Geoenvironmental Engineering (Environmental Geotechnology): Landfills, Slurry Ponds & Contaminated Sites

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Lecture - 07
Principles of Landfilling

Welcome back to this class. We are going to make a little bit of a gear shift. Last time we were discussing integrated solid waste management and how to reduce the waste reaching the ground. We now enter into the core domain of land filling, of placing the waste on the ground, and where we have to do a lot of design to ensure that the waste does not harm us all or the people or the habitat or the animals or the vegetation which is around the waste. So, the next 50 minutes we will be discussing on principles of land filling.

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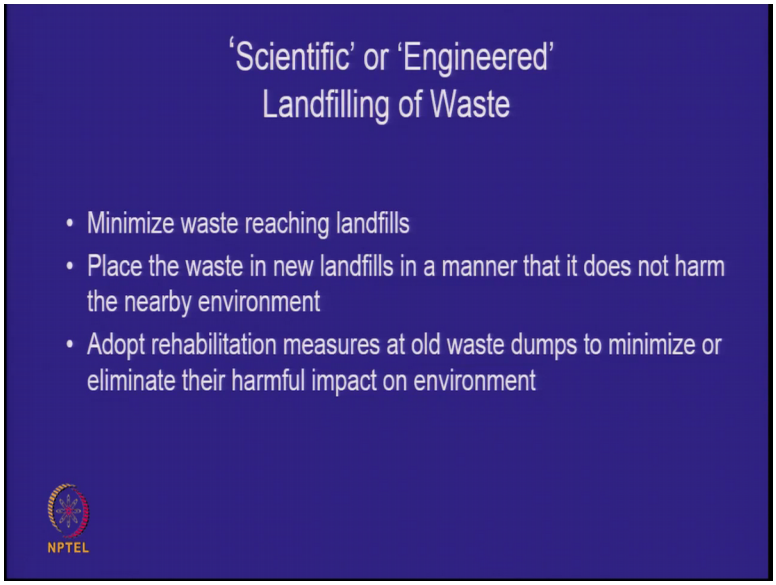

So, the underlying principle is minimize the waste teaching the landfills and that is through integrated solid waste management. We have to close the tap. We have not to put a lot of buckets at the end of the overflowing bathtub to control. The water scientific or engineered landfilling is basically placing the waste in such a manner that it does not harm the nearby environment.

So, minimize the waste, the waste which is still going to come we place in a safe manner. If we have old waste dumps, then scientific or engineered rehabilitation or control of the waste dump implies, adopt rehabilitation measures at the old waste dump to minimize or eliminate the harmful impact of the dump on the environment. Now please understand the old waste dump has already impacted the environment in the past.

Let us, say a dump has been there for 10 and 50 years, it has already made an impact, but what would we like to do first we would like to ensure that it does not spread the contamination does not spread and finally, we would like to ensure that the waste dump or that land which is beneath the waste dump goes back to it is original pristine state. That may be very difficult, but the immediate measure always is to contain the spread of contamination.

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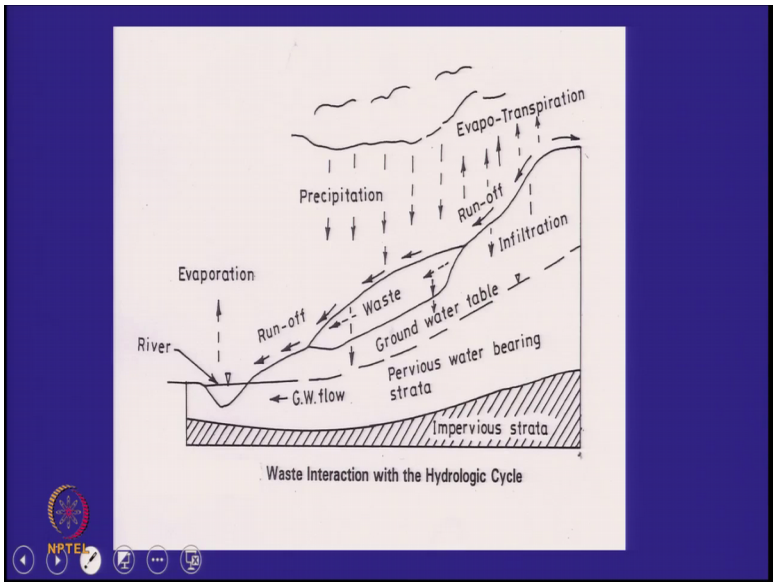

We have done this before, when you place waste on the land, it becomes a part of the hydrological cycle precipitation, runoff, seepage through the waste, ground water contamination, surface water contamination, the water evaporates, becomes clouds precipitates again and so all the time the waste is a part of the hydrological cycle.

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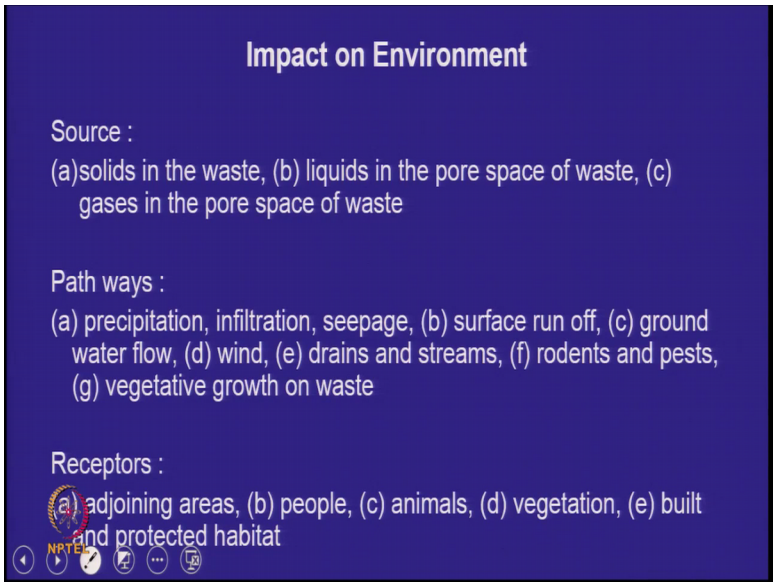

The waste is a source for contamination. The solids can cause the contamination, the liquids in the pore space of the waste can cause contamination and the gases in the pore space can cause contamination. Path ways precipitation infiltration seepage the leachate will cause contamination. Surface runoff can cause contamination which is passing partly through the waste or top of the waste.

Groundwater flow will be the pathway; the wind can carry the bad order the gases which are generated from a waste dump. The drains and streams can carry the surface runoff. Rodents and pests which are much larger in numbers on waste dumps than the natural environment; they also become the pathways for contamination. And sometimes you will find that on the top of the waste we may put soil and then do vegetative growth on it.

So, that vegetative growth or the grass becomes a part of the human consumptive cycle that or the animal consumptive cycle that also is a problem. The receptors are adjoining areas people, animals, vegetation, and the built and protected habitat.

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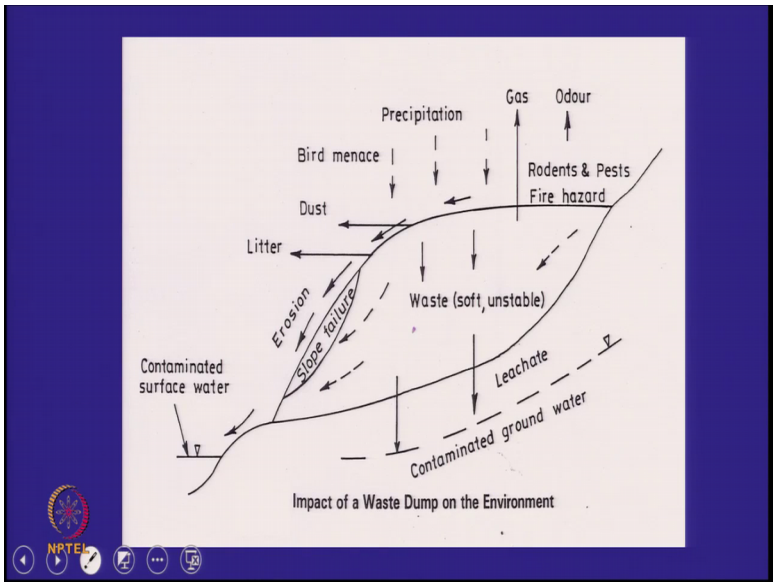

So, we have done this before, the moment we put the waste on the ground, these are all the things that are happening. And our job is how to prevent this from happening. The most critical one is the issue about groundwater contamination, because everything else moves away. You have gas, you have odor, when the wind will come it take it away, you have contaminated surface water when the monsoons will come the river will get washed, but this just remains where it is.

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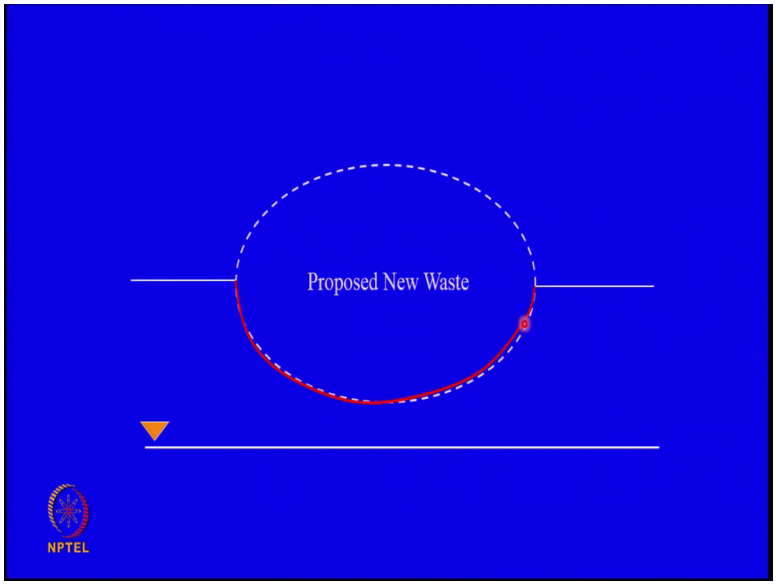

So, let us say I have a site, where this is the site that is the water table at that site. And I am planning to put my waste here, which means I will excavate the soil. So, that I can make more capacity and I will go above the ground level in place in the waste. So, this is just a conceptual diagram. I want to place the waste in such a manner that it does not impact the groundwater (Refer Time: 05:32).

So, my immediate reaction is, why do not I put something impervious at the bottom of the waste. If I put something impervious, the leachate will not go into the groundwater. I have then isolated the groundwater from the leachate, but what happens? If the leachate it cannot go down it is start accumulating inside the waste.

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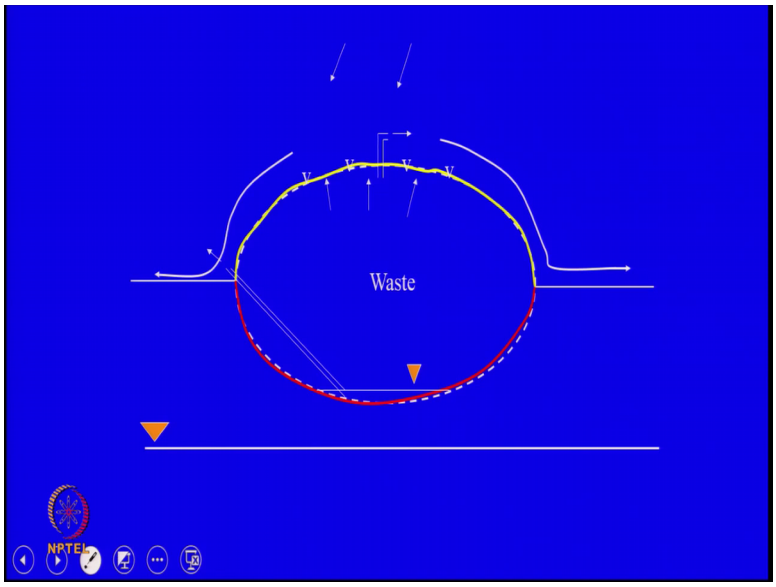

And then what will happen? Will become full, then what will happen, it will spill over. Because rain will keep on coming every year and the leach it will keep on ponding up inside the waste. Then look like a great solution. Well then let us look at it philosophically what next will you do, let us prevent the rain from coming in, if you prevent the rain from coming in great you will not have more Egypt.

So, all problems are solved. So, I need something impervious at the bottom and I need something impervious at the top. Do you understand some problems? Let us see. Even if there is no rain, the waste is wet it is food waste it has liquids in it. So, after some time those that liquid will squeeze out from the pores, because you have got normal stress acting on the waste. And this leachate it will collect here. A little amount pretty

concentrated, typically you can just see says concentrated the line solution because at least the salt will come out on it.

And if it is this problem, we should not be bothered because we have an impermeable liner at the bottom, but often given you this example that the roof that we make on top of us, is only as impervious as the drain pipe which is operational. That means, the roof is impermeable as long as the water falls on it and drains off into a drain pipe. So, both the drain pipe of the roof gets clogged then the water gets pondered on the top. If you have a ponding of the water on your roof for a day or 2 you find wet patches coming under the roof so that means, those concrete is impermeable supposedly.

So, it means that it is very it has low permeability, but it has some vulnerability. So, if my leachate is going to remain bonded on this impervious material, say for a month then I have a problem it will leak. So, I have very few materials which will not leak. Maybe we will discuss this when what kind of material we should use, but be ready to answer all these questions if I use a metal sheet and aluminum sheet what is the most impoverished material and will it leak or not you can use concrete bitumen clay will discuss that, but it all leaks.

So, this is not a solution, we need a drain pipe. So, we need an impervious material which is not immediately allowed the leachate to go down, but whatever accumulates on it we want it to run away. So, in a conceptual form, can I have a drain pipe below, you can only have a drain pipe if you are on the roof now because then water will flow down by gravity, but if you have below then what will you do? You have to pump it out there is nothing else you can do about it.

So, I did ask you to dig and go below, you did it yourself you said I want to store a lot of waste. I only this much area of land and let me go and put the waste below the ground, I never asked you could have putted above the ground you could have made a multi story building and put wasting it. I am the saying that what are the alternatives available try.

So, I need to put in a straw or a pipe which will then remove this leachate as and when it is accumulated. So, it is this remember, just remember your bathroom floor. You take a bath that is the water remain on the bathroom floor, you have a pond of water. Why because it all goes to a drain pipe, but they would drain clog, you are using the shower at the top and your feet are not coming under water. And then you know drain pipe is

clogged they gotta clean it up, but otherwise the flow is the floor of your bathroom horizontal or inclined.

Student: (Refer Time: 10:00).

Is it inclined in one direction or 2 directions?

Student: (Refer Time: 10:05).

A 2 direction- because one direction cone will take water from one side of the room to the other side, but it has to go to a corner. So, there is a double integration to your floor. So, that all water will go to the corner which has the drain pipe. So, you have to build something like that, all the water should come to a corner you should be able to send in your straw to that corner and pick up and there should not be anything left on the top. So, if you have a nice bathroom floor, which is dry when you go home then you like the builder, but if you have a bathroom floor which is got a small negative slope; that means, 80 percent of it is dry, but in the corner there is a wet patch you know what kind of a builder wallet right. And we do not want that wedge pads because eventually that wet patch will leak.

So, we want a beautiful floor where everything runs off to the corner that is critical to a good (Refer Time; 11:01). We have very happy, but what starts to happen is, that there are reactions taking place inside the waste and gases forming by methnazation is taking place anaerobic reaction, methane is form, carbon dioxide is formed. So, like a balloon when you put an impervious thing at the bottom, and you put a impervious thing at the top and like a balloon your waste begins to bloat up.

And I tell you methane is very explosive. In every now and then sometimes the explosions and sewer lines why because methane gets fire. So, I didnt want this methane to bloat up. So, what will it start to happen is it will want to come out from this pipe, but these pipe is for the leachate collection it is under the sump, which is always under the leachate.

So, this does not work as a gas release chamber. So, I have to put another straw (Refer Time: 11:56) more like a went, shut make a make a went at the top. So, that the gas came it. And I am not allowing the gas to escape, I am collecting the gas see the leachate

which I am going to pump out I can put it into a drain because there is contaminants in it. Similarly, the gas which is coming out it is a greenhouse gas; I can not let it go. So, I collect this. I collect this I allow the emissions to come out along controlled pathways.

Please understand this is critical to the design. I must have pathways the emissions should go towards the pathway, and I should be able to collect it and then later do whatever I want to do with that I want to treat the gas, I want to flare the gas, I want to recover energy from it I want to treat the leachate, whatever I want to do, I want to recirculate it I should be able to collect these things.

So, this is good. So, far now I think I have a nice a I have a nice representation of what you want to do. Or is there another alternative of handling this. Let me finish this first will tell you what I think then we will all discuss will go back to your kitchen and see how you handle your waste in your house, and then we take the simile from there. As well after I have done this I need to ensure that whatever water falls on this it runs off, it does not remain at the top. Let me explain. This waste is biodegradable it will eventually settle right.

And what happen to the cover the cover will become like this. It will become can at the moment the cover is convex upwards. If the center of the cover begins to settle with time and you know settlements can be pretty large with municipal solid waste 20 to 30 percent of the height that is a huge amount of settlement that is not the settlement of soil because the biodegradation reduces the volume of products.

So, it is possible that this cover will become like this it will have a depression. Now if you have a depression at the top it rains. And if it rains it will pond. So, you have to one maintained the convex shape; that means, if it settles you have to fill something. And secondly, you have to have an efficient surface runoff system. It is very important it is like you know trying to keep your cricket field right, when the rains are coming. You want your one day match to start or 20 to start.

So, he says to hour delay, after that the pitch will be dry. So, you say have, I would have made a pitch we should dry off in one hour, why? I will put more drains underneath; water should come from one end of the field to the other end of the field traveling 100 of meters. So, the issue is still the same here I must have a system which allows the surface

order to drain off as quickly as it falls on the top. It is like the roof it should be inclined, it should be no ponding a wall.

So, we have a surface water drainage system. I mean this I just want you to understand that this this horizontal width what do you think is the size of this horizontal width. It may be a football field or 2 football fields. So, you may have to put in a lot of drains intermediate surface water catchment rains to make this water run away. And finally, I do not want my cover to erode. I mean, I you say, soil, and soil will started rolling every time it rains, because now you have got a convex sloping shape. So, therefore, you need vegetation. So, you need a erosion resistant cover. You need a cover which is has vegetation on it. All you need a cover which does not erode. So, that in essence is what is the principle of landfill.

Now, let us discuss it, can we do something? Better remember that, this can we do something better. The waste that we are getting has all the recoverables remove from it, right. So, let us not say can we reduce it or make it vanish, I am only talking about the 30 percent waste of 40 percent waste, which is coming, can we do something else to this. It is open for your suggestions. This is one way of doing it, this is some kind of philosophy. So, you think you can do something else? Well let me put this in perspective. You have a dustman in your house in your hostel room or whatever. So, there is a strike by the carom sharis there was one strike, in east Delhi municipal corporation it was coming in the papers right you remember, but this strike is special you cannot throw the waste outside your house.

So, a little guys not going to come for the next one month; so let us see what solution? Because that is the solution we will adopt for the landfill. You are living in a house every day you are eating you are doing the cleaning of your house, the sweeping of the house repair work. So, for 2 months, this person will not come to collect the waste you cannot throw it in a bin because the big problem what will you do with the waste for 2 months. After 2 months somebody’s going to come.

Student: (Refer Time: 17:40).

Wonderful, so you will compress it to form a cylinder and put a piston in every day you will compress it. It compresses some liquid will come out you will put it on the drain. So,

he will compress it and store it. Store it I do not know how? You have compressed it now here is the waste.

Student: Plastic (Refer Time: 18:00) plastic bags.

Plastic bag: so he is got a plastic bag in his mind; pretty good. Plastic bag your dog will come and it will scratch the bag and start eating the stuff because you had very nice non vegetarian yesterday. And all the egg products are lying in the bag, but if not the doubt dog the cat will come and so what will you do to the plastic bag?

Student: Some isolated (Refer Time: 18:28).

So, you will dedicate now one of your bed, one of your bed rooms for keeping the waste. So, what else I mean we are living in a one bedroom or 2 bedroom flat and you know nobody is going to come to collect the waste. So, what are you going to do about it? No I at least you will do something about it, that is that is one of the ways you can do about it that compacted put in the plastic bag, that is not compacted let us put it in a plastic bag. In the plastic bag you know you will see after some days some black liquid at the bottom. So, you want you are not. So, sure plastic bag is designed to be waterproof enough for a month or two.

So, you will put 2 plastic bags now you do not want the leachate to come out and you do not want the smell. I am very sure you do not want the smell is not that right? Then professor Datta the as told you that after one month that bag will become because there will be gas inside, any other thoughts?

Student: (Refer Time: 19:26).

Sure. So, if you have a lot of plants in your balcony which several of us do not, then I can use it.

Student: (Refer Time: 19:37) plastic bags and (Refer Time; 19:40).

No first we are having every day the garbage. So, you are wanting to use all the garbage in your plants is too much. Even if you have 10 pots or 15 pots in your balcony after some time, they will fill up you can only use this as an addition to the soil not to replace the soil. So, yes she is back to minimizing the waste. She is back to using the waste as

compost is whatever pub you can have a composting plant in your house, you can have a bad methnaztion plant, I am told at a very small level in your house. So, you still with the plastic bag, any other solutions; more I think about is plastic bag, this diagram is also beginning to look like a plastic bag to me, know you say leachate the liner at the bottom there is a cover at the tour just think over a huge plastic sheet. So, it becomes a plastic bag is that what it is? Yes, it is.

So, if you do not get waste pickers to your house and you cannot throw it out of your boundary wall, you will put your waste you do not want to smell it, you put it into a thickest plastic bag or 2 3 plastic bag and you will close it from the top and if the issue of the gas coming out you will put a straw at the top, but then you will put it in a pipe which is outside your window. And you will put it in a drum, I mean suppose every day I am using is this alright is this an enough waste coming out every day. So, I need to put sixty such packets and I have to keep. So, I would not use a full room I will buy a big drum, you know a plastic drum.

So, that the dog cannot come in, and I will put it into it and there will be a pipe which will be. So, I will have one plastic bag then the second plastic bag then the plastic drum outside it that will take another leachate, I am sure it would not come out. I am bothered about the plastic bag having a lot of gas first I will wait and see whether in 2 months is a lot of gas going to form or only professor Datta was giving some wild theory, that it evolved it may take longer. So, I do not know how fast the processes will these are you in a cold climate, I you in a wet climate I in a hot climate definitely hot climate processes will be faster. So, if there are issues of that and I have to put a straw. So, that the gases or I have to open them periodically.

So, the gasses extinguished otherwise I just put it into a lot of plastic lot of impermeable, I am isolating it from the environment. Is there another solution? So, when we have another solution, we will look for it. Till that time this is the only solution. That we have this is the only we have to converted into engineering this is all philosophical to the principles.

So the difference is you have a small plastic bag, I have a big plastic bag. How big is my plastic bag? One kilometer wide, one kilometer, long 40 meters high and that is my plastic bag. That seems like a very huge plastic bag. Can you build one with no leakage?

That is the challenge that is the challenge. So, you can do micro encapsulation in small plastic bags and put all the small plastic bags in a big landfill and say all right my plastic bags on or you can have one big plastic bag.

But let me tell you the surface area of a big plastic bag is less than a lot of small bags inside a sphere. So, therefore, the economic solution is to have a big bag. It is not a plastic it may be made of soil for all you know it may be made of concrete it may be made of metal, I have no idea. Whether it is a syntax poly tank or whether it is what, but at the moment it has got impervious things here, and impervious things at the top.

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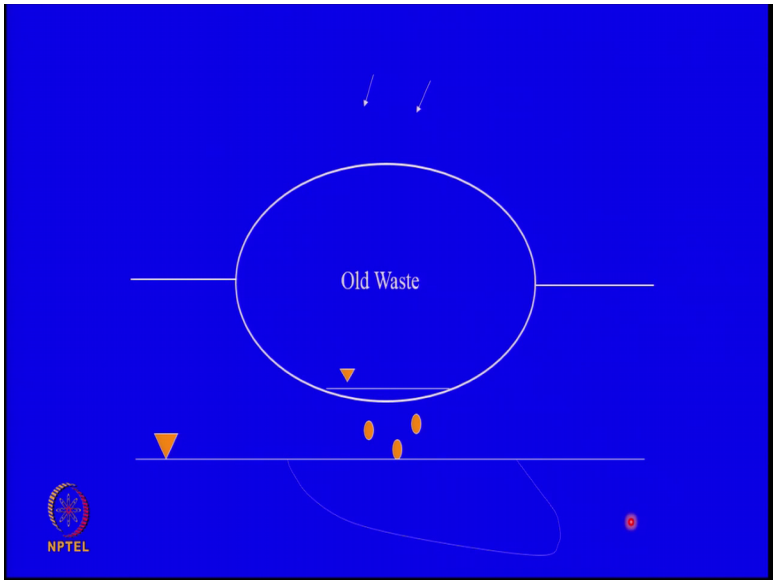

Let us go forward. If I am old waste, then I am stuck, because an old waste, already the groundwater is contaminated. I hope you can see this line clearly it is a little thin, but this is a the contaminant clue.

So, in the old it has been there for the last 15 years, rain has been falling and pollutants have been going down they travel very slowly. So, they havent runoff from the site they are still beneath (Refer Time: 24:23) a little beyond the waste underneath.

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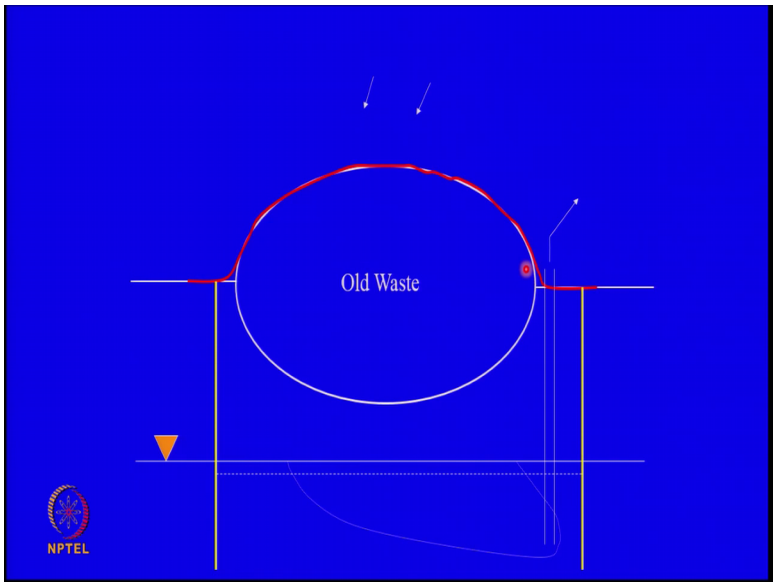

So, the only thing we can do is, we can first try to prevent any more water going into the waste. You can put a cover, and then we can try to prevent this flu from traveling in the downstream direction by putting a vertical cut off wall here, and a vertical cut off wall here. So, if you want to look at it in plan, if this is my waste dump.

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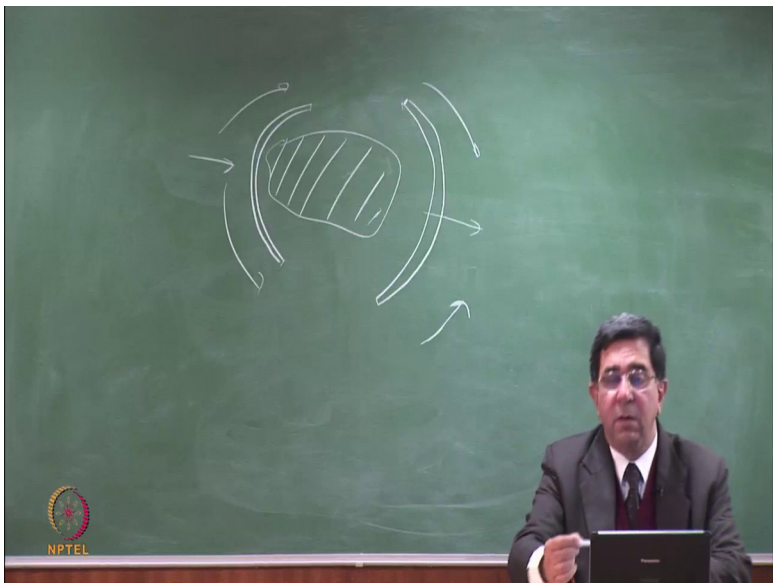

I am looking at the waste dump in plan, and the groundwater is flowing like this. Then what am I saying is I will cover this, and I will put some kind of a cutoff wall here. And I cut off wall here. So, at the moment the groundwater is flowing below the waste, and

therefore, it is carrying the contaminants towards the downstream side right. When I put this the tendency is, it will bypass the area.

So, for the spread of contamination may be limited so that is what is the concept which is depicted here. The concept of vertical cut off walls or vertical impervious walls. Ideally of course, I would like to have a impervious layer at the base of the contaminant plume as well; however, it is very expensive. It can be done, but this is a solution which is normally not possible. So, what we try to do is, we try and take the vertical cut off walls to as deep as an impervious layer if there is one at the bottom.

Otherwise these are hanging walls does not matter. So, typically the solution takes this form. If you do not have an impervious layer at the bottom, I put the vertical cutoff wall here I put the vertical cutter wall here. And then I pump out this contaminated flume using a well. So, the idea is, I reduce the water level inside these walls and therefore, I do not allow anything to travel out. This is called pump and treat methodology, put a cover amount of leachate being produced is greatly reduced, put cutoff walls the flow of the groundwater beneath the waste is reduced, pump out the contaminated plume and treat it and re inject it.

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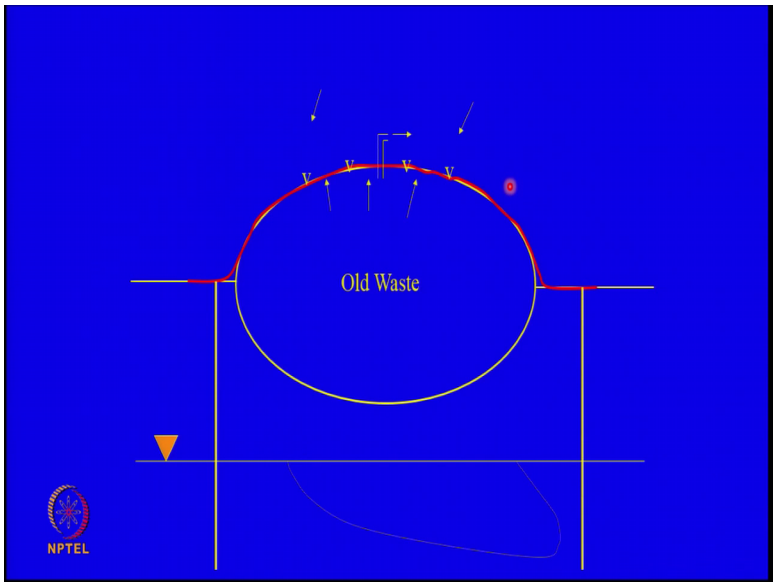

So, that you get the flesh, good quality water back into the soil. And at the top you have to do the same measures you still have to have a gas collection system. You still have to have vegetation. So, that you have a cover which is not eroded with time. So, that is the

concept of control for an old waste dump. The peculiarity is that instead of having a liner you need a vertical cut off wall.

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So, what we have said so, far in terms of philosophical term is to reduce the environmental impact we should isolate or contain the waste in an impermeable barrier. That is the philosophy that we have said here. You do not like it we are ready and open for another philosophy, but at the moment that is the only one you have got. Actually we would like to homogenize things. We would not like to encapsulate you know separately, but once you try and homogenize waste into the soil you might will be passing on the contamination to the soil.

So, at the moment it is isolated or contains the waste. Do remember that no matter what material I make including this very beautiful membranes of polymer, infinite isolation is not feasible. Good barriers perform well for 50 to 100 years, but cannot last 1000 or 1000 years. So, we do not have a material which will last for geological time frame, your I mean just look at your grandfather's, great grandfather's house. They made it out of concrete or brick or lime and surkhi and what, but they thought they were building a house for 100 years, but that is about it that house is not going to stay for 1000 of years.

What we see which stays for 1000 of years are these old forts. How come they stay there for 1000 of years? They are not made of concrete; they are made of rock segments of broken pieces of rock. Rock is a material which will stay for 1000 of years. It is been

made over a long period of time. And basically what will happen the jointing material will fall off.

So, even in the old forts what is falling off? The rock segment remains unaffected, but whatever was used as the joining material that peels off with time. So, infinite isolation is not possible. So, we again come back to this diagram, which is what we were not happy with we do not want this, I do not want to be next to this dump.

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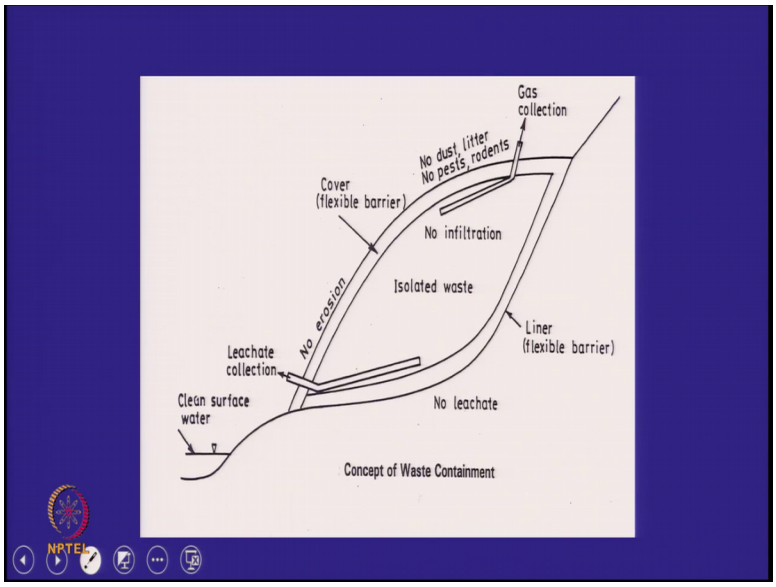

And this is the concept. This is the concept of land filling. You put a put a flexible cover or a (Refer Time: 30:13) barrier at the top, you put a flexible barrier or liner at the bottom; nothing can come it nothing can go out; so no leachate, no surface water contamination. Collect the leachate by a set of pipes; collect the gas at the top the set of pipes. It does not affect cleavage it is environment, but as I said after 50 to 100 years these barriers will not perform as well as you have designed them. And by that time the waste should either be stable or we are just looking at this as a temporary placement facile.

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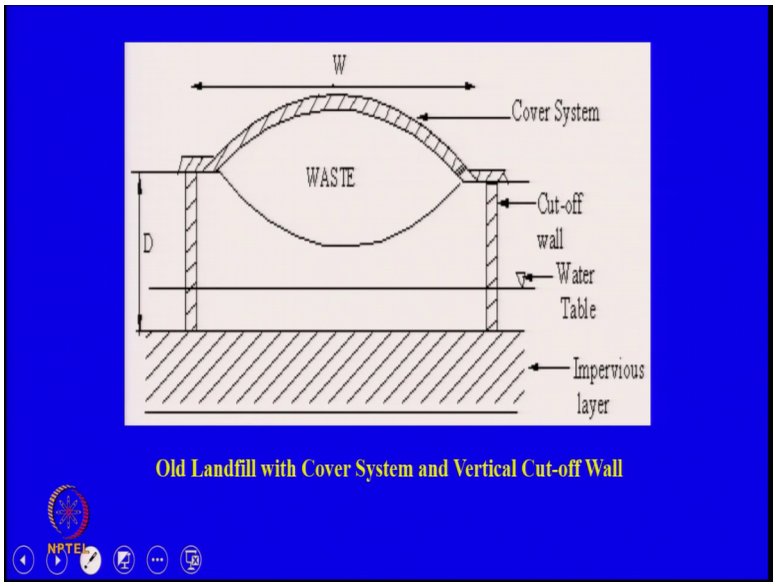

So, that was this is the solution for existing old waste. And if you can get an impervious layer at the bottom then the vertical kind of wall should reach the impervious or a clay layer at the bottom

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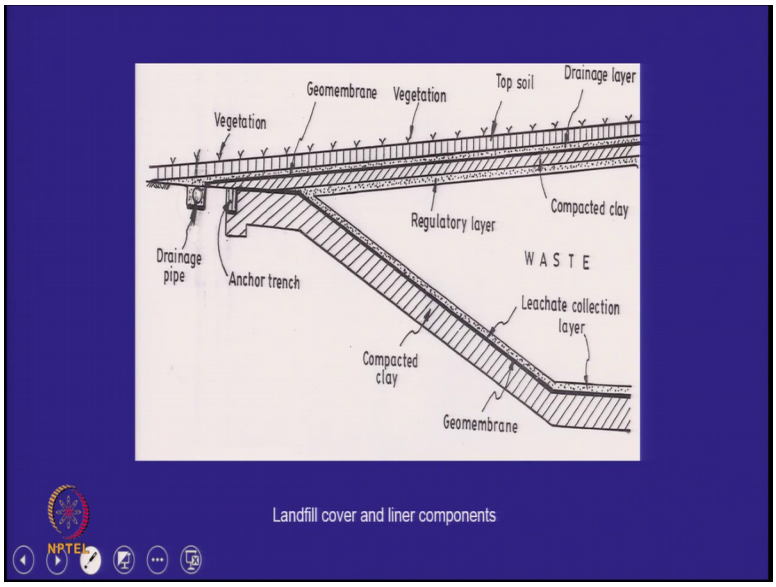

The important thing to see is, and I go back we are looking at this first. This is what it is conceptually and this is the engineering. See the cover is made up of multiple layers and we will we will come to the end in the detailed design, but the cover and the liner are made up of multiple layers. And these multiple layers are required for containing the

waste and preventing the spread of contamination. So, let me try and articulate this. If you put a waste in a scientific or an engineered manner on the ground you create what is called an engineered landfill.

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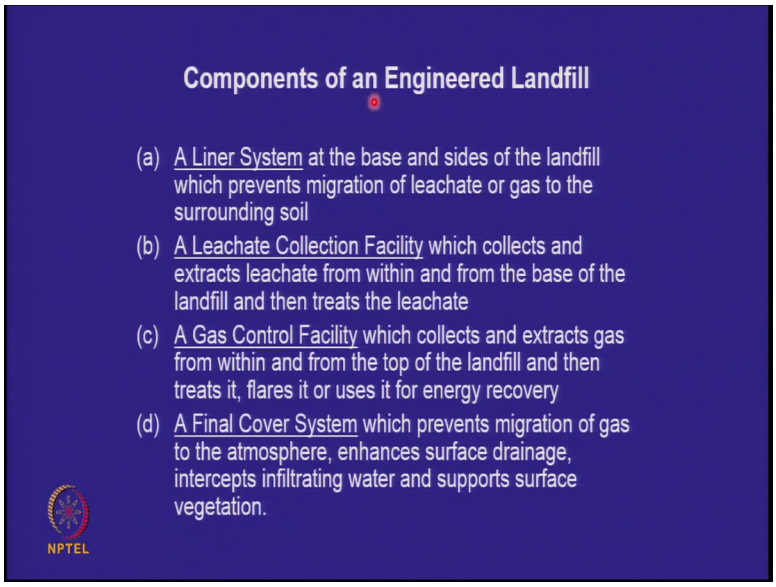

Now the engineered landfill will have 1, 2, 3, 4, 5, 6, 7, components: 1, 2, 3, 4, 5, 6, 7, components. It will have a liner system an impermeable base.

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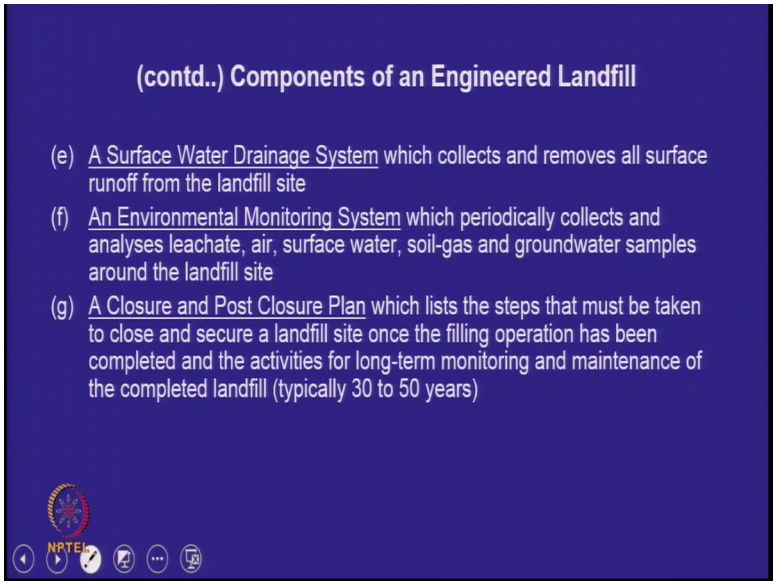

So, a liner system at the base for the side of the landfill, which prevents migration of leachate or gas to the soil; so it is impervious to water it is impervious to gas. We think if

it not being allowed to go upward should not be able to go sideways as well. You have a leachate collection facility I showed your straw, the straw which takes out the leachate. It has a leachate collection facility which collects an extra Baxter leachate from within and from the base of the landfill and then treats the leachate. So, the leachate has to be handled in some manner.

Where will this leachate go? How will you treat? It now there are several options, but we chose to go to a treatment facility; we need a gas control facility which collection extracts the gas from the top of the landfill and from within the landfill and it treats this the gas and it may flare it means you have got gas, which can be burnt. You burn methane you get carbon dioxide the greenhouse gas effect of carbon dioxide is much lower than methane.

So, you may flare it or you may use it for energy recovery. So, you actually can have a waste dump from which you put in some pipes, the gas is coming out and you can have a small thermal power plant, where you will burn the gas and get lake city and that is happening in several locations in the US. Then I have a final cover system, which prevents migration of gas. And gas will not come in your pipes if it is not prevented from escaping from the surface, suppose you do not have a cover at the top the gas can go out. So, first you have to constrain it in a balloon effect, and then it is pressure will make it go into the gas control system.

So, final cover system which prevents migration of gas to the atmosphere enhances surface drainage; that means, your cover system has to be convex upwards. Intercepts the water does not allow it to go into the waste and supports surface vegetation. So, it is not all that simple. You want a facility which looks green typically you do not want a concrete finish, why this is aesthetics issue you have these are relatively big mounds. So, when you see them from far off people are not happy with the great finish. They want a green finish. So, therefore, you cannot have a black membrane like a black plastic bag and you cannot have a concrete finish which is gray.

So, you have to have a surface finish which will then allow you to grow, layer grass or the local vegetation of that area on it. Other than these 4 you need a surface water drainage system. So, there have to be a lot of drains which will collect all the surface water falling at the top and take it away. We need to have an environmental monitoring

system. At least we should know when the landfill is leaking, I mean we are putting all the waste in a concentrated location, we have we should monitor it that the contamination does not travel (Refer Time: 35:44) beyond the boundaries of the landfill.

So, detect leakage early, is one of the concepts for this environmental monitoring. And finally, we should have a closure and a forced closure plan. You take a site in which I can accommodate the waste for 25 years right. I get 2 football fields or something maybe more and I find that I can accommodate my waste for 25 years. And after that the site is closed. While the waste is coming it is active there are trucks, there are dozers, there are excavators that are moving equipment their people who are maintaining the size the pipes the drainage systems.

And finally, it is all over. No more waste will come site has to be abandoned. If you cannot walk off a site because you still got the waste in there and you are not sure it is stable it is still producing some contamination. So, you need a closure and a post closure plan. What is going to happen to the site after you walk off, it are you going to have a golf course on it are you going to have a parking area on it. Can you put buildings on it? Intuitively the answer is no it is a soft settling mass. So, you cannot put buildings on it, but you can use it for some other purposes.

So, you must make a closure and post low your plan; that means, how are you once you have got a closure and post closure your plan then you can work out your maintenance costs. Suppose you are making a public park, people can come and you have controlled your gases you have controlled the smell, people find this is a huge open space to come under supervised monitoring they can come. So, and the revenue that you can generate from that can help you maintain the sign because you have to keep your lechate systems going lechate collection systems, gas collection systems going, surface water drains, if the surface is settling you have to set it right.

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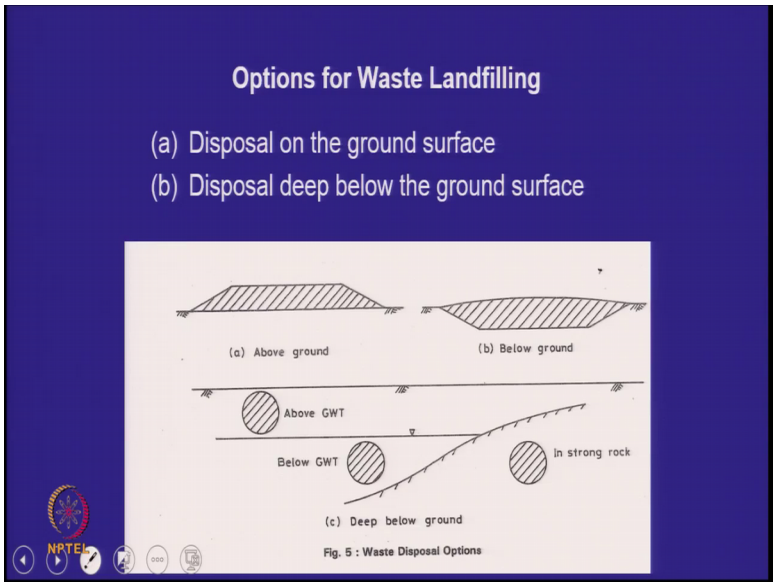

So, needed closure and a post closure plan; these are some of the options for land filling. I can dispose the waste above the ground and below the ground. So, this is all disposal on the ground surface, I can excavate and dispose it or I can dispose it above. Is there a question? You can have a combination of both; that means; you can also have a waste which is going above. So, the idea is where land is limited you want to maximize the amount of waste that you can place. How deep below the ground can you open do an open excavation.

Student: (Refer Time: 38:19).

So, eventually you will hit groundwater table if you have gone order. So, that is one factor that you cannot go much deeper than 2 meters above the ground water table level, suppose the ground water table is deep belowm how much can you excavate well, typically we like to do unsupported excavationsm I am not going to do a 20 meter deep excavation which will require sheet piles and vertical walls.

So, we will have to normally somebody may excavate I have seen it happening 7 to 8 meters with sloping ground, 7 to 8 meters is like 2 basements like 2 basements right and then above it, can we dispose of the below in cavities and rock or not, well let us look at this. So, please understand that excavations like tunneling and putting the waste in it are very expensive. Putting the waste in soil beneath the ground water table is not allowed,

because this is a totally saturated medium, but in strong rock, you may have to dispose some very toxic or hazardous wastes like nuclear waste.

So, we are disposing nuclear waste say 2 kilometers below the ground surface in strong wrong. Because strong and competent rock will not have water and we have large strength to be able to bear the any of the unusual stresses, which might get induced because of the waste.

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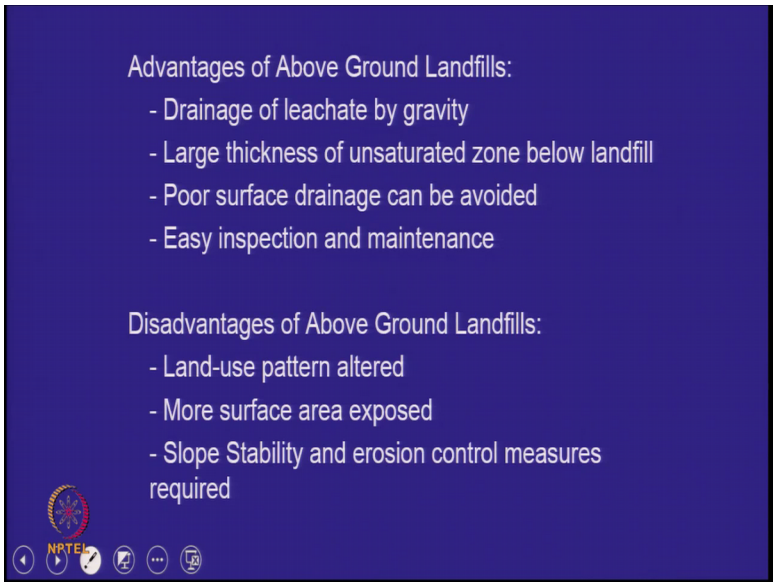

So, really we can dispose above the ground, just below the ground or deep below in strong rock. Above ground landfills have the following advantages leachate will come out by gravity like it goes off your bathroom floor you do not need to put on a pump leachate that is a big advantage. And there is a large thickness of unsaturated zone beneath the land. That means it has a lot of holding capacity right. And therefore, you have well away from the water table. Poor surface drainage can be avoided you are higher than the ground you can make a convex shape there is no issue in it, and all the surfaces can be inspected except the bottom. All the surfaces can be (Refer Time: 40:54) accepted except the bottom, but the disadvantage of above ground landfill is, you have altered the land use plan.

There was the horizontal ground; you made a mound on it. More surface area is exposed the top is exposed and the sides are exposed the top is exposed and the side that exposed. So, because more surface area is exposed, there are issues of slope stability and erosion

control. In a below ground landfill what is exposed? Temporarily the side surface areas will be exposed during the excavation and placing of the waste, but after that only the top is exposed. So, there is no slope above the ground.

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So, the disadvantages here your slope will remain there for the entire life and the post closure period. So, more surface area exposed and slope stability issues. Advantages of below ground landfills. Well if you have below and above ground more waste storage per unit area. Excavated material can be used as covering for covering the soil. Parks golf courses parking lots can be developed on the finished area; that means, the finished area is not very high. It is at the same level as the ground.

So, you can make a park or parking lot or golf course and long term slope stability issues are not an issue problem. While the of facilities under operation you may have a slope stability should have a heavy rainfall, but after it is closed, then the slopes have got waste on top of it there is no issue. The biggest problem is that you can only bring out the leachate by pumping. So, you need Alexa t and your pump should work when you put on the switch. So, we need regular pumping for leachate collection that requires external power. And good surface water drainage is required. You know if you finish the surface of the below ground landfill at ground level it will settle with time. Then there is a tendency of water to pond over it, the water from the adjacent areas can also come out to the low lying areas.

So, either you should finish it a little above the ground or you have to have excellent surface water drainage facilities. So, let me summarize this. For very toxic waste, you can dispose a deep bellowing rock. This is usually applied for nuclear waste. Otherwise hazardous waste landfills and non-hazardous waste landfills any other ground, either above the ground or below the ground. You cannot go below the ground in 2 cases when the water table is very close to the ground surface and second case when there is rock near the ground surface. Because excavating in rock is exorbitantly expensive. Otherwise one tends to dig a few meters and make a below ground or a below ground and an above ground landfill.

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So, these are the 3 options. Now what types of landfills do we normally deal with? We have hazardous waste landfills which deal with most of the industrial waste which is coming out from processes, we already talked about it and we have a non-hazardous waste landfill which deals mostly with municipal solid waste coming out of a facility. And we have inert waste inert waste landfills, where the word inert evolved is to be understood in the context of construction and demolition waste.

So, these are the typically the 3 types of landfills which are available or should be available in a city. The inert waste landfill for construction demolition waste is virtually a temporary storage facility, because you will be recycling your construction and demolition wastes after processing it, but other than that you may all have also have

monofills for high volume waste. If only one type of waste is coming out in huge quantities a thermal power plant will set up several thousand tons of waste per day, it is only ash.

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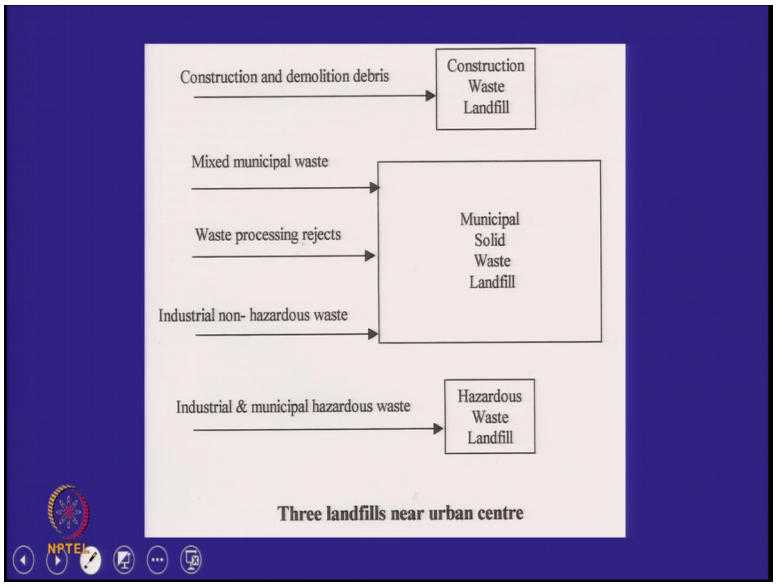

So, you can have a monofill; that means, a single in a in one single area only one type of waste, this for solid waste and industrial waste will be pretty heterogeneous with different sources. Ash ponds and mine tailings ponds are mono fills for high volume waste and then as I said the special landfills for highly toxic or radioactive waste.

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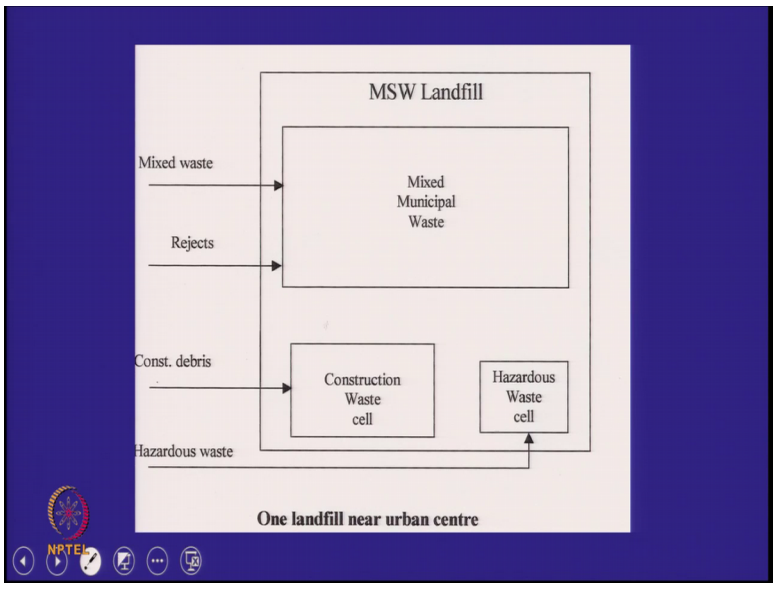

And there are 2 configurations; we have already talked about this again. All the landfills can be at one location. The municipal landfill is the biggest. You can have construction waste landfill and the hazardous waste landfill, but the maximum waste comes here right. This can be one facility, it can be monitored very closely and very accurately, but if the distances are very large, then you can have the 3 facilities set up separately.

Even a one landfill for municipal solid waste which gets the mixed municipal waste the waste processing rejects even the industrial non-hazardous waste will come here. Because if you send the industrial non-hazardous waste into hazardous waste landfill it is very expensive, the hazardous waste landfill has got most Indian mangers for environmental protection.

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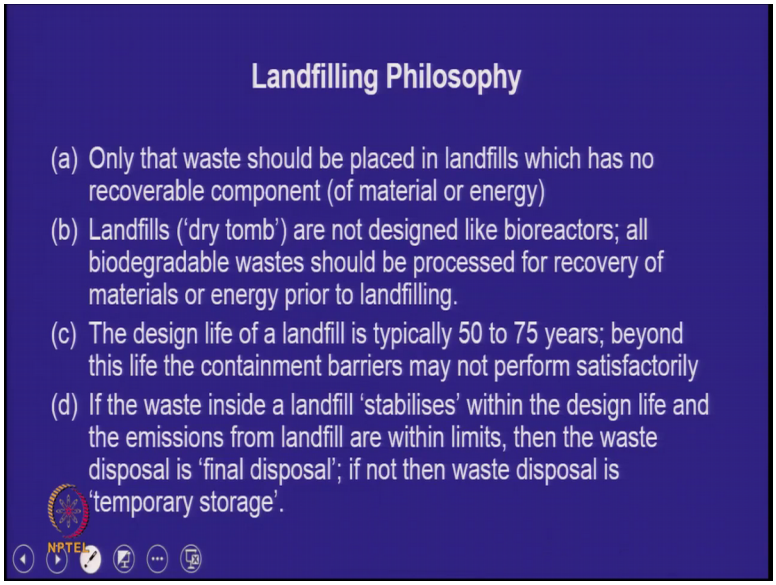

So, C and D wastes can go to a separate landfill and hazardous waste can go to a separately landfill. So, with these 2 configurations, let us spend the next 3 4 minutes on the land filling philosophy, what have we said so far. So, first aspect of land filling philosophies only that waste should be placed in a landfill which has no recoverable component. Do not place any material in landfills which has a recoverable component. If it has it has to go to the appropriate processing unit. Languages that we are talking about are called dry tube landfills.

These are in you know impervious at the top impervious at the bottom, these are called dry tomb you do not allow any water to come inside it. So, they are not designed like bio

reactors. You will hear of a term called bioreactor landfill and we will discuss it in the next class, but you should remember that if you have a biodegradable waste, it should be sent separately to a biodegradable waste processing facility.

The landfills that we are discussing here are dry tomb landfills where all biodegradable waste which was reutilize label has gone to a compositing or a by methnazation and anaerobic or aerobic composting plan. The design of a landfill is typically 50 to 75 years the same as this for this building beyond this the containment barriers may not perform satisfactorily.

Now, the impervious material if it is metal or if it is polymer the manufacturer said this is last for 3 hundred years. That is not important, when you join these metals around joints then the joints may fail after sometime. So, it is not about the parent material it is the total system how does it perform it will perform 50 to 75 years. Now if the waste stabilizes within the 50 to 75 years you know after 75 years, if you dig up the waste and there are no contaminants in it, whatever had to wash out has washed out. I have gone out of the leachate or whatever had to degrade has degrade and the gas is no longer being produced; that means, the waste is stable then it can be harmonized with the environment.

Then this waste is in it is final resting place; however, if after 50 to 75 years it still has contaminants, the leachate shows it still has contaminants the still gas emanating from it. Then this is only temporary storage and what will you do after 50 to 75 years? If it is temporary storage what will you do after 50 to 75 years. Or you will do exactly what you did to your grandfather's house. What did you do to it you broke it down and made it model new house, similarly you will have to excavate this hole material put in new liners and the unless technology has changed in 50 to 75 years, which it might and you have to realign the system and put the material on top.

So, we have quickly captured the principles of land filling. Now there are many alternate schools of thoughts in environmental engineering on how you should handle solid waste. This is one of them. You think there is another way, we will be open to have detailed discussion on, how to how to handle waste the other way. One of the terms you will hear a lot is called bioreactor landfills. So, you have a little assignment which has to be submitted by Monday. Please write a paragraph on what are bioreactor landfills. And

please tell me in how many countries are they being used extensively, just get an idea. So, how many countries are bioreactor landfills is being used. So, that will be the opening discussion that we will have in the next class. In the meantime, if you have any questions or any clarifications I am happy to.

Student: (Refer Time: 50:54).

Question being asked is when is the final curve would end is a brilliant question because. So, if the landfill is designed.

to be operated for 25 years. I, going to put the cover after 25 years. Now, we operate the landfill such that we put a part of the cover every year. So, suppose I have a very long one kilometer landfill, then I am not going to put the waste 1 kilometers. I am going to put the waste in suppose it is going to be filled up in 20 years. So, I am only going to put the waste in one twentieth of the one kilometer. And I am going to raise the ways to it is full height in that one. And at the end of the year before the monsoons come, I am going to put the final cover and next year I am going to move forward.

So, the fundamental mistake which many people make is they make a huge landfill we get funds under jnn urm for our landfills and people have got funds for 5 years of land filling 15 years of land filling and they made this huge landfill basis. And once they made this huge landfill basis and now you start filling it up, and it is absolutely wrong to fill it up in horizontal direction. You are supposed to make small phases and finish the phase to the full height and then cover it. And then go to the next that is the only way you can get less leachate and that is the only way you can prevent a lot of infiltration into old waste. If you spread, it out even if you are doing it over 5 years you are getting 5 monsoons falling on your waste do didnt operate a landfill where.

Student: (Refer Time: 52:39).

So, the intent is to have interconnected incrementally increasing landfill area. So, they are interconnected they are they are a part of a grand plan, if you do not plan make the plan correct phase plan correctly you got it all wrong. So, the question is when do we put the cover, we do not put the cover after if you have a landfill for 20 years you do not put it after 20 years you put it every year. And the second question is if every year I am operating a phase of the landfill are these independent phases or do we connect them. If I

make them independent phases, I lose a lot of airspace; that means, where I can put the waste.

So, when I put the next phase it is integrated with the earlier phase and therefore, all the systems are also integrated the cover is connected the leachate collection system is connected everything gets connected. Any other thought on a clarification on right. Then we will stop here. And we will start next time, when we will all like to understand what a bioreactor landfills and how great are they.

Thank you, have a good day.