Environmental Geotechnics
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Lecture – 13
Soil – water Environmental Interaction

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I thought let me include in lecture number 5, Soil-water Environment Interaction with subtopics as Soil-Water-Environment Interaction, The Natural Environment, The Man-made Environment, Response of the soil to the Environment, Basic Concepts which are normally used in Analysis of Geomechanical Engineering Problems and of course, some Flaws which are in Classical Geomechanics.

Now, before I start, I would like to read out your mind; in your opinion what can be discussed in these topics? Can you briefly throw some light on these topics? Now let us talk about soil-water-environment interaction. So, given a chance what you will like to talk about? So, in today's lecture I will try to show you that only mechanical issues are not very important, there are lot of other issues which should be talked about.

So, this is where actually I thought of talking about the concepts which you use and these concepts are nothing but the hypothesis or lemmas. You know and mathematical form we say what are the hypothesis associated with the subject and then, we will try to find

out some flaws in classical geomechanics. So, after having identify the flaws, in what way we can incorporate the solutions that is right.

So, the solutions cannot be a sub topic. After finishing this the solution part will start. So, let us go ahead with these subtopics and see what how we can justify these issues.

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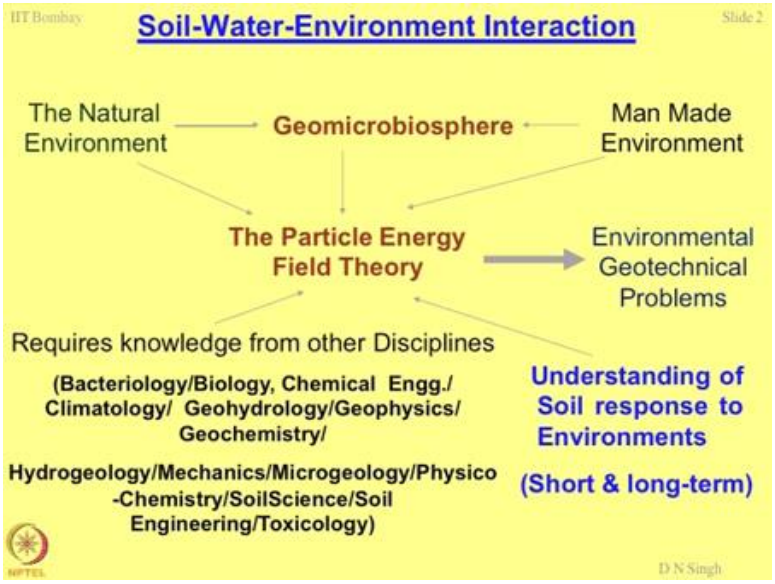

Now, this is a big matrix, the soil water environment interaction. So, I have been asking you have been discussing in details that how interaction is taking place. The most important thing is how to define interaction.

Well, on the left-hand side, you have the Natural environment and on the right-hand side you have Manmade environment. We will try to understand what are the attributes of these two types of environments later. So, by definition natural environment is the environment which is purest form and manmade environment is supposed to be the nature which is contaminated, adult rated you know not fit for inhabitant or whatever.

Now, what is connecting these two is Geo-micro-biosphere. We will try to define this, were also what is meant by Geo-micro-biosphere. What is you understanding about this word? If you dissect it here geo is geo materials microbial activities, there is sphere in which the activity between geomaterials and microbiological you know activities are going on; you agree with this. So, you could have always asked that why it is important to bridge these two environments with this concept of this word.

I think in present day scenario you cannot you know get relieved of this middle term. We have enough time for long actually people are not bothered about this geo-micro-biosphere and you have been trying to understand how the subject or the mechanics part of it is shaping up. Now, this line is a philosophy; how geo-micro-biosphere is influencing the natural environment and how this system is influencing the manmade environment or vice versa. Now, if you want to quantify what is happening really in this geo micro biosphere, you require a theory and this theory is known as PEF. That is the Particle Energy Field Theory.

And the basic idea of using this theory or developing this theory is and we should be able to solve most of the problems which you are coming across in our profession that is solution to the environmental, geotechnical problems or geoenvironmental engineering problems. So, we will try to touch upon this; what are the components of this theory; what are the attributes of this theory. But before going to that in your opinion what is the meaning of developing this type of a theory.

When you say the particle energy field theory; what is significance of this type of a theory and its development? So, basically how a particle is going to behave in a given energy field and when you say energy field is a flux of energy. What are the different flux says which you are aware of? Magnetic flux, electrical flux, electromagnetic flux, thermal flux, then, chemical flux, biological flux; combination of all these fluxes.

Now when you say simple advection what type of flux is this water seeping from one point to another point whatever flux is this either gravitational that is right or so there is a mass transport phenomenon. Now, how these mechanisms are going to get governed because of a certain energy field application, this becomes a very interesting theory and whole idea of developing this theory is that we should get solutions to the problems which we are facing.

Now, as I have written here you can notice that this theory will require lot of basics and fundamentals. I am not going to deal with all these subjects in toto and in details. This just to remind to all of us that the background of this theory is lying in all these subjects or you have to use the fundamentals or the basics from these subjects to inculcate in this theory so that you can get the right answer; Bacteriology, Biology, Chemical Engineering, Climatology.

How bacterial activities are taking place into the soil, I think our CSRE prople are doing lot of work related to this; tissue culture, Chemical Engineering, Geohydrology, Geophysics, Geochemistry, Hydrogeology, Mechanics, Micro-geology, Physico-Chemistry, Soil Sciences, Soil Engineering and Toxicology. So, and the list can continue for long and forever. The whole idea is that we want to understand how soil responses to the different environments in which it is placed.

When we say particle the particle is nothing, but soil mass or a geomaterial. So, for that matter how rock is going to behave; how soil mass is going to behave and so on and particularly, we want to understand the response which is short term and long term. Any example of a short-term response of the soil and a long-term response of the soil which use in classical geomechanics? So, consolidation theory is a long-term phenomenon; how about the short-term?

Student: Vibrations.

Vibrations. Yes, loading simple loading. You take a soil mass and load it. So, whatever response you are getting is a immediate response. So, talk about elastic properties elastic settlements. So, elastic settlements are nothing but immediate response or you call it as a immediate settlement also, but then there is a difference between immediate settlements and consolidation settlement. So, this should be a basic guideline in your mind that when we talk about the response over a period of time or certain duration. There is something which is required to understand the basic behaviour of the soil over a for long duration. Now creep is the good example of short term or long term behaviour?

Student: Long term behaviour.

Long term behaviour. So, unfortunately classical geo mechanics does not touch upon creep. What we say is 90 percent consolidation has been achieved and then, later on what happens to another 10 percent consolidation? It goes on, but people are now trying to understand what is the influence of the creep on overall settlement response of the system. There is one of the issues which makes you clear, at least in a some abstract way that what is the basic difference between short and long term responses.

So, scope is quite big. I think you will understand that you have to make a theory and this theory should get input from different subjects or different observations or from

different experiences all right. To different problems where the time domain may extend up to infinity and ultimately, what we are trying to do? We are trying to study this whole mechanism for the man made environment and we are trying to compare how much deviation, we have you know covered or we have created from the natural environment.

So, this is the best way to understand the basic fundamentals of environmental geomechanics. Is this part clear; covers the entire gamut of the activities or something is missing. So, we have a theory; we are getting inputs from somewhere; we are we have an objective function or which we are trying to get a solution and we know the solution is valid in a certain time domain. Clear? So, this seems to be a good model at least to explore further, all right.

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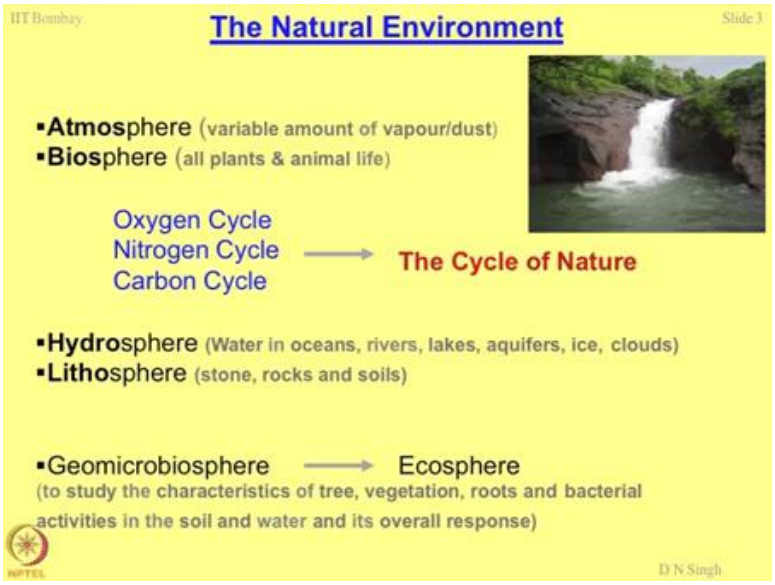

Let us define now natural environment. So, this is what the natural environment is. Clean water, clean air, good vegetation, rocks are shining. This scenery I have taken from Badlapur. Now what are the components of the natural environment? As most of you must be aware of the first thing is atmosphere. What is meant by Atmos? It's nothing but vapor. So, we talk about the vapor or the dust which is present in variable amounts in geosphere or biosphere and biosphere.

So, second component which is very essential is biosphere, which can includes everything all sorts of animals, plants, living objects and what the attributes of biosphere. The attributes of biospheres are oxygen cycle, nitrogen cycle and carbon cycle. Now, this

is what is known as the cycle of nature in short. I will touch upon these three cycles slightly later. Next comes hydrosphere. As the name suggest its nothing but the water.

So, water which is contained in oceans, rivers, lakes, aquifers, ice, clouds and so on. The next one is Lithosphere; lithos is nothing but a stone. So, lithosphere consists of all sorts of stones, rocks and soils and then, comes your Geo-micro-biosphere which is equivalent to ecosphere. Now, why it is important to talk about Geo-micro-biosphere? Basically, this will include all sorts of mechanisms which are going on in nature.

So, you have trees, vegetation, roots bacterial activity in the soil and water. So, overall response of the soil if you want to study, we have to understand how geo-micro-biosphere is behaving or what are the attributes of geo-micro-biosphere. So, this is a latest fashion where people talk about geo-micro-biosphere rather than even your what is it say geosphere is it not. So, the activity which has been added is mostly the activity of the biota or the bacterial activity.

So, generation of methane, decomposition of soil weathering of soil because of microbial activity and so on. I do not know whether you are aware or not, but there are some books available where they talk about biotechnology in civil engineering and in some of the chapters, they have talked about how consolidation can be accelerated with the help of bacterial activity.

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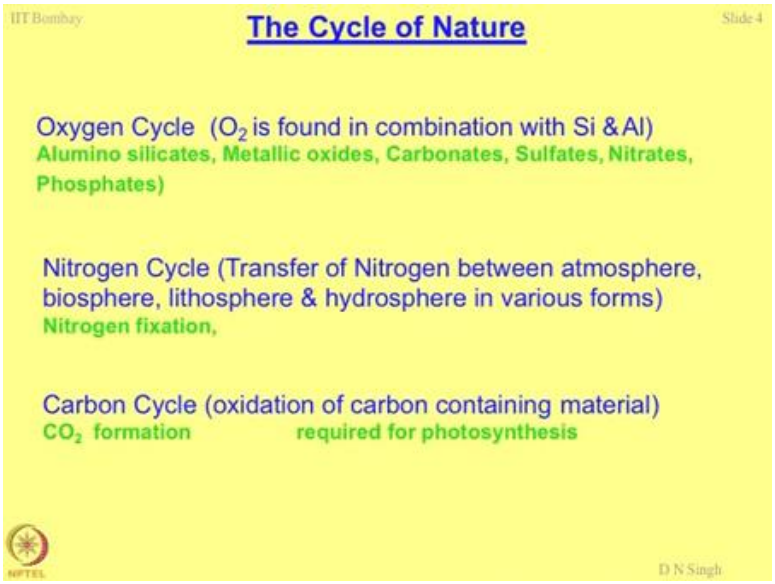

So, what is the cycle of the nature? The first component of cycle of the nature is oxygen cycle.

So, basically oxygen is found in combination with alumina and silica. So, you take any soil mass and you try to do its chemical composition by using XRF analysis (X-ray fluorescence). So, what will notice is that this oxygen gets fixed with alumina and silica or any cation and it forms basically alumino silicates or metallic oxides, carbonates, sulfates, nitrates, phosphates and so on. The second component is nitrogen cycle; how transfer of nitrogen takes place between the soil and the atmosphere biosphere, lithosphere, hydrosphere in various forms. A good example is nitrogen fixation. Any example which comes to your mind which is related to nitrogen fixation?

So, there are some bacteria which fix nitrogen into the roots of the plants and that is what actually is the main you know food or on these only bacteria may survives basically. So, there are some nitrogen forming bactoria bacteria see these concepts you can use in modern day geotechnology. Carbon cycle; so oxidation of carbon containing materials, you take paper or any material, you incinerate it. So, what happens? Ultimately, everything gets converted into carbon.

It is very interesting that carbon is the most important element of life, where you talk about carbon dioxide formation and what this carbon dioxide does? It’s required for photosynthesis so it becomes a part of the food chain. So, you think of a situation where these cycles are getting affected because of human involvement. So, this is a sort of a pollution which you are creating into the atmosphere or in biosphere its.

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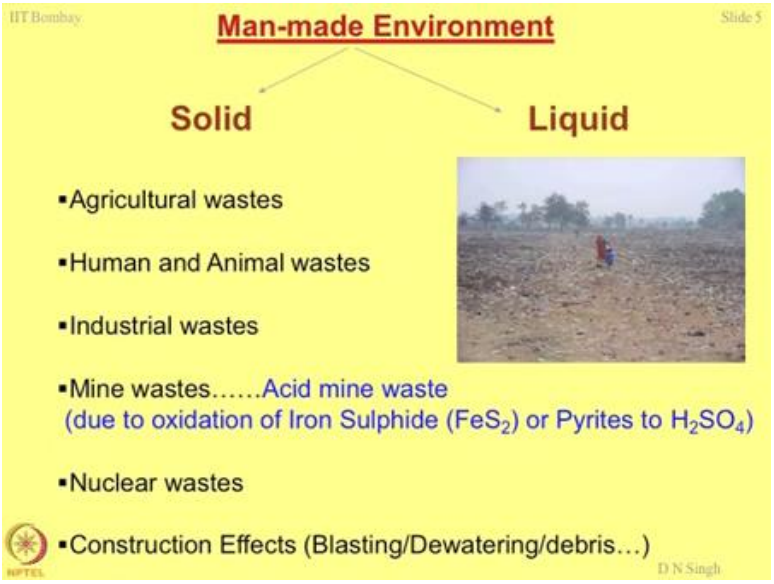

Now, what are the attributes of the man made environment? This is what man made environment is or even much dirtier than this sometimes.

You have, lot of letter you know thrown everywhere. It could be a dump yard, it could be a land fill, it could be any place in the so called civilized society. The whole city itself looks like this, sometimes there are two attributes. When we talk about manmade environment, we talk about solid and liquid phases; why don't we talk about the gaseous phases or the vapor phases? Normally environmental engineers, they talk about vapor phases more and we do not consider vapor phases much.

Idea is simple either vapors will solidify or they will liquidify and then they will precipitate. So, ultimately the ground is going to receive the contamination in the solid form or in a liquid form. So, this is where actually our domain starts our interest starts. Now, these are the issues which are contributing to manmade environment; different type of agricultural wastes.

So, most of the wastes is generated because of agriculture activity; can you name some of the wastes which are coming out of the agriculture industry excessive use of fertilizers and pesticides; that is right pesticides is becoming a major source of concern. ICAR Indian Council of Agricultural Research, they sponsor lot of research for dealing with ground contamination, soil contamination, crop uptake, amount of contamination which crops will uptake through the roots and which becomes a part of the food cycle. You

agree? Human and animal wastes and we are famous species for creating more and more pollution.

So, need not to be discussed much industrial wastes, we will discuss this group in details later on. What type of industrial wastes are causing direct threat to manmade environment or environment and when we talk about industrial wastes, there are two types of wastes or two other two basic categories hazardous and non hazardous wastes. We will discuss about them later. Another category is mine wastes; most of the mining activities going on in all the developing countries or the developed countries. And these wastes are the source of acid mine wastes. What is known as the acid mine?

So, basically this is a oxidation process. So, any unattended mine or abandoned mine of coal which is lying in atmosphere or environment for a pretty long time; what happens this is oxidation of iron sulphide and which gets converted into the pyrite oh sorry pyrite into the H_2SO_4. So, these H_2SO_4 starts leaching out and becomes a part of the water table.

And it may contaminate the drinking water sources. Nuclear wastes are becoming a very big issue in present day civilization and particularly in context over country now city like Bombay, where you have too much of debris because of construction effects. So, blasting is required to make new ground new facilities, underground structures, deepening of reservoirs, channels, seas and so on; dewatering is required several places and debris, construction debris is a big issue particular in mega cities.

So, every 5th year, 7th year or 10th year you have to demolish either the building or refurbish the building. So, the biggest question is where to throw the debris which are coming out of this industry. There is an agency in Bombay known as Yuva. Yuva in Navi Mumbai. So, sometimes when you get a chance to go, please go and visit them. It's an NGO. What they do is they collect the debris from different parts of the city and they recycle it.

So, they make concrete of low grade, cement of low grade and different type of construction utilities by using the construction debris. A good example is tiles, building blocks and so on and these tiles and building blocks can be used for construction of lower grades. E waste is also a new topic; yes, I think I should add here; that is right. The

E-waste is also gaining a major importance. Yes, you should also be a part of the industrial waste.

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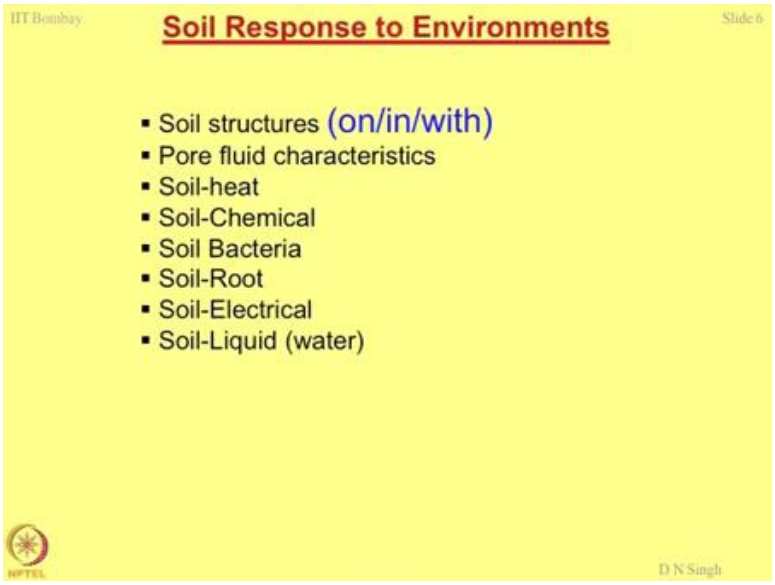

So, when we talk about the soil response to environment, the first parameter would be the soil structures which are made on the soil, in the soil and with the soil. Do you understand the different between these three on in and with? When we say the soil structures made up with the soil, on the soil, in the soil and an embankment is made on the soil, with the soil but not in the soil. A tunnel is made in the soil; clear?

So, this is how just by using different words the context gets changed completely. So, when you are talking about soil response to environment, the type of environment in which you are working, the soil structure is going to respond accordingly. Heaving of the soil, you do excavation and the entire soil must may heave or it may cave in is just because of a type of boundary condition which you are imposing on the system. So, excessive pore water pressures, excessive water table and then what happens? The response is in the form of heaving or subsidence or caving in of the structure.

Another interesting way to locate or to identify the effect of soil sorry the effect of environment in the soil would be if you study the port fit characteristics; my analogy to this is always is just like your blood report. So, the whole idea is that you take some specimen from a human body and then, you try to understand the history of the patient;

what are the symptoms of the patient; what medicine should be recommended and ultimately, prolonged monitoring and all which we have discuss in previous lectures.

The same thing people are trying to do by extracting the pore fluid of the solution. The best way of doing this would be you take a soil sample, apply some pressure on it and then whatever solution comes out of the soil sample is nothing but the pore fluid solution, pore fluid. Now, if you understand the pore fluid chemistry or its characteristics; you can understand that how soil is going to behave in a given environment.

So, first of the flux which we had been talking about is soil heat. So, this is the interaction; how soil is going to interact with a thermal flux or the heat? What is the immediate effect if you heat up the soil? First thing is it will redistribution of moisture; what causes shrinking of the soil to occur is a redistribution of moisture. So, when you heat up the soil, when you impose thermal stresses on the soil mass, the first response of the soil is that it gets a redistribution of moisture. Because of that what happens because of that some tensile strength develops in it. Tensile stresses develop in it and because of development of tensile stresses suction develops in it and then, once all these things are beyond a certain limit the system cracks. So, when your tensile stresses are more than tensile strength, the system crumbles or collapses. A good example of soil heat interaction would be when you talk about the foundations for furnaces, refractory systems and so on. The cables which are buried in the ground most industrial activity, they required too much of cabling underground cabling power supply in mega cities.

So, what is happening the moment you supply power underground, there some heating effect going on and your system gets affected because of that. The soil is more susceptible to moisture migration. This you are study in classical geo mechanics in the form of compaction curve; is it not? So, a bit change in moisture content corresponds to significant difference in its dry density and the grain structure all right. So, those effects are very very important to be study.

The second in the list is soil chemical interaction or the response of the soil when it comes in contact with chemicals. We have been talking about this since the beginning of this course that chemical flux would have lot of attributes like temperature, concentration, radioactivity, toxicity, hazardousity and so on. So, how soil is going to

behave when it is coming in contact with a chemical flux or in an environment which is chemically very aggressive.

So, disposal of any waste of high intensity on the ground. So, the biggest issue is everybody wants install an industry, but then as an administrator, as a planner or as an environmental activist are you going to allow everybody to install a industry. So, this is what is known as EPA. So, this is why the role of EPA comes into the picture environmental protection agencies. So, they do study of a subject of a project and they give the clearance. So, what is the meaning of the word giving clearance? That means, you can go ahead with this type of project.

So, the biggest issue there is in what way your industry is going to impact the environment. So, you have to study the impact and analysis of the whole system. Soil bacteria; now, this is the subject actually which most of the civil engineers had not talked about earlier, but as I told you sometimes in the beginning of this course, my personal feeling is that wherever or whatever the limitations of geotechnical engineering are, they can be backed up if you take bacterial activity in account, particularly when you talk about containment of hazardous waste.

A good example is you cannot create a barrier which is totally impervious, but you can use some bacteria which can create a system mostly impervious. I think we talked about bio concrete that is a good example. Soil-root interaction; this is what geomicrosphere would be geo-micro-biosphere would be where you are talking about the response of the roots and the soil ok. What type of osmotic process goes on; what type of nitrogen fixation process goes on and so on. The another flux would be soil electrical; that means, you apply electrical flux and see what is the response of the soil. Interestingly, I think that day when you visited my laboratory, you must have realized that we are doing some studies related to the response of soils when it is exposed to electrical field.

The basic idea is how soil is going to behave under electrical flux and this can be used as a very good fingerprint to characterize it. Right now also people are doing this; can you give me an example of soil electrical analysis somewhere which you are using in geomechanics? Tomography in electrical surveying yes is it not so; what is the basic concept there you are passing some current in the ground and then you are seeing resistivity.

So, resistivity mapping you can do of the ground. So, it is not a very new concept, but what people have realize is that they have been talking about the response of the ground without going into the details of the fundamental properties of the soil which get affected because of electrical flux. And of course, the last but not the least is soil liquid; that means, when it comes in contact with liquids. I am using the word liquid intentionally because soil water is I would say better known, but water replaced by some other fluid becomes soil-liquid interaction.

So, these are the responses which normally people try to model in their studies and then, they try to see how the soil is going to behave. When you talk about aggressive environment, if this liquid phase gets contaminated, it becomes aggressive. If dose of chemicals becomes high, it becomes aggressive. If dose of bacteria become high, it becomes aggressive; is it not. Pore fluid concentrations are very high, it becomes aggressive and so on.

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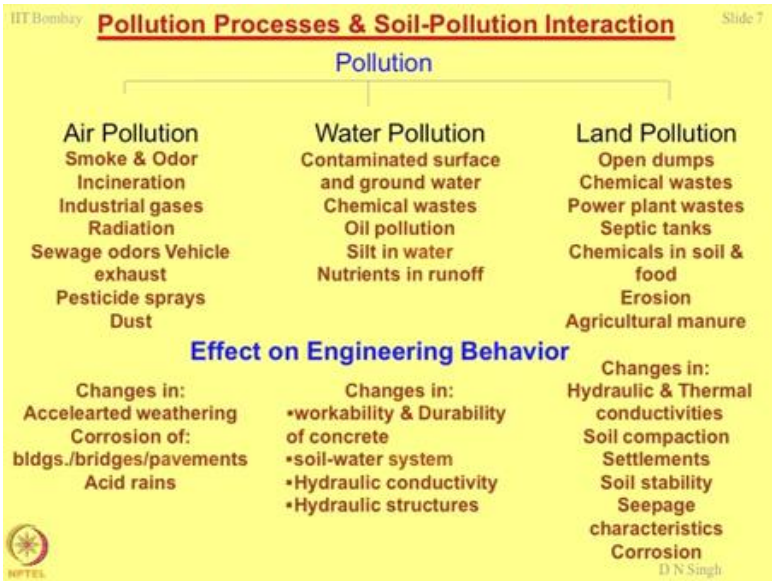

This slide gives you an idea about what are the pollution scenarios and how do they affect engineering behavior of the soil mass. So, I put it as pollution processes and soil pollution interaction or soil contaminant interaction. So, when we talk about pollution, there are three types of pollution which we consider; air pollution, water pollution and land pollution. So, air pollution deals with smoke and odor, incineration of waste, the

type of gases which are coming out of the industrial units, the type of radiation which is coming out, sewage odors, vehicle exhaust, pesticide sprays and the dust.

So, this is the air pollution. Normally, environmental geomechanics does not really consider them as separate entity. What we do is we study these things under the heads of water pollution or land pollution. The simple philosophy is that in the gaseous form or the air pollution form, things will precipitate on to the ground or in the water body, but hard core environmental is they will definitely talk about air pollution.

So, what are the effects on the engineering behavior, when you talk about air pollution? So, it changes in accelerated weathering or corrosion of buildings, bridges pavements and acid rains. So, all of you are aware of these issues are suppose is it not accelerated weathering is nothing but in coastal regions the concrete gets weather too fast. Why do you find weathered soils in coastal regions? This is one of the answers; do you agree? The climatic conditions are quite aggressive. When you talk about water pollution, this is contaminated surface water and groundwater, chemical wastes which are being discharged the oil pollution, oil slicks, oil spills silt in water. Any example of silt in water; comes to your mind? Paper industry; I had given with this example.

So, paper industry is supposed to be the major bug as far as water pollution, land pollution is concerned. That's why they say you save tree to save environment people are against creating paper is it not. Nutrients in runoff. So, the water pollution will cause nutrients to runoff. What are the effects or the changes in the engineering behaviour of the soil? Workability and durability of concrete gets affected; soil-water system gets affected; the condition of the aquifers. Hydraulic conductivity gets affected, how?

Because of the water pollution that is right. The hydraulic conductivity I think I have talked about this few lectures back, if some contaminants are present in the ground water, what happens? There is a flushing of fines from the soil mass and because of that hydraulic conductivity may get affected and if hydraulic conductivity gets affected, the stability of hydraulic structures will get affected definitely.

So, when we talk about land pollution, this is of interest to geotechnical engineers when we talk about open dumps, the landfills, the chemical base which is coming out of the industry, the power plant wastes like fly ash GGBFs, silica fume, what else fiberglass waste and so on. The type of septic tanks which we are operating; chemicals in soil and

the food because from the soil there is a uptake in the plants and that becomes a part of the food chain. Soil erosion takes place as you said rightly; the cohesive property of the soils gets loss because of acid contamination. Agricultural manure is also a type of a land pollution. Why people are against using what you call it as a cow dung fuel?

There is a there is a philosophy that should not be used as a fuel; why? It has mercury. So, if you incinerate mercury and that is why actually villages you will find most of them have this problem of night blindness or loss of vision. So, that is the reason why people are against cow dung incineration for cooking purpose. This again will change hydraulic and thermal conductivities because the fines may get transported and because of loss of fines the compaction gets affected, the settlements will become a problem; stability of the soil becomes a problem, seepage characteristics change and corrosion all the of the soil takes place.

So, this is a scenario where the pollution processes, they effect and they influence the behavior of the soil mass. I hope this covers most of the scenarios is it not. So, when we talk about water pollution and land pollution, its mostly the leachate which is coming out of these ways forms which is highly toxic and hazardous and its responsible for altering the properties of the soil mass.