport minus retardation capacity of the porous system.

So, when you say retardation capacity of the porous system, these two terms are very well known to you is nothing but the porous media characteristic which we have been talking about. Now, the term which is appearing for the first time or which is quite new for you is K_d. Now, this is what is known as distribution coefficient. What is the meaning of term distribution? See this is what I have shown you earlier that if you allow enough time for a contaminant to come in contact with the porous system because of very low seepage velocities, what is going to happen? It starts communicating with the porous media.

Now, how much communication is going on is nothing but distribution; that means, what percentage of contaminant gets or is getting interacted with the porous media, so that means, this is where we say what is the fraction of the contaminant which is getting distributed from a liquid phase to the solid phase of the soil mass. See you should appreciate that these are all philosophies, and philosophies have been put in mathematical forms, clear.

So, now let me ask you a question. If K_d is much more, what happens to the concentration at a given point, and whether it whether this type of situation is useful helpful to you or not?

Student: (Refer Time: 04:50)

That is right what is the meaning of this if you have a clay barrier, where the clay minerals are very active, what is that they are doing?

Student: Their particles

That is right.

Student: (Refer Time: 05:01)

Correct. So, this is the whole philosophy of designing a clay barrier system. You have to design clay barriers using a sieve, I am using the word sieve which not only allows water to move out, but it stops cations also from the solute or contaminant. So, the name of this type of sieve is molecular sieve that means your porous media is acting now like a molecular sieve. It will not allow certain molecules to even pass through itself, and that becomes the best possible barrier system which should be utilized at a waste containment facility. Is this part clear? Clear?

Now, $\Delta C/\Delta t$ you can obtain very easily. You can measure the concentration by conducting either the boreholes or in the laboratory you can measure repeatedly after certain time by taking a sample or dozing. And then you can measure by using atomic absorption AAS or ICP or whatever. So, this term is very well known $\Delta C/\Delta t$. D_i you can obtain by conducting different experiments, I had shown you one experiment in the previous lecture by using diffusion cells. $\Delta^2C/\Delta z^2$ can also be obtained, rate of change of concentration with respect to time. You can monitor at two three different places how concentration is changing, and you can know the concentration profile change; V_s is easily measurable.

The most challenging task is K_d. And this is a big headache. Government of India spends almost not less than 100 crores rupees in the research where K_d determination should be done very precisely. Most of the mines where uranium is been taken out. If your K_d parameter is not determine properly, the life becomes hell, clear. So, one side too much of industrialization, too much of mining activity ok, very good for your nation to become a high-profile nation, but then second side what is going to happen your own populace is going to die because of all this contamination. So, this becomes a very tricky issue, but this is a very big exercise going on right now, where K_d determination has to be done in different labs about 22 labs have been selected in the country, our lab is one of them.

And we are now trying to formulate a methodology to streamline the methodologies and methods which are adopted for determination of K_d ok. So, the first step in modelling would be after you have got these parameters, you should get an answer from this equation in the form $C = f(t, z)$. So, what is the concentration at a given time at a given distance? That is what you are interested in as a user. So, D_i is the diffusion coefficient, and K_d is the distribution coefficient.

Now, with this information, I would be in a position to take you into the world of sorption, desorption mechanisms. I hope you will appreciate this, unless this was given to you, there is no point talking about sorption and desorption process. Most of the mathematical models are available these days in the form of finite element codes and finite difference codes and there are several commercially available packages which are available which can give you a solution to ADE, this also known as ADE - advection diffusion equation.

Now, let me ask you a question whether this is one-dimensional equation or a two-dimensional equation or three-dimensional equation?

Student: One-dimensional (Refer Time: 08:52)

It is a one-dimensional equation. So, you should appreciate the point at one-dimensional equation you will have his own limitations when you solve the real-life problems. So, that is where you have to talk about. $\Delta C/\Delta t$ as a function of. $\Delta C/\Delta z$, $\Delta C/\Delta x$, $\Delta C/\Delta y$. So, keeping the time domain constant how the distance domain is varying in terms of concentration becomes a real challenge, all right.

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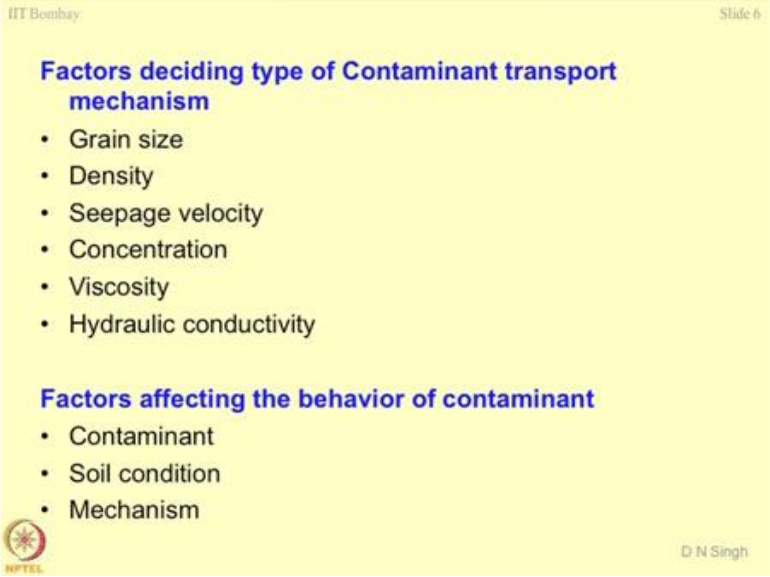

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Slide 6

Factors deciding type of Contaminant transport mechanism

- Grain size
- Density
- Seepage velocity
- Concentration
- Viscosity
- Hydraulic conductivity

Factors affecting the behavior of contaminant

- Contaminant
- Soil condition
- Mechanism

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So, I hope this part is clear that there is a new term defined as k_d and we have to obtain k_d by somehow. So, this we will talk about a bit later. Let us understand what are the parameters or the factors which decide the type of contaminant transport mechanism. So, the first is grain size. I have given you some very raw examples like sand and clay, and what is the difference between the mechanism of contaminant transport in sands and clay advection diffusion, all right. So, grain size is very important, density is very important, seepage velocity is extremely important, concentration of contaminant is very important, viscosity of the fluid or the solute is very important, hydraulic conductivity of the media is very important, then comes factors affecting the behavior of contaminant.

So, these are two different things. These parameters influence the mechanism. You agree? The mechanisms are four – advection, diffusion, dispersion and hydrodynamic dispersion. So, these are the parameters which are going to define what types of mechanism going to prevail in a system. Now, the factors affecting the behaviour of contaminant or the fate of contaminant. So, the first one is contaminant itself whether it is reactive or nonreactive, clear or radioactive, or decaying type. There could be a contaminant which does not come out of the porous system it gets decayed completely within it, all right. So, there could be a situation.

The second term would be soil condition, what type of soil conditions you are talking about; and of course, the mechanism which is going to govern. So, the whole idea of showing you these points is what is the, I think this is what I wanted demonstrate to you, ultimately it boils down to the mechanism which is governing the contaminant transport. So, it is not a very easy and simple way of modelling thought it appears to be, because this term itself will take care of all these parameters plus many more parameters into account.

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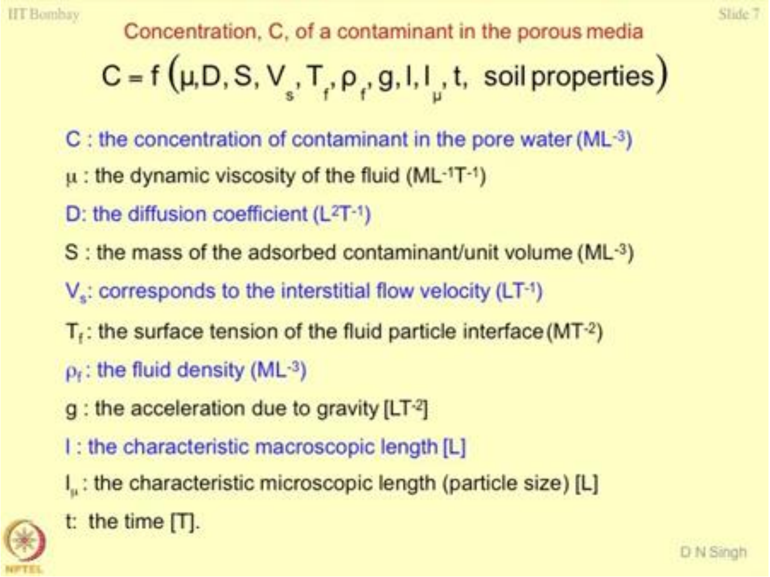

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Slide 7

Concentration, C, of a contaminant in the porous media

$$C = f\left(\mu, D, S, V_s, T_f, \rho_f, g, l, l_\mu, t, \text{ soil properties}\right)$$

C : the concentration of contaminant in the pore water (ML^{-3})

μ : the dynamic viscosity of the fluid $(ML^{-1}T^{-1})$

D: the diffusion coefficient (L^2T^{-1})

S : the mass of the adsorbed contaminant/unit volume (ML^{-3})

V_s: corresponds to the interstitial flow velocity (LT^{-1})

T_f: the surface tension of the fluid particle interface (MT^{-2})

ρ_f: the fluid density (ML^{-3})

g : the acceleration due to gravity $[LT^{-2}]$

l : the characteristic macroscopic length [L]

l_μ : the characteristic microscopic length (particle size) [L]

t: the time [T].

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Let me quickly run through if you want to do modelling, what are the parameters which would be required. So, concentration C of a contaminant in the porous media can be defined by these factors. So, C is a function of viscosity, diffusion coefficient, sorption coefficient, seepage velocity, surface tension, density of the fluid, g value gravity. Two type of dimensions I have used here. You are doing a course on centrifuge modelling. So, I am sure that you must you would have been using this type of equation which are nothing, but pi Buckingham theorems so multiplied by the time and the soil properties. Soil properties happen to be lumped parameter. It is very difficult to distinguish between one property; another property just like that.

So, concentration of contaminant in the pore solution or the pore water is defined by these parameters, where we use the dynamic viscosity of the fluid. D is the diffusion coefficient. S is the mass adsorbed of the contaminant per unit volume. V_s corresponds to the interstitial flow velocity is nothing but seepage velocity. T_f is a surface tension of the fluid particle interface. ρ_f is the density of the fluid; g is acceleration due to gravity; l is the characteristic macroscopic length. What is microscopic length?

Student: If we assume a (Refer Time: 13:10)

Physical dimension.

Student: (Refer Time: 13:11)

So, my question to you is if I am using or let me not ask you let me show you how it will vary, you should try to catch the point that what is the difference between macroscopic dimensions and microscopic dimension. So, l_μ is the characteristic microscopic length which is nothing but the particle size. And of course, your t is nothing but the time. So, all these parameters are required to form a π, Buckingham theorem. How many parameters you have? 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11. So, out of 11, how many equations can be formed? 10, clear. The most vulnerable set of the equation would be with 9 unknowns.

If I make two parameters dependent on each other, so that means, any contaminant transport problem will have at least 9 parameters which either you have to know beforehand or you have to determine or you have to compute it by some mechanism. So, this is just to show you the complexity of the problem when you talk about contaminant transport in porous media.

Now, your colleagues from hydraulics cannot deal with such a complicated situation, because what they deal with is all these things will disappear there, soil properties, microscopic length, macroscopic lengths will not come into the picture. Your seepage velocity is nothing but discharge velocity. Diffusion coefficient also becomes a free molecular diffusion in water. So, it is very easy to obtain it clear. So, there it is a subset of the problem which we are talking about. So, contaminant transport in porous media happens to be a very, very broad problem though contaminant transport in free water supply happens to be a subset of it clear. So, just to give an idea about how modelling is to be done.

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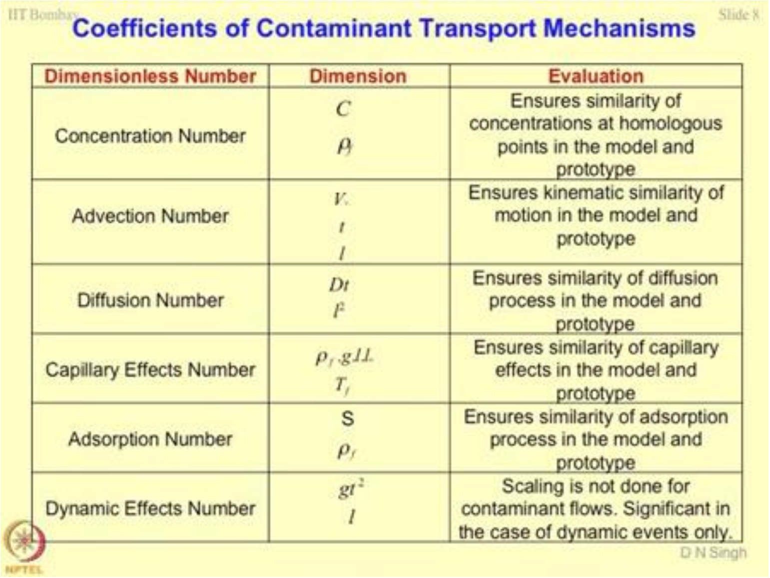

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Coefficients of Contaminant Transport Mechanisms

Dimensionless Number	Dimension	Evaluation
Concentration Number	$\frac{C}{\rho_f}$	Ensures similarity of concentrations at homologous points in the model and prototype
Advection Number	$\frac{V_s \cdot t}{l}$	Ensures kinematic similarity of motion in the model and prototype
Diffusion Number	$\frac{Dt}{l^2}$	Ensures similarity of diffusion process in the model and prototype
Capillary Effects Number	$\frac{\rho_f \cdot g \cdot l \cdot L}{T_f}$	Ensures similarity of capillary effects in the model and prototype
Adsorption Number	$\frac{S}{\rho_f}$	Ensures similarity of adsorption process in the model and prototype
Dynamic Effects Number	$\frac{gt^2}{l}$	Scaling is not done for contaminant flows. Significant in the case of dynamic events only.

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Now, when you do modelling you must have learnt a lot in your centrifuge modelling course that you require some dimensionless numbers. So, these are the coefficients of contaminant transport mechanisms which you have to generate out of those 9 parameters with govern the contaminant transport. So, the first parameter is known as concentration number. So, concentration number is nothing but concentration divided by density of the fluid. And this ensures similarity of concentration of you know homologous points in the sample and the prototype.

Advection number: advection number is nothing but seepage velocity multiplied by time divided by macroscopic or microscopic, macroscopic that is right the physical length of the sample. So, this will ensure kinematic similarity of motion in the model and the prototype. Diffusion number, diffusion number is nothing but D. t/l^2. So, l^2/t is nothing, but inverse of D in dimension. So, this becomes a non-dimensional number. So, this ensure similarity of different process in the model and prototype.

Capillary effects number, most of my students are working in capillary effects on the soil. You get you may also be working in the same Sneha. So, how do you define capillary effect number? In the surface tension come into a picture, microscopic length, macroscopic length multiplied by the gravity affect and the fluid density. So, truly speaking this is nothing but the ratio of the surface tension force, and the inertia forces; inertia is nothing because of density of the fluid.

So, inertial force is divided by the surface tension forces are nothing but the capillary effects. So, this talk about similarity of the capillary effect in the model and prototype. Adsorption number how much is getting sobbed on to the system divided by density of the fluid. So, it very very dense fluid may have more sorption or less sorption. It is a difficult question to answer, because again it will depend upon the activity of the fluid. But a good way of defining adsorption number would be a dense fluid like honey, whether it will diffuse easily in the porous system or water will get diffused into the porous system with some contaminants.

Student: (Refer Time: 17:55)

Correct, so that means, a denser material should have lesser sorption into the system. Similarly, your dynamic effect number: so, dynamic effect numbers are nothing but microscopic length or microscopic length?

Student: Microscopic.

Microscopic length physical dimension of this system, because gravity is coming to the picture. So, l/t^2 is nothing but inverse of g. So, this becomes a non-dimensional number. Now, the way I look at these numbers is these are nothing but the controlling valves. What is the meaning of this? If I want to study what type of phenomena is going to occur in a porous system, when a certain contaminant comes in contact with it, if I use this numbers I get a very clear cut mathematical image of the mechanism which is going to prevail in the system; otherwise, you cannot perceive and visualize it.

But if you are playing with these numbers, it gives you a feeling that if number is between a and b, this type of mechanism is going to prevail. If this number is between c and d, this type of situation may prevail or may not prevail; that means, what you are doing is now you are one step very close to quantifying mathematically the mechanism which is going to governed in a porous media.

So, remember what we have done we have talked about different mechanisms, we have talked about the models. We have emphasized on how to get the parameters which are involved in the models. And now we are talking about how to quantify the whole process. Is this part clear? So, there are four steps in contaminant transport mechanisms when we talk about contaminant transparent porous media.

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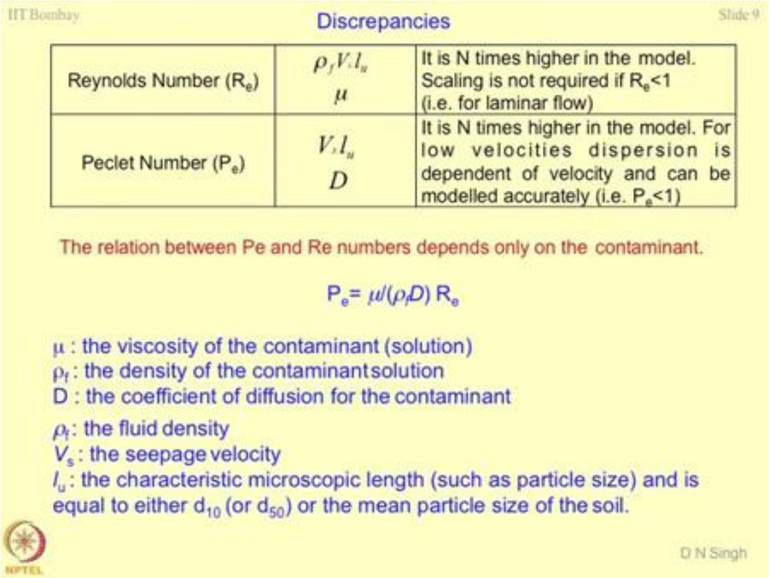

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Slide 9

Discrepancies

Reynolds Number (R_e)	$\frac{\rho_f V_s l_u}{\mu}$	It is N times higher in the model. Scaling is not required if $R_e<1$ (i.e. for laminar flow)
Peclet Number (P_e)	$\frac{V_s l_u}{D}$	It is N times higher in the model. For low velocities dispersion is dependent of velocity and can be modelled accurately (i.e. $P_e<1$)

The relation between Pe and Re numbers depends only on the contaminant.

$$P_e = \mu/(\rho_f D)\, R_e$$

μ : the viscosity of the contaminant (solution)
ρ_f : the density of the contaminant solution
D : the coefficient of diffusion for the contaminant

ρ_f : the fluid density
V_s : the seepage velocity
l_u : the characteristic microscopic length (such as particle size) and is equal to either d_{10} (or d_{50}) or the mean particle size of the soil.

NPTEL

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Well, there are few anomalies, what are the anomalies discrepancies. The discrepancy number one is Reynolds number. You have been dealing with Reynolds number always when you talk about seepage flow. How to define this term is a inertial forces divided by viscous forces. So, this is nothing but the inertial force, ρ_f is the density of the fluid multiplied by seepage velocity multiplied by?

Student: Microscopic.

Why microscopic, why not macroscopic?

Student: (Refer Time: 20:12)

That is right because of this is the seepage which is taking place through pores that is right. So, please remember this that this is not the macroscopic number. And then we used another word or another number which is known as Peclet number. So, Peclet number talks about concentration migration, particularly dispersion phenomena. So, you have seepage velocity multiplied by again the microscopic length of the sample specimen divided by diffusion coefficient.

Now, discrepancy is in the way that truly speaking, there is a school of thought which says that Reynolds number should also get modeled when you do different modeling exercise, but then a great respite is even if it gets modeled the Reynold number is so low that even if you multiply by 300, it is always going to be less than 1. This type of analysis and debate was presented by Dr. Ashok Gupta, and lot of his papers who worked on the centrifuge modeling of seepage analysis. So, this is where we defended one axis by saying that Re has to be always less than 1; otherwise, this is not a flow through porous system it becomes a open file open pipe flow where R e varies from 1 to 10 which is not the case with any soil rock system.

Now, comes the second issue that is a Peclet number. So, Peclet number even if it is higher than sudden n value; n value is nothing, but acceleration or artificial environment condition. So, here also P_e is going to be less than 1. And order magnitude of P_e and R_e would be in 10^{-7}, 10^{-6}. So, any acceleration level which you may apply on the soil sample will not cross R e and P e more than unity, clear. So, I have defined these coefficients over here the relationship between P_e and R_e.

So, if we just substitute these terms and you derive a equation you will find that $P_e = \mu/(\rho_f. D. R_e)$. Now, this becomes a coefficient, which relates Reynolds number with Peclet number. Again, I will repeat Reynolds number is nothing but the number which controls seepage or the flow in porous system. And Peclet number is the number which regulates transportation of contaminants from one point to another point. If there is no flow, there will not be any contaminant transport except for the case when you are talking about diffusion.

So, this is where R_e becomes much, much, much less. So, mu is the viscosity of the contaminant; ρ_f is the density of the contaminant; D is the diffusion coefficient of the contaminant. ρ_f is the fluid density; V_s the seepage velocity; l_u is the characteristic microscopic length such as particle size it is equal to d_{10} or d_{50} of the mean or the mean particle size of the system. How to define mean particle size if d_{10}, d_{50} is known?

Student: (Refer Time: 23:33)

Not average.

Student: (Refer Time: 23:36)

There are different ways of defining average particle, mean particle size. The way I would like to define this is under root of $d_{10}. D_{50}$. This is again depending upon different research groups and authors. So, as you say normally $(d_{10} + d_{50})/2$ is never done. It is.

Student: (Refer Time: 24:00)

I know, but when you talk about the mean particle size, it has to be a sort of a you know GP (geometric progression) of the two terms. So, it is a very interesting world of researchers, now I will show you how these modelling can be done.

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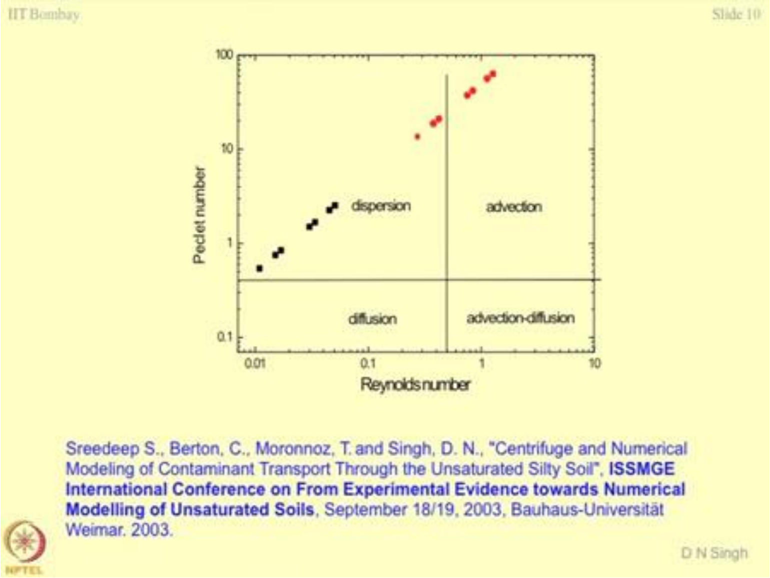

Sreedeep S., Berton, C., Moronnoz, T. and Singh, D. N., "Centrifuge and Numerical Modeling of Contaminant Transport Through the Unsaturated Silty Soil", **ISSMGE International Conference on From Experimental Evidence towards Numerical Modelling of Unsaturated Soils**, September 18/19, 2003, Bauhaus-Universität Weimar. 2003.

Now, this paper was presented by my students Sreedeep, Berton and Moronnoz at a conference. What we did is actually my dream is to develop this model further if you plot Peclet number and Reynolds number on x and y axis, you have four types of contaminant transport mechanisms. So, depending upon in which zone, the values are falling. Without doing much of you know analysis, I can tell you immediately that what type of mechanism is going to control, this is what actually I would have love to do is a half way through.

So, most of the points which you could do are falling in dispersion. It is very difficult to model soils to get some results in advection diffusion and diffusion zones, though it looks very easy. But you make a sample and repeatedly you will end up because we did lot of analysis here 3, 3, 7 plus 10, 13, 13, 15 about 45 samples we have tested here if point corresponds to almost 3 repetitions of 4 repetitions.

So, advection is very easy to get. Now, in sands if I keep on adding clay, what is happening? I am traversing from right hand side to the left-hand side, so that means, Reynolds number is decreasing and so is Peclet number clear. So, I fall in this domain, but this domain itself is such a big domain, where I can reduce Reynolds number, but then I should have expected increase in Peclet number. So, that becomes a modeling challenge.

I am just trying to show here that two numbers can also be correlated with each other. And if you have a sort of a electronic interface ok, where automatically P_e and R_e are recorded from a landfill. And you have a data base of this type, where immediately you will come to know what type of mechanism is going to prevail in this landfill and you can take precautionary measures. Is this part clear?

Student: (Refer Time: 26:42)

Yes, in some of the situations, yes, you can create. So, artificially you can induce Reynolds number, which are much higher which are even Peclet numbers will also become very high because of that ok. So, these are situations which you can simulate, but the most trivial situation would be in this domain, but nature does lot of contaminant transportation only in this domain. So, all your salt water intrusion problems are somewhere here, a bit of them will be falling in advection diffusion.

So, what is happening? R_e is increasing at the cost of P_e; here P_e is increasing at the cost of R_e. So, these are perfect. If this line goes in this direction, it becomes a pure clay aquifer; if this line goes in this direction, it becomes a purely sandy aquifer. So, you can do modeling for a certain type of aquifer also if you have this type of a data base all right. I hope you must be clear by this standard how these parameters can be utilized in solving real life problems.

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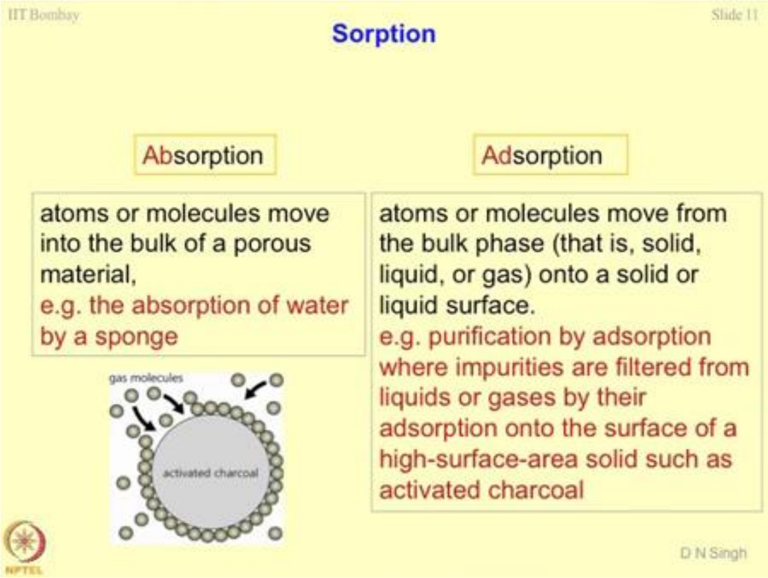

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Slide 11

Sorption

Absorption

atoms or molecules move into the bulk of a porous material,
e.g. the absorption of water by a sponge

Adsorption

atoms or molecules move from the bulk phase (that is, solid, liquid, or gas) onto a solid or liquid surface.
e.g. purification by adsorption where impurities are filtered from liquids or gases by their adsorption onto the surface of a high-surface-area solid such as activated charcoal

D N Singh

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So, let me quickly finish now sorption process. So, sorption is nothing but you have any grain or a parking space in general where most of the cations come molecules come, they get adhered to this, they get parked over here. So, in simplest possible form there is a sorption phenomenon. So, it has two components absorption and adsorption. What is absorption? Atoms or molecules move into the bulk of a porous material example the absorption of water by a sponge.

Now, once this mechanism is over, then the tendency of the system is to migrate into the molecules or atoms. Now, this is what is going to be adsorption. So, if you read the definition, atoms or molecules move from the bulk face that is solid liquid or gas onto a solid or liquid surface. So, it is further the penetration. So, purification by adsorption where impurities are filtered on the liquid or gases by their adsorption onto the surface of a high surface area solid such as activated charcoal.

So, this is the basic difference between the two absorption is still is a physical phenomenon. However, adsorption has to be a physico-chemico mineralogical phenomena that means this is where all the activities of or the total activities of the system comes in the picture. Is this part clear?

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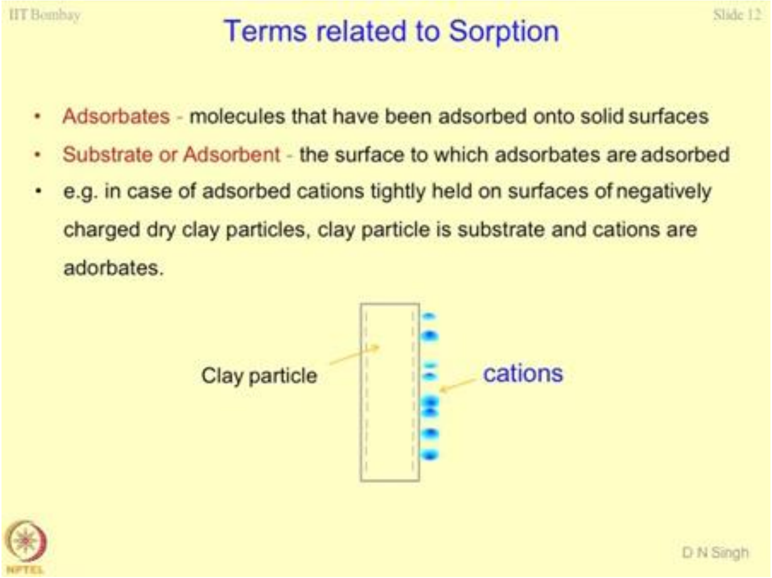

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Slide 12

Terms related to Sorption

- Adsorbates - molecules that have been adsorbed onto solid surfaces
- Substrate or Adsorbent - the surface to which adsorbates are adsorbed
- e.g. in case of adsorbed cations tightly held on surfaces of negatively charged dry clay particles, clay particle is substrate and cations are adorbates.

Clay particle

cations

D N Singh

Terms related to sorption are adsorbates that is the molecules that have been adsorbed on to the solid surface. Substrates or adsorbent, the surface to which adsorbates are adsorbed; in case of adsorbed cations tightly held on the surfaces of negatively charged dry clay particles, clay particle is substrate and cations are adsorbates, I have missed sorry it should be adsorbates.

So, it is a good schematic diagram. These slides have been prepared by Suchith. So, you have a clay particle which is negatively charged; and then the cations are adhering to this clay platelet. So, it is a electrical balance is there, first of all that nullification of charge is there. So, this type of mechanism where the cations are getting parked onto the clay particles is a sort of a sorption phenomena all right. So, clay particles are providing enough space for the cations to come and get parked over there.

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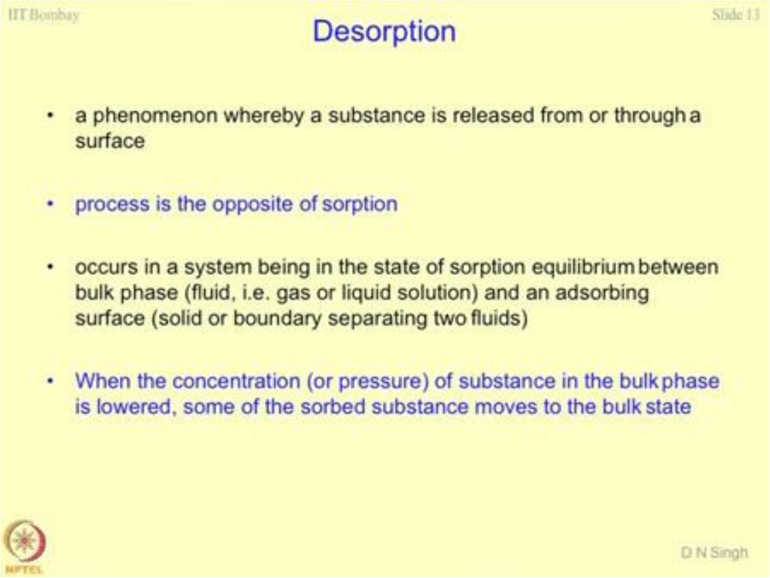

Desorption

- a phenomenon whereby a substance is released from or through a surface
- process is the opposite of sorption
- occurs in a system being in the state of sorption equilibrium between bulk phase (fluid, i.e. gas or liquid solution) and an adsorbing surface (solid or boundary separating two fluids)
- When the concentration (or pressure) of substance in the bulk phase is lowered, some of the sorbed substance moves to the bulk state

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The reverse mechanism is desorption that means whatever gets out freely, so a phenomenon where by a substance is released from or through a surface becomes a desorption phenomenon. Process is the opposite of sorption and occurs in a system being the state of sorption equilibrium between bulk phases all right. A good example of this would be you have this water filters which are normally used in the home. So, dirty water you have a sludge formation on the candle of the water filter all right. So, it is a simple absorption process first of all, but because of the impurities which are quite active the tendency of this system would be to migrate into the candle or that calcium carbonate thing which is the candle. So, it migrates into it.

So, suppose if you do not wash it for several months. And then take fresh water supply and keep this candle over there what happen then the reverse migration of all the sludge is which is formed under candle into the freshwater. So, this becomes a sort of a desorption process. Now, these mechanisms are normally used when you are dealing with remediation techniques in the real life. So, when the concentration of the pressure of substance in a bulk phase is lowered some of the sorbed substance move to the bulk state. So, these are the copy book style of defining the desorption process.

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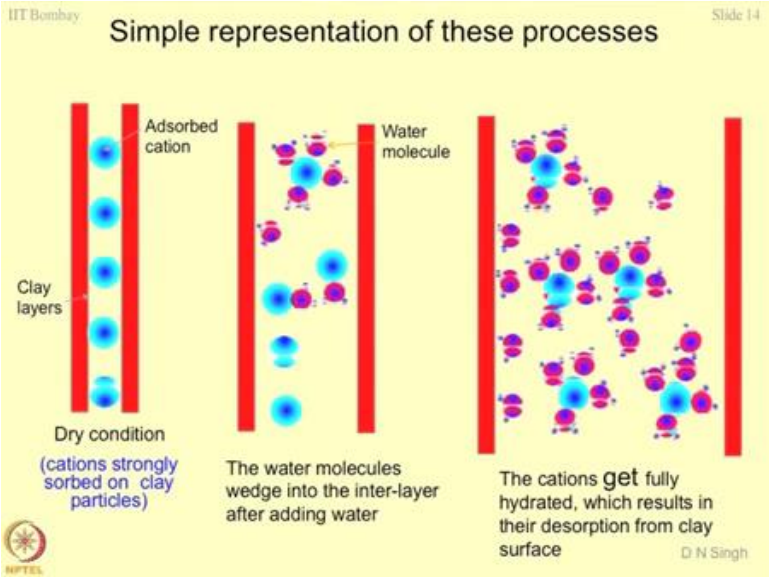
IIT Bombay

Slide 14

Simple representation of these processes

Dry condition

(cations strongly sorbed on clay particles)

The water molecules wedge into the inter-layer after adding water

The cations get fully hydrated, which results in their desorption from clay surface

D N Singh

Now, this is a slide which shows these processes in a simplest possible form you have the clay layers in which the cations are getting locked or parked. So, they are strongly sorbed in the system when the system is dry, you add water to this is a hydration going on. And this is detachment from the surface of the clay. And you keep on doing this process much more water if you add what happens all of these systems are free to come out.

So, that is what I have written here that clay layers you have cations which are trapped into this these are nothing but the adsorbed ions cations. In the dry condition cations are strongly sorbed on clay particles. You add a bit of water, so water molecules make them quite hectic. The tendency is to get detached from the clay platelet is a sort of a desorption process which has started.

So, the water molecules wedge into the inter layer after adding water, and this is the final stage; this is the intermediate stage. So, the cations get fully hydrated which results in their sorption from clay surface. So, this is how the sorption, desorption mechanism keeps going in the nature all right. So, I will stop here today.