Environmental Geomechanics
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Lecture No. 35
Geomaterial characterization-XI
(Chemical Characterization)

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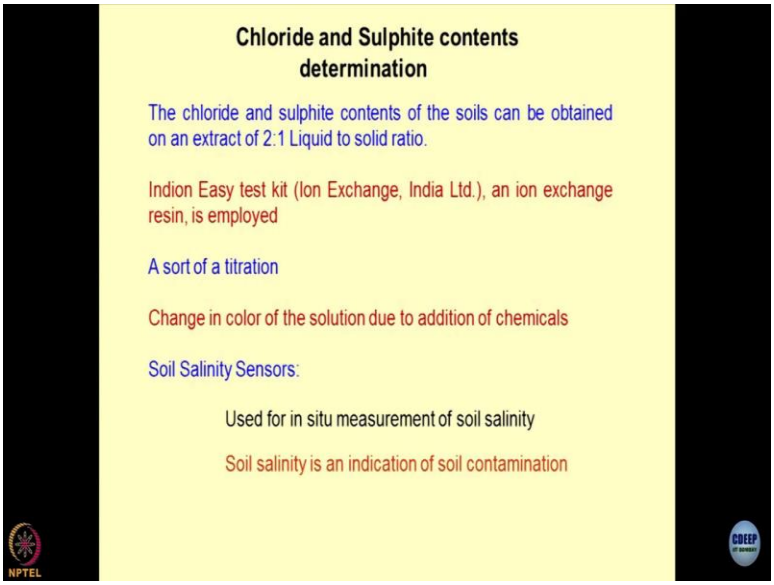

When we talk about the contamination of soils, particularly two components that is the chloride and sulphide become very, very important to be detected in the soils why any guess why people should be talking about chloride and sulphide contents. The reasons are very simple, because if you have soils which are having lot of chloride and sulphide what will happen as a geotechnical engineer where I will face problems **"Professor - student conversation starts"** foundation could get corroded, very good, excellent. **"Professor - student conversation ends."**

So, the moment you do anything related with the concrete or cement and if the soils are very aggressive having a lot of chloride and sulphide content or sulphate content, we are going to attack the foundations, and there are several cases of foundation failure, which have induced because of these two culprits. So, what is normally done is that you take the soils and dissolve

them in water. Normally we maintain 2:1 liquid, solid ratio that means, you take the weight of the soil, and two times the weight of the soil is in the liquid form is added.

And this is stirred for several hours on a hot plate and so that all the chemical species get leached out. And once the leaching process is over you measure to filter the supernatant or the liquid and then the chloride and sulphide concentrations there are ion-exchange kits which are available in the market. These kits are similar to the ones which are used for checking your urine samples. So, this chemistry is same either its biochemistry or chemistry of soil normally call as soil chemistry.

This is a sort of titration and which you are doing and knowing the number of drops of the ion exchange resin which you put in the solution you can compute what the concentration of the contaminants is. So, change in the colour of the solution is a good identification of what type of chemicals and what is their concentration which is available in the system. This is where actually soil salinity sensors are also being used; they have been found to be very useful.

And there is a lot of soil which has saline in the neck in the all over the world and not one country, and because of the salinity, you cannot even use them for agriculture purpose. So, suppose if I am creating underground facility storage of hydrocarbons, and the first question is what is the level of contamination in the soil because very soon you will realize that if soils are heavily contaminated, even if you create a very thick concrete wall as containment or for the underground tanks.

The chances are that all these chemical species will diffuse into the precious material which you are storing underground, including hydrocarbons and the water because even concrete is porous. So, through pores, the diffusion process may occur, and the entire utility items which you have stored might get contaminated any sort of a concentration gradient ultimately would cause the diffusive contaminant transport. The way you are dealing with the advective transport $\Delta H/L = i$ and the hydraulic gradient occurs, and the seepage takes place the same way when concentration gradient develops; these chemical species will migrate and become a part of the hydrocarbons and the water you are storing.

We will discuss in detail so, soil salinity in an indication contamination level of the soils. The need of the hour is all the saline soils or heavily seawater in through that impregnated soils can they be converted can they be rejuvenated will have a big problem, I hope, and the entire country is facing the coastal area as well as the locations like Kutch area deserts, where you will realize a lot of impregnation of the saltwater is taking place in the geomaterials or soil, and then this becomes a big question that how to construct the infrastructure, how to lay the foundations of the infrastructure.

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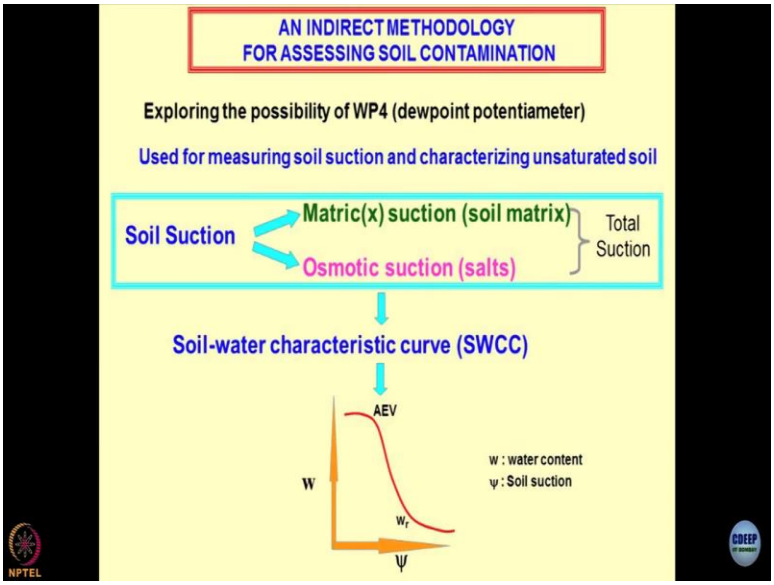

This is the technique which was developed by one of my PhD scholars during his PhD research Dr Sredeep you have to meet him all of you he is a professor at IIT, Guwahati. He did a wonderful work to develop a lot of new innovative things in this context and what we have done is we had used new equipment not now 2003,4 when he was working with other first time in the country somebody had used this WP4 equipment, we what we call it as a dew point potentiometer dew point I think you understand what is dew point this is the moisture or the water vapours getting condensed on a surface.

So, that is the dew point, and then potentiometer is equipment which would measure what the volume of the fumes or the vapors which are getting condensed on its surface is. WP4 is the name of the equipment which is supplied by the company WP4 is normally used for developing

suction versus moisture content characteristics of the geomaterials. Now, this is a point from there the initiation of unsaturated soils starts. Fine.

So, those of you who are interested in learning how to characterize the soils for their unsaturated state you have to go through the enormous amount of work which our research group has done starting from Sneha Kurian this to Kannan Iyer, I think Sneha Jayant and Hanumantha Rao, Ravi Ranjan Rakesh, Sredeep and so many people who have used his equipment and Vikas Thakur. So, these are the guys you should read their papers and try to see how these equipment have been utilized and how the guidelines have been developed for establishing the basic characteristic curve for the soils, which is known as a soil-water characteristic curve.

So, when we talk about the soil suction, there are two components, which everybody talks about. One is the matrix suction, which is because of the matrix of the soils sometimes we call this the matrix also. And the second one is the osmotic suction, which is because of the presence of the salts in the soil. And nowadays I am working on a third component of the soil suction any guess what that would be? So, if you analyze this closely, you will find that the soil matrix represents the physical state of the material, sort of compaction gamma D is very important.

And what about this osmotic suction, this represents the chemical state of the material. So what is remaining? Very good. So we have started now talking about the bio suction and to of M-Tech students they work in this context Asha and Meenu if you see the paper they have tried to work on, and they are established that these type of suctions are very important and they cannot be ignored in the geomaterials. So, for the time being, I will restrict my discussion on matrix suction and the osmotic suction because the first time you are getting initiated into these type of discussions.

So, you can always build upon once you have the basics. So, soil water characteristic is mostly utilized by the guys who are into the field of agriculture, or water resources. So, if you talk to your colleagues who are doing modelling of reservoirs, irrigation modelling, irrigation scheduling soil, nutritional analysis and all they would be very eager to know as SWCC This is also known as soil water retention curve as the SWRC but being a geotechnical engineer, we like

to use the term as SWCC rather than as SWRC, but the connotation is same either soil water retention or soil-water characteristic curve.

So this essentially is a relationship between the moisture content which could be either gravimetric, or this could be volumetric also, it depends upon what technics you are using. So, if you are taking out a sample from the field, which is undisturbed, you can bring it to cut in small pieces and use the WP4 or pressure membrane extractor to obtain the suction. So ψ corresponds to the total suction, and W corresponds to the moisture content. This could be theta also theta is the volumetric measurements. So I can plot a relationship between moisture content and suction.

So the way you read this graph is less of the moisture content, what happens to the suction value, extremely high. And the more the moisture content, the soil, the suction values less. That is true because the saturated value will not show you negative suction or negative pressures. So this characteristic which you see the red colour is a sort of fundamental behaviour of the soil. And if you are very good to learn this subject, please refer to the papers by Vikas Thakur and Sredeep.

We are we have talked intensively about the measurement of ultra-high suction in the soil and interpretation of SWCC and how to develop SWCC and how to use this SWCC followed by the work of Dr Hanumantha Rao who has used SWCC to derive unsaturated hydraulic conductivity of the soils. So many times we have this question what is the state of the development of this subject? I hope now we are getting the answer. Remember sometime back; you are asking these things.

It is not the first time this has been discussed. This has been under our radar since several years, and we have done a lot of work, and I can proudly say that we are the pioneers in working in these areas nobody thought of these issues in geotechnical engineering as back as 2002, 2003, in fact, early 2000, so as far as the interpretation is concerned, what I have shown is that the initial portion of this curve was almost flat and then as shown a point over here as an air entry value.
Now, the air entry value is the value of the suction beyond which the water only, sorry at this point only the air will enter the pores, not before this. So, the way the cycle valve works, you have the valves there, and then you are pumping air it cannot come out. It is a sort of a reverse

process. We are sucking out the water from the soil, but we are making sure that the air does not enter to the soils what are the meaning of this. I still assume soil is to be saturated.

So, as long as the soils remain saturated, the moisture content is very high, but their suction is extremely low. So, this entry value can be a sort of inflexion point, how to opt-in the inflexion point, you extend this straight line portion and then use extended this straight line portion wherever they cut this becomes the air entry value. And air entry value is a unique signature of the soil, which has something to do with the type of the soil the gamma D.

The particle sizes and of course, the method of measurement and the environmental conditions. So, nowadays the philosophy is like this that if I know that as SWCC I need not do any other experiment, long back I had talked about the speculative modelling application of artificial intelligence and geomechanics. I had talked about different types of software's which are used for speculative modelling. So, if I know one of the parameters or if I know the as SWCC curve, I can speculate all other properties.

So, air entry value it would be of great help to people like us who are into designing the barrier systems designing the disposal repositories for nuclear waste, why? Because soil is under continuous threat of elevated temperatures and the moisture migration is taking place from the soil. So, I would like to study, because of this thermal influence, how the moisture gets changed in the sample, and how the properties are changing over a period of time.

So, these are the applications and implications of this study. The second term which you are observing here is Wr, which would be very useful for the guys who are into agricultural sciences because Wr corresponds to the residual moisture content. So, residual moisture content corresponds to the wilting point. Correct. So, people like you who can devise the automatic sprinkling systems if you have SWCC and if this SWCC in the software, what you can do is you can link this whole thing with an actuator and that actuator will actuate the irrigation system.

So, I can do precise irrigation, the moment my set drops below Wr the suction values are going to be extremely high, I can measure the suction in-situ by using a different type of sensors. And I

can put an algorithm in such a manner that the moment moisture content and the suction drops below a certain value, I get a trigger, and that trigger induces the irrigation. This could be a technique for disposal of the toxic waste also, where what you would like to do? If because of the inherent heat of the disposed waste?

The tendency of the geometry is to crack. What I would like to do, I might like to have to do; artificial saturation also keeps the system saturated, do you realize this. So, this is what the state of affairs is, here you have to do complete engineering of the systems which are extremely life, I hope you are getting an idea about the applications would be you were asking something back. Air entry value is the point beyond which the moisture will drop, but air will not enter into it this also known as the bubbling point.

So, this is the point beyond which the moisture loss is taking place, but you are stopping air from entering and that is used for different applications you are not allowing the system to become unsaturated, but of course, what is running out. So, this is a sort of equilibrium which is existing at the interface of the contractile surface. I was thinking like so, at the shrinkage limit, what happens is the air enters, no slightly below shrinkage limit no never at shrinkage limit also your sample is saturated, clear and you take all at most care that the air should never enter.

Remember, if you have done haste, and if you have fried your sample, it is not a correct estimation of shrinking limit sample should never crack number one if the sample has cracked so, after taking out that you should really use a lens to see whether the sample has cracked the error has entered into it or not. If air has entered discard the sample should never be used. So, by concept, the shrinkage limit is the one below which is still the soil is fully saturated or at this point the soil remains saturated and air has not entered into it that means the cracks have not formed agreed.

So let us not complicate the things use this air entry value sir. I told you air entry value is the one if you look at this graph, the moisture remains constant. So, this is the point where the tendency of the air is just to enter into the system. And because of this what is happening is the moment you increase they will be a decrease in the moisture content and decrease in the moisture content

is still holding from air to enter into the system. Clear. And then after that what is going to happen is if you apply pressure on the soil sample lot of water will come out. So, that is why we call this as the initiation of entry of the air into the soil sample. Type on Google air entry value and bubbling point of the membranes and then see the videos. Is it okay?

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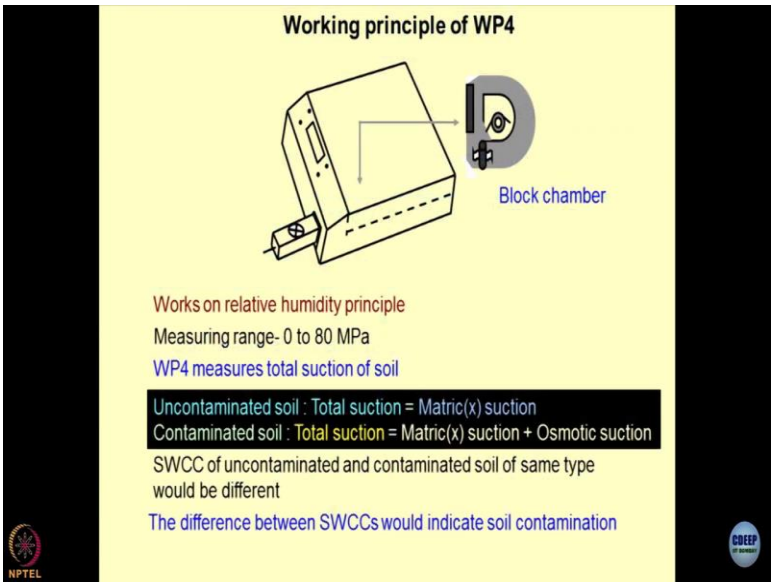

So, working off the WP4 said equipment which is commercially available, this appears to be a sort of a chamber where you have a dryer in which you can mount the sample overhear in a small cup, and there is a block chamber inside. So, if you look into it, this works on the principle of relative humidity. That means if I take a sample which is saturated, and if I leave it beneath the fan, what will happen. The moisture will evaporate and this moisture in the form of the evaporation if they get condensed on a mirror.

That mirror I can use some infrared technology to measure what is the volume of the moisture which has got condensed over there. So, this is the calibration which is done in the form of electronics to measure what is the relative humidity of the sample and this relative humidity can be converted into the suction value directly this is this technique is also known as chilled mirror technology, chilled mirror technology read about it, which gives you the total suction.

So, the point here to be noticed is that most of these WP4 type of instruments they work in the range of 0 to 80 MPa but of course the new ones in the market go up to 350 megapascals also of

the suction value remember these are negative questions, but what we are proven is that this equipment cannot be utilized for the range of 0 to 1500 KPa for that the pressure membrane extractor works better. So, in short, pressure membrane extractor and the WP4 result should be utilized together to get this SWCC more about this, please read from the papers which have referred to particular the paper which has been written by Vikas Thakur.

Now, the pretext what we take from here is that if I take the soils in their native state, which might be contaminated, and if I establish this SWCC and if I washed the soil sample several times by using water or different chemicals, and if I keep on measuring the air suction values will be a difference. And that is what the contamination is now; you may ask a question that, in real life we cannot do this. They will be millions of tons of the millions of metric cube of the soil which might be contaminated.

So, how would you draw a parallel between the laboratory exercise and the exercise? So, the answers could be like, I am using this technique, first of all, to establish what is the level of contamination, whether the soils are contaminated or not. Second is I can create a small prototype sort of a thing in the lab to show if this is the volume of the material and this is the level of contamination, how much washing is required to get rid of all the chemicals which are adhering to it and then this becomes a this can be scaled up in real life.

So, these type of challenges are still lying ahead of us, we have to overcome them laboratory studies have been done, but when you have to take them to the field at a bigger scale, you have to be very judicious in applying them. Does this answer to your question that what is the significance and how the practical applications of these techniques have been made. If you look at this, it is not a matter of time, what is more, interesting is I have to come up to the tail of the graph.

So, for a few soils, we have seen that this take months. All these experiments are basically the test your nerves patience, particularly when you are working on the organic materials, it is very difficult to lose out moisture from them, even after drying and if you are drying them, the chances are that they may catch fire or they may distort the volumetric deformations could be

there so becomes very tricky to work on it, but I hope you can understand that these are the questions which are being answered, which will become tomorrow's guidelines and tomorrow's code of conduct.

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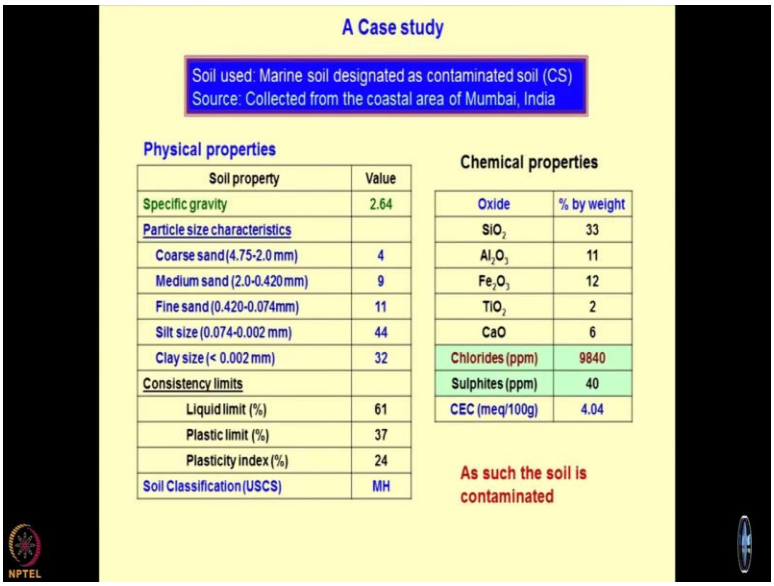

So, this is a case study which I wanted to share with you. Incidentally, you only talked about the case studies today. And then this is the case study which I am talking about most of the coastal regions, particularly the ports are very much concerned about the quality of the soil, and all this comes under the green initiative of the government of India. So, most of the boards have to comply with the status of the green port.

I hope you understand what the meaning of the green ports that means, first of all, this is a zero-waste discharge; nothing goes out of the port area in the gaseous form liquid form or the solid form. But if you do the audit of most of the ports will realize because the cargo handling and the soil are becoming contaminated, imagine chemicals which are being brought in urea particularly different type of assets, petroleum hydrocarbon items of day to day life and so on.

So, they get spilt over when you stack them, and this is becoming a big work for environmental technologists to establish that the soil is there are uncontaminated in case they are contaminated or to clean it up. There are many instances where the fire has taken place at this place of storage is of these consignments which are known as containers, they have exploded also, and these

terrible accidents happen in the factories. And once they meet this fate, you have to clean up the entire area so, if you characterize the soils of the marine nature, which are on the coast of Bombay.

These are the properties of the soils, you have specific gravity, particle size distribution, liquid limits classification is the typical average size of soil, and these chemical properties come from the SRF analysis X-ray fluorescence. And then if you look at the chloride and sulphite content, these are extremely high, and the calculations capacity is also high. So, chloride content tells you that the soils are impregnated heavily with this marine seawater, and then you have to do something to create the facilities over there. So, what we did is, we take took this other initiation point for studies.

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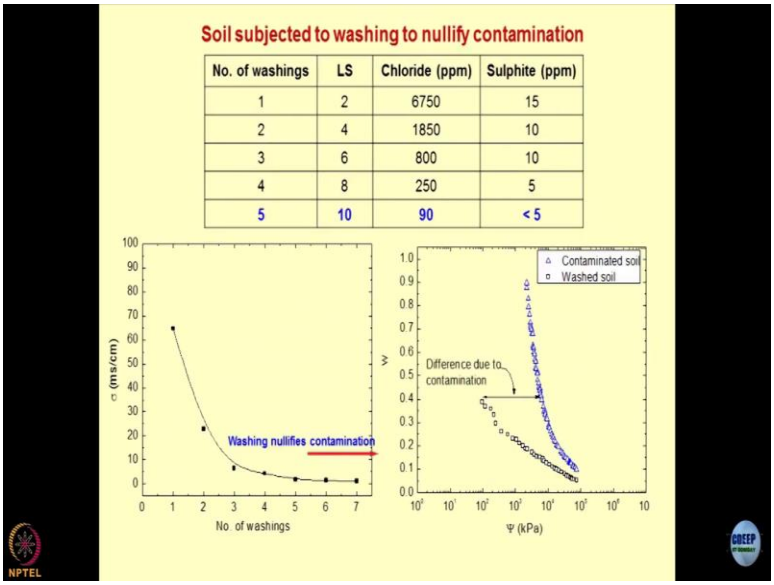

And we started washing them to nullify the contamination level. So what we will observe here is that we have given number of washings to the soil sample, LS is the liquid to solid ratio, process simple, you take a certain amount of soil and add two times the water. So, this becomes L / S is equal two measure the chloride content and sulphite content and keep on increasing the volume of the water to wash the soil sample, or you can literally wash it also.

So then L / S becomes four times, six times, eight times, ten times and then keep measuring these things and then you get something which is within the permissible limits. So, this is one of the

techniques which we worked on. And what we have shown here is that if you measure the electrical conductivity of the supernatant, and number of washing, what will observe is that as the number of washing increases, the conductivity of the pore solution decreases.

So remember, we were talking about the pore solution and its application to establish whether the soil itself contaminated or uncontaminated. So, in literal words what you have to do is you have to bring down this salinity from this point to this point if you want to make this soil usable for different applications. So, electrical conductor the data has to be manipulated in terms of the time and money. So, these type of relationships has to be developed.

And then if you measure the SWCC of the contaminated and washed soils, so what you will realize is that these are the peculiar SWCC curves for the contaminated soils and uncontaminated soils or the washed soils. And what will realize is forgiven moisture content, there is so much suction different. Now, this is the osmotic suction. So what I am trying to convey here is that soil-water characteristic curve itself happens to be an interesting way to establish the level of contamination of the soil.

"Professor - student conversation starts" These washing processes are done in large scale. So that is what I told you sometime back that before you launch something in the market, what do you do? The thing? Is that wash water, it is like you ever read our mind? So that this is going to be a secondary source of you are right. What are the other technologies what you have to do to keep on trying different options? You cannot say that I cannot do it. It is like we are just transferring the pollutants from one, so that is right so from your own mistakes, you learn, is it not? Somebody must have washed soils in the beginning.

And then someone else must have asked this question that what you are going to do with this slurry third person would I was how to dry it up this why the fourth person would have asked how would you reconstitute the samples from the slurry state to this state. This is how the growth develops when a lot of questions your questions are valid. Now, coming back to your point the question would be any not to do the washing is, a connotation, there could be another interesting way of getting rid of the contaminants by making this a stand mark is a benchmark.

And saying if I do any treatment clearly and if my results get superimposed on this graph on the left-hand side or right-hand side, I know that this is 100% drying or the cleaning process **"Professor - student conversation ends"** and where do I stand if I adopt any other technique and quantify my efforts that what type of decontamination of the soils I have achieved by other methods, now this is what exactly Ganaraj is doing. Suppose if I give you a heap of the mountain like the mountain which you have IIT campus on which you climb and see the Mulund.

This is the size of the mountains of the red mud, let us say industrial byproducts which line here and there. Somebody asked me a question, can you neutralize this whole mud so that I can use it for some purpose. Are you getting this point, this is where this type of study becomes very useful. So what I will do is I will inject some gases, and I will inject some chemicals, and I will inject water. And I will do all sorts of logistics to take out the effluents so that they do not pollute the world, geoenvironment.

And after doing all this, if I take out a sample and do this test, and superimpose it over here, I know that complete washing was this and I am somewhere here it shows that, I have the contaminated the soil, yes the answer is better than saying nothing can be done and lower down the extent of contamination of the soils because these are the solutions which have to be given to the industry and the governance. So imagine if I remove all this chloride and sulphide with pH equal to 13, I am sure you can walk on this material with your rubber shoes why?

It is got forward if you slip over there and if you touch the material you are gone. It is very dangerous to work on this type of deposits and go to Australia, and there are the soils which might be having some paid contents and acidity of the soil for that it could be other 2.52. Again, you can access these places forget about taking of sample with the help of a drill bit itself will get dissolved in no time for these other challenges which people are facing and trying to work on. So this must be giving you an idea about the complexities associated so the people who asked the question where the solutions.