Environmental Geomechanics
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Lecture – 11
Recent Trends - II

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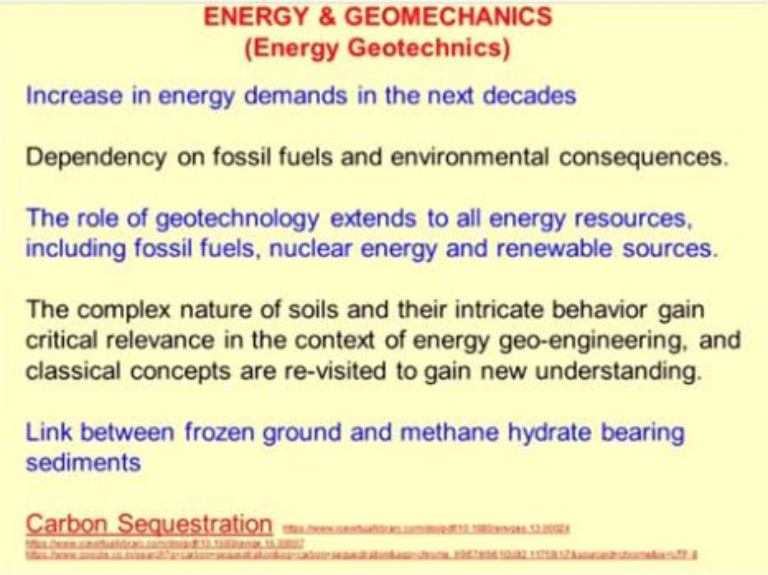

So, let us talk about the energy which is the requirement for everybody in today's world, let me take you through a bit of the conceptual thinking first, I mean everybody knows that energy is required and there are the school of energy and energy sciences is very famous, in fact, we have a school of energy also. Energy is the term which is multi-disciplinary, clear so a good name given to this is energy geotechnics.

There is a journal also by Divya on energy geotechnics; international journal, so everybody knows that there is a big demand for energy in the days to come, so everybody says save energy, but you must realise that in today's society is clear, everything is energy-based, so many mobiles, so many gadgets, laptops, so many tablets, so many electronic devices to be charged every day morning.

And we are talking about energy saving, what a paradox, check it out on the net that how much energy is required to sustain the society in another 20 years and what is going to help you in your sustenance, very soon you will realise that mining of coal is a big curse, so and what do you produce out of it; we will discuss, alright. So, the question is on where I am going to bring energy; people talk about hydrothermal; sorry, hydroelectric, people talk about solar, people talk about wind, people talk about you know wave energy, and so on, the very insignificant quantity of the energy can be generated by these devices at very high expenditure.

So, this also talks about you know, the fossil fuels are getting exhausted and their predictions, by what time the hydrocarbons will vanish, what time the coal will vanish, so the question is what should we do beyond that, what are the consequences to the environment because of these fuels and this is there I hope you will realise that geotechnical engineers have to play a significant role in the energy geotechnics particularly, nuclear energy, renewable resources, fossil fuels, alright.

So, this subject earlier, you know never used to be discussed in the realm of geotechnical engineering, what we must be realising is that these are something very, very utopian but yes, now people have started working, and there are few guys who have gained a lot of knowledge and taken enough lead in these subjects soon. Now, what happens is because of the complicated nature and extreme complex composition of the geomaterials.

It becomes challenging to understand you know what type of behaviour this materials will exhibit, when you talk in terms of the energy geo technics, so all these concepts have to be recast, they have to be re-understood, they have to be developed and masters is the right time when you know it is our job like people like us should train people like you to think ahead of what has already been done. Now, this is an excellent example of now, I am talking about the hydrates.

What you are talking about from the very first lecture, you know what the link between the frozen state of the geo material which not many people study in undergraduate and even post graduates unfortunately in our country is but you will realise that these are the gold mines so,

once you understand this subjects better, your you know, manoeuvrability becomes much more in your profession otherwise, you remain to pertain to the old thoughts.

So, energy geotechnics is the one which is the link between the frozen, ground and the methane hydrate-bearing sediments which are deciding a specifically. I do not know, how many you aware of carbon sequestration **"Professor – student conversation starts"** To capture the carbon and yes, you are right, carbon captures, yes, you are right, I do not know the application, then you know everything if you know that how to steal the carbon from the environment.

And pumped into the geoenvironment that is sequestration, alright, capturing something from somewhere and pushing it into another matrix. Yes, want to say something in your words; like you capture and you sometimes store in the sea, sequester. You call it blue carbon like other carbon, like this, okay, so for your help, I have a link, so it will talk about this sequestration process, and where we are as a country, well this is a job mostly which was done by the guys who are in mining.

"Professor – student conversation ends" So, they used to talk about methane gas sequestration, and geotechnical engineers become very interested in this, why? Because there is a fluid phase and porous media is coal or porous media could be the soils.

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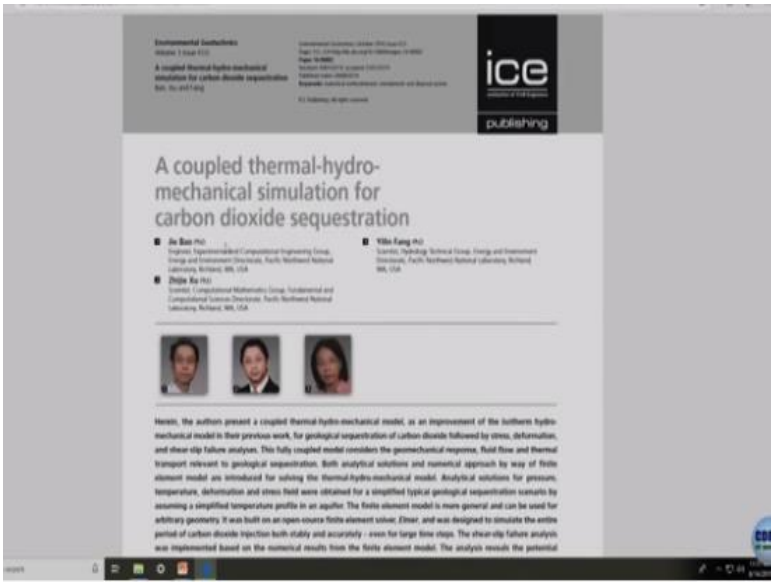

So, if you see this paper; a coupled thermo hydro mechanical simulation for carbon-di-oxide sequestration, you can learn what is happening in this context, these are the guys who are doing lot of work in this area.

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There is another one which is I think would be useful for you, this is another paper on finite element model for simulation of carbon-di-oxide sequestration, alright, this was the volume 1, issue number 3, I just to give you an idea about what is happening in the world in today's context, so the material in which the sequestration is taking place is the porous system, clear, it could be rocks, it could be soils, it could be coal, it could be resins, whatever.

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And then you are pumping in the gaseous phase or fluid phase; this is another interesting paper; carbon sequestration potential of South Wales coalfield, I think I was talking about this.

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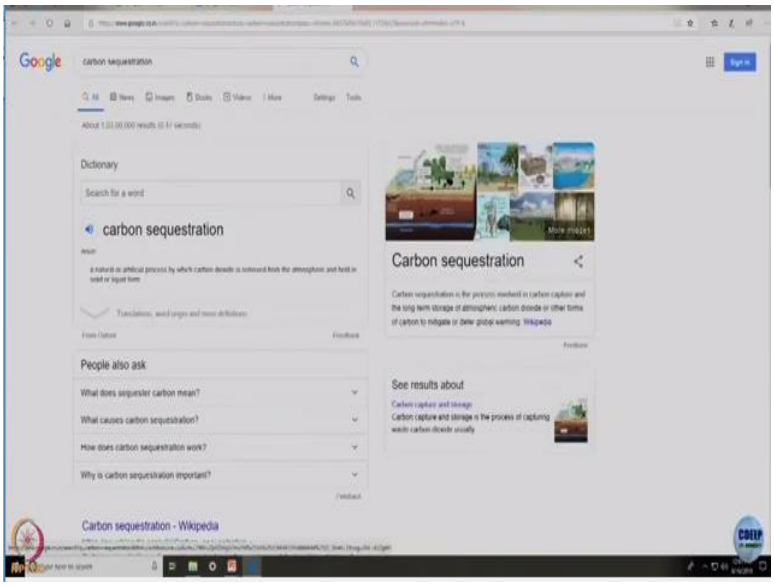

What is research gate? **"Professor – student conversation starts"** It is a platform for many research scholars, where they share ideas, or they share queries, yeah, in research gate, correct. What is the advantage of this? You can like know the contemporary issues and you can solve the queries of other research scholars, very good, I am quite happy. **"Professor – student conversation ends."**

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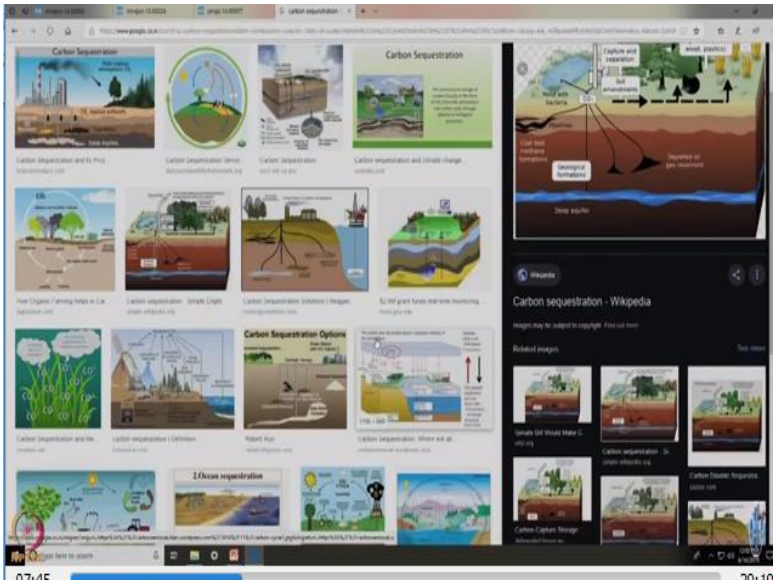

This is what the sequestration is in simple words, you know if you look at here, what is happening is that most of the industries are emitting carbon-di-oxide in the environment, if I can capture it somehow and if I can pump into the deep aquifers, where you have methane gas, alright, so it is just like reverse of pumping out a test which you did in hydraulics, you have this pumping in the test.

But rather than water being injected, what I will do is; I will inject carbon-di-oxide so, carbon-di-oxide is heavier, or methane is heavier, correct, so CO_2 and CH_4, so that means lots of difference, alright, understood. So, you are flushing lighter gas by injecting heavier gas, clear, must have the whole heart and that is what the carbon-di-oxide sequestration is, read a bit more about it those of you are interested.

So, here if you can see that they are injected wells sorry, they create wells, and through one of the wells, they will inject carbon-di-oxide, and whatever methane is present in the aquifers particularly, coal seams, they will flush it out from the other end, they can use it for, so I am saved of mining because mining has a lot of problems. So, the whole mechanics of this process if you have to study, this becomes very intricate, so I will try to touch upon how do deal with these type of situations in this course; environmental geomechanics.

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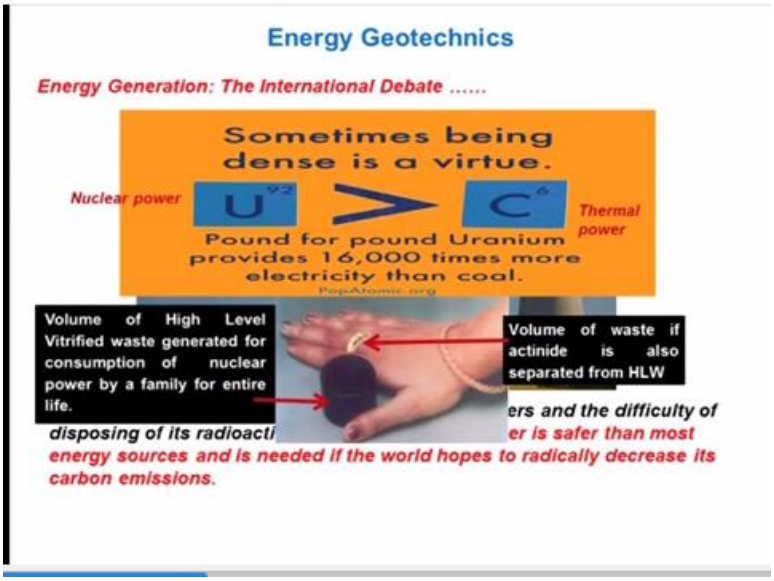

You know people are trying to talk about whether the nation should be depending upon the fossil fuel or they should go nuclear; I will come across something of this sort, whether treaties are being signed by different countries, where you know government's fate might also depend upon the type of decisions which are taken in the country, check it on it, a lot of information is available.

NPT; non-proliferation treaty, why we should go nuclear alright, and why they are not satisfied with the conventional processes, thermal; what is thermal; incinerate coal, run turbines by steam which you do by boiling water and then run turbines and generate electricity, lot of consequences you produce an enormous amount of fly ash.

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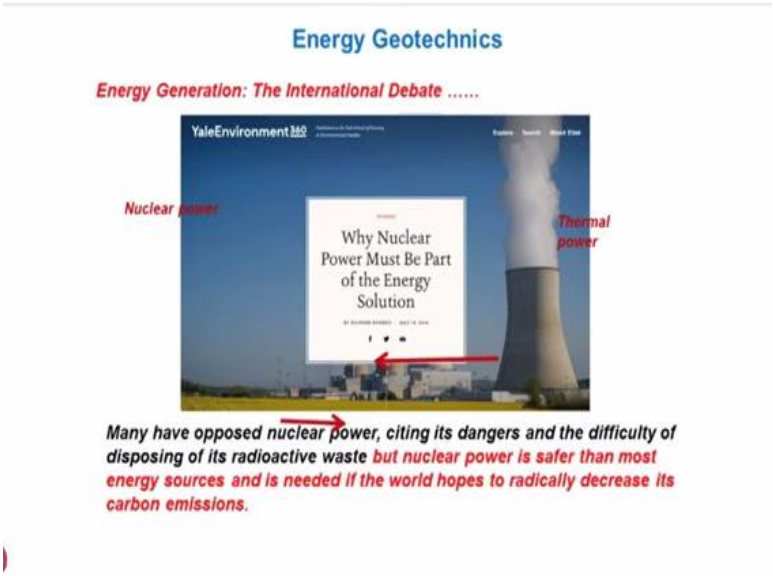

The big question is where to dump it, where to throw it, how to stop its movement into the atmosphere, air, volumes, so if you are incinerating let us say, a certain amount of coal, equal amount of the fly ash gets generated or more than that, the calorific value of the coal is less, many times if the coal is of good quality, clear. Mining has own issues, several problems so, based on why do not we go for let us say something which is more sophisticated is the question which is the in the national debate.

So, many are opposing this thing which party you will belong to, you want to oppose nuclear power or you want to promote this nuclear power. **"Professor – student conversation starts"**

You want to promote, okay, why? It has less disadvantage compared to thermal, okay what comes to your mind, what type of less disadvantage it has? The wastage; as you said the fly ash; those problems will not be there in nuclear waste

There will be some other problems then, it is quite dangerous, it will yield more; yeah, you are quite close to the correct answer, let me answer the question and let me create a discussion on this, so many people have opposed you know that country should not go nuclear, and we will talk about this. **"Professor – student conversation ends."** Citing it is dangerous and difficult in disposing of the radioactive waste, yeah that is true.

So, here we talk about quantity versus not safety, intensity but nuclear power is safer than most of the energy sources and is needed if the world hopes to radically decrease its carbon emissions. So, the present day the biggest problem is carbon emissions, you produce cement carbon emissions, you produce steel carbon emissions, clear, you construct buildings carbon emissions, alright.

So, this is where; this type of technology is supposed to be clean technologies, so check it out on net what is mean by clean technologies, however, suppose you know, this is what the conventional thing is the discussion, suppose if use uranium and suppose if I use carbon, what is the risk associated with this, what are the volumes associated with this you know and this is where the energy geotechnics become very intense for people like us, who have been dealing with both the sectors.

I mean I deal with atomic sectors, l deal with the thermal power sectors and I understand what are the issues so, the question is if I use uranium and I use carbon, what is going to happen? So, the situation is something like this, I mean the nuclear power uses uranium and carbon is used by thermal power, this is how you can compare the 2, and guess what is what? Lack of carbon and yes, it's a ring in the finger, this is what has been is compared.

So, the logic is you know, the volume of high-level vitrified waste which you generate for the consumption of nuclear power by a family of an entire life is this, it is reverse as what you are

saying and the volume of waste, if actinide which is present is also separated from the high level waste, so this is a comparison and the whole discussion was that when I incinerate tons of coal, at what cost; by damaging the environment so much, by damaging the agricultural lands, clear.

By creating so many other types of environmental issues, displacing people from one place to another place because when you are doing mining, you have to acquire the land, you have to displace the guys, alright. So, all these are the issues, however, when you are adopting to the nuclear power now, this is what is going to happen, so the volumes are going to be extremely less but then what the other side of the story is?

Volumes are less, but the intensity of the waste in terms of concentration and radiation is extremely high. So, what technology is does, he or she compares, x1 parameter, x2 parameter, x3, x4 parameter and let us optimise them, you understand, so this how the optimisation comes in the picture. What I should be following; x1, x2, x3, x4 and what type of equation I am going to generate, how the economy of the country will get influenced.

What is your role in the economy of the country, hope as the geotechnical engineer you realise this from today's discussion, is this part okay, how much you can contribute, you never imagine, how these atomic reactors will be run? **"Professor – student conversation starts."** Sir, I was thinking like, it will have more merits and at the same time, it is going to have like as you said the intensity will be more, so related disadvantages also.

So, like how do we like fix that this is the one that we have to go forth, correct, big question, sir, even if we go for nuclear power plants, there will be issues related with the mining of uranium and; the volumes are important, so from one mine, I can sustain well for another 100 years of the lights, the amount of uranium which is present and carbon; you must have heard about uranium enrichment also, know, in your 10+2 physics you must have done, I am sure.

How do enrich the ores, it is a big technology, start quantifying things now, until now it was too much of abstract thinking, is it not, **"Professor – student conversation ends."** so let us talk about now contaminant geomaterial interactions. Interaction part I think I have explained quite a

lot and contaminants are also clear to you, anything which is unwanted, undesirable clear, which you never expected in the system and what is our system; is geomaterials, alright or bi, sorry micro bio geosphere, if you remember I sometime back, I coined this term.

So, in this system if any contaminant comes, it is not a good situation but supposes if it comes, I am helpless, I want to understand how the interactions are going to take place.

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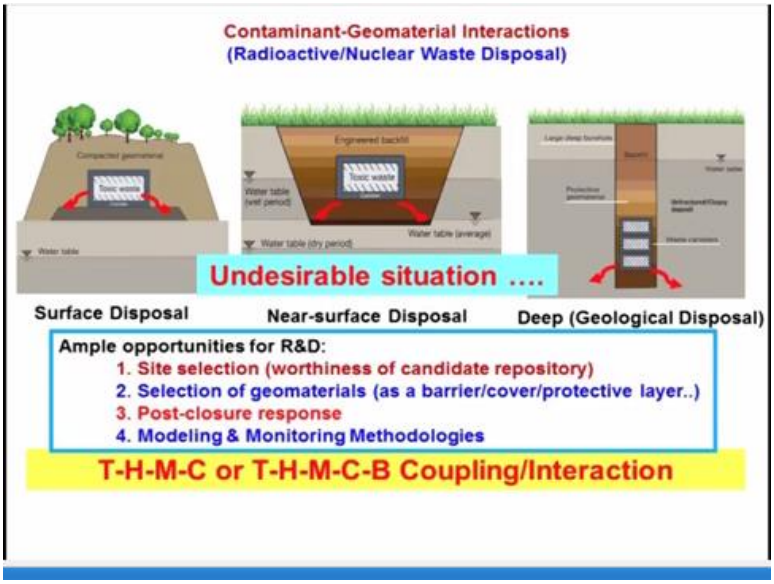

So, the first question which was asked is how would you dispose the nuclear waste because the more and more furnaces I run, the more and more coal I was using tandoors for that matter you know, any type of oven, the more and more ash you are generating, and you had an idea, my ash I will dispose in your home, next door, is this correct that is what happens, their ash comes to your courtyard.

So, we will throw it there; they will throw it here, this is how the game was getting played, unfortunately, in this case you cannot do this because there are few watchdogs, who are watching what is happening in your country, this is being observed by international agencies. So, one of the options is that you would take this atomic waste contained it in canisters, canisters are normally made up of lead, you know because leads are retarders of atomic activity; radioactivity.

So, these canisters contain toxic waste which is nuclear in nature and normally, they are stored on the surface with special measures, and they are covered, so this is the compacted geomaterial, and on this, I can grow the vegetation, and there could be water level, good scenario, this is what is known as surface disposal, provided the activity of the toxic waste is tolerable, so most of the waste which is coming out of the R&D units, our gloves, you know the scientist who is associated with the atomic waste; atomic activities.

Surgeons, doctors who are giving therapies of different types by using different types of isotopes, a different type of medicines, weaponries, clear, irradiations of different type of crops; potato, onion, you must have noticed, nowadays onions and potatoes do not germinate, even if you keep them in your kitchen for several months why? During our days, we were kids, and you are of your age, you just buy it today, and tomorrow it is used to germinate.

What do they do, what magic they have done? Something interesting they have done is it not, you agree, so there are facilities where the truckloads of the agricultural produce go and there irradiate it, read about this, very interesting way to create a profession for yourself. Another good example is you know; so these are the applications of you know, the units were the activities is being used for different purposes is known as surface disposal.

So, all these types of waste which comes out of such units is within tolerable limits and hence it can be contained and buried in a geomaterial. Then the question is; what type of geomaterial I should be using and why? Suppose, if I keep it a stag like this on the ground, earthquake comes, there could be wear and tear of the canister itself, and inside, the activities kept, so what is going to happen; everything will become a part of the geoenvironment, it will spillover.

So, whenever nuclear establishments have met with a disaster which was a recent one which mankind is unable to forget? What happened there? Yes, a beautiful combination of the two things which I have been discussing, clear, so it is a natural disaster influencing atomic establishment. Chennai, Kalpakkam, so read what happened there, you know is becoming a big issue, how to safeguard your establishments, you need millions of what; litres of water from the sea to run a reactor.

So, you cannot put it in mainland, clear one advantage and disadvantage, second; now, the disadvantage is Tsunamis, when they come, yes you are very right, what happened in Japan so? Clear, what happened in Chernobyl, clear, so these are the issues, in Kerala what is happening, what industries there at Chavira beach; so the bigger problem is not the titanium; titanium cannot be mined like this, it is thorium.

So, look at the beauty of nature, why Kerala is so precious for the guys who are associated with the atomic industry? Nature does magic, the sand which comes on the beach contains a lot of activity in the raw form, and this is processed in the Indian Rare Earth Limited, so they collect sand, it is blackish colour sand. Now, next time when you are there, please go and visit this site, alright and you say that you are from IIT Bombay, you know the whole story, and you like to see what is happening there.

So, they do farming of sand; each time wave comes, it deposits, I do not want to lose this knowledge, otherwise, what will happen, it will go back, so they do literally scraping of the top layer of the soil from the beach, they process it, they keep it aside, next batch comes but now, what is going to happen because of this? Yes, suppose, this process goes on, on and on and on, you are not returning anything to the sea, what is going to happen?

Beach erosion that is what is happening, in most of the areas nearby, ride through wall through the entire belt of Malabar belt and this tremendous problem with the country is facing hope you realise now the issues, each city has its own issues, groundwater and we will talk about why industrialisation could not be done, why the atomic industry is flourishing and issues related to geoenvironmental aspects.

So, the question here is that what type of geomaterials should be utilised, so the question mark here is that what type of geomaterials I should be using, from where they will come, so the selection of geomaterial is a question mark, what properties this material should be having? They should be protecting this unit against the rains, compacting them itself is a big challenge because the buried units are there inside and these buried units are quite active.

So, you cannot just say I am compacting it, okay the properties which are required; nothing should come out of it in any liquid phase, gaseous phase, okay, water table should not fluctuate so much that everything becomes wet, forget about the instability which you can take care of, vegetation should be done because plants ultimately provide a cover. Look at the second situation, yesterday I was asking this question, whether I should go above the ground for disposal.

Or I should go beneath the ground, clear, which one is better, no unique answer, I mean I will sometimes use this, I will sometimes choose this, I might make a trench over here, few tons of meters deep, I will design a good engineered backfilled on the top of this, I will keep the toxic wet canister and burry it, make it perfectly sealed so that even if water table fluctuates, nothing should permeate into an out of it.

Now, this is normally done for near-surface disposal, and there are lot of facilities in countries which have been created known as NSDF; near-surface disposal facilities, your most of the geotechnical engineers, are working right now, they are giving solutions. The third one is deep disposal; you go quite deep inside the ground; this is hundreds of meter deep and where you encounter the rock mass.

And in this rock mass, you keep the canisters and make sure that when you are dropping them from the top because of the impact, they do not get crushed or burst and then use the backfill. Now, this is what is known as deep geological disposal. A geotechnical engineer studies all these 3 situations, you know we are discussing by leachate, and I gave you an example about the landfill.

The landfills are exposed to the environment, and rain comes the water interacts with the waste matrix and takes out the heavy metals; the same thing is going to happen here if you are not careful. So, what I am showing with the red arrows is that the activity may leach out if you are not very careful if the disposal system and the backfills and the compacted geomaterials are not designed properly.

And when I say design, this is the material which has to be worthy of tolerating all the attributes of the waste, high-temperature, disintegration, radioactivity, chemical concentration and so on, clear, it should not get altered for years together, so this is an undesirable situation. Now, the question is how you would check this? All these things are studied under the realm of post disposal, so this is the big word, you know post disposal or near-surface disposal, people call it old disposal of atomic waste.

And this is where geotechnical engineers will play a very, very important role; now I am sure you will realise once this type of situation occurs, the geomaterial contaminated traction is going to take place, the attributes of the waste which are going to come out from this unit are going to interact with the geomaterial which could be soil, which could be mineral and hence the interaction is going to take place.

This opens up a lot of revenue's for geotechnical engineers, you know and what are these revenues? First of all, site selection, what type of soil I should be using, where I should be dumping this waste, what type of geological formations which are worthy of locating or depositing or throwing my waste, alright, we call this as the worthiness of the candidate repository, selection of the site becomes very, very important.

If India has to become a nuclear measure, we should be having more and more disposal sites, clear and that depends upon the attributes of the waste which we are generating, selection of geomaterial itself which are generally termed as barriers, covers, protective layers and so on, from where this type of soil will come, how would you place them, how would you make covers out of it, so that nothing goes out of it, no radiations go out of it, water does not come into the system and so on.

Post closure response; having done all these things you know, disposal, how the waste is going to interact with the geomaterial, it is a huge question and truly speaking, these processes are going to occur over several 10's and 100's of years, so when you are designing these type of systems,

time becomes essential. Remember, in the last lecture; I was talking about the environmental impact analysis has to be done in 2 domains that are time domain and distance domain.

So, x, y, z, t becomes my motive, so if at all this type of leakage take place, how the geo environment is getting affected up to what distance, up to what time, another way would be after this much time, how much would be the impact, so this is how most of the establishments are designed, clear and then comes the monitoring. Once I have disposed of everything, how would I monitor whether the system is behaving alright or not?

So, if you understand all these steps, this is a very complicated thing but very, very intricate but very you know evolving and it is basically, it catching the attraction of several guys nowadays and this is where we talk about THMC; Thermo hydro mechanical, chemical interactions. I think I have already given you enough feedback about what is the thermal effect, the waste might be at elevated temperature, how the hydraulics of the trash is going to come in the picture at high temperature.

How the mechanical property are going to change, compressibility, shear strength, consolidation and so on because of chemical interaction, the second one is THMC and B also I have added to this, biological, so this is what is the coupling and communication which is the order of the day, everybody is trying to master this and I hope you can understand why this subject will becoming more important because this has a strategic importance, this has of commercial significance and so on.