

Geoenvironmental Engineering (Environmental Geotechnology): Landfills, Slurry Ponds & Contaminated Sites
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Lecture - 14
Covers for Landfills - Part 1

Good day to all of you, last time if you recall we finished the discussion on liners for landfills. And today we will move on to covers for landfills.

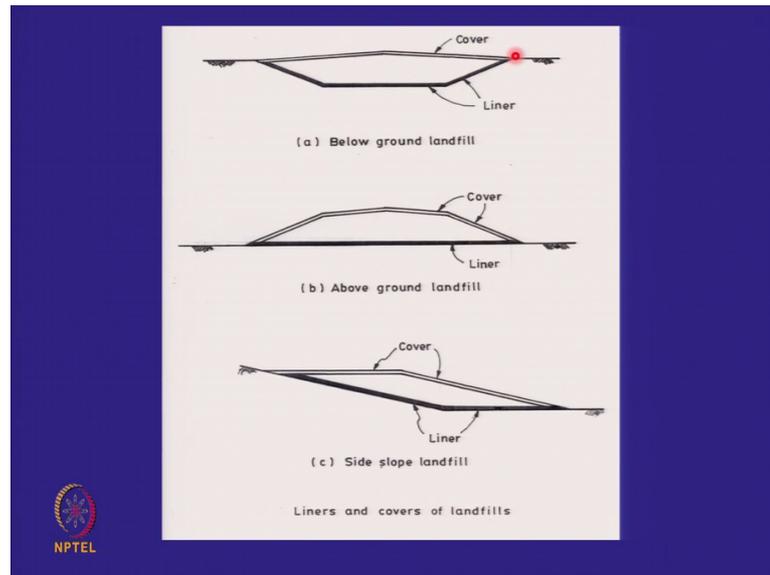
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And just to recall I mean the philosophical concept was that we will have a cover, a liner and 2 straws to take out the gas and leachate; to a cover, liner, gas collection, and leachate collection.

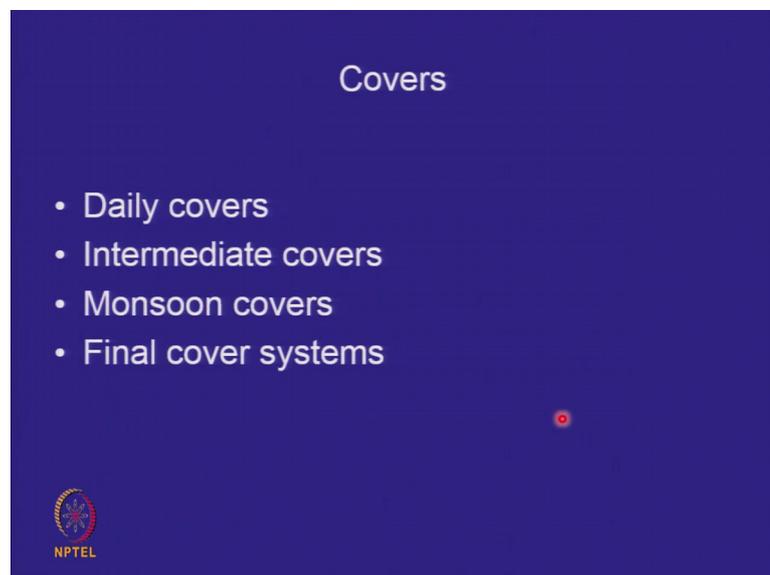
So, we have a finish this aspect, today we are starting this and in the future lectures we look at leachate collection and gas collection, but if you will recall we are basically having the philosophy of a dry tomb landfill right. And dry tomb means no water should get in and no water should get out. And no gases should get in and no gases should get out, whatever has to come out has to come out by in these 2 straws. The leachate collection pipes and the gas collection pipes, because then we can control them we can do whatever treatment and control that we want to do on these 2 sets of emissions.

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So, when you look at the cover for a below ground landfill the cover is less, for an above ground landfill the area of the cover is more than the area of the liner.

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And for a side slope landfill they may be of similar magnitude depending on the shape. And when we talk of covers you remember we talked about daily covers intermediate covers monsoon covers and final cover system. So, daily cover is; what is the soil we put on top of the waste every day and how thick is it typically.

Student: 15.

15 centimeters 6 inches 8 inches at max, whatever you can conveniently put whether dozer or earth moving equipment which is spreads soil; intermediate covers are those which are placed at the end of a phase or at the end of a year. Our attempt is to put the final cover, but at the end of the year if you are not able to put the final cover it on the working phase then we put an intermediate cover, which is thicker than a daily cover. And we will recall how thick was this intermediate cover; anybody recall the thickness of that.

Student: (Refer Time: 03:34) 60 centimeters.

In the 60 centimeters is a little excessive, I think it is more like 45 centimeters. That is the kind of a thickness that we use, monsoon covers are temporary covers put for the 3 or 4 months or when it is raining right. And these may be in the form of removable covers one they are removed after the monsoons are over , but even within the monsoons if you have a window, within the monsoons if you have a window that the rain has stopped for 2 days, and you want to place your waste and you should be able to remove it. So, most of them are like flexible polymeric covers, but they are not like thick polymers because these are temporary covers, only to keep out the rain water. And final cover systems are what we are going to discuss today.

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Functional Requirements of Covers

- (a) Must minimise infiltration
- (b) Must act as a hydraulic barrier (similar to that in a liner)
- (c) Must prevent landfill gas from escaping
- (d) Must enhance surface run-off
- (e) Must prevent surface erosion
- (f) Must support vegetation
- (g) Must withstand long-term settlements
- (h) Must exhibit long-term slope stability

 Must withstand surface exposure to loads (eg. traffic) and environmental conditions.

And the word is now not a cover, but a cover system which means it is more than one material more than one layer.

So, what are the functional requirements of covers? They must not allow rain water to get into the waste because then leachate will be formed. If some rain water gets into the cover it must encounter a hydraulic barrier similar to that in a liner. Simultaneously if you are collecting gas, for the purpose of energy recovery or for the purpose of minimizing greenhouse gas emissions then it must also prevent landfill gas from escaping. So, far when we looked at a barrier we were looking at a barrier to water, when we were looking at the liner system, but now we are looking at a barrier which must also prevent landfill gas from escaping. Of course, if you have a waste which is not producing any gas which is not biodegradable or which is not having any methane emissions then this is not a primary concern.

However, if it is municipal solid waste with significant biodegradable content then you have to prevent the gas from escaping. One of the requirements of a cover is just like a roof, the roof is slightly tilted to enhance surface runoff water should not pond over it. Similarly, the cover must have slopes which enhance surface runoff. And it should not be erodible it should not be that water flows on the cover and carries away fine particles makes erosion gullies and that kind of erosive processes must be withstood.

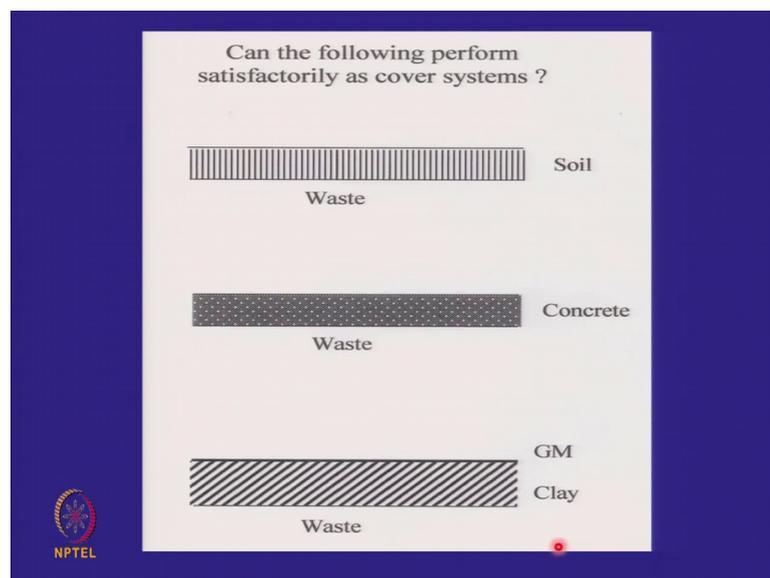
Vegetative green covers are very soothing to the eyes. So, from purely an aesthetic point of view, when you clear these large dumps or mounds you like them to have a green look. So, you must be able to grow vegetation on it now I am not saying you can grow vegetation in a desert. So, if you are in an arid climate where rain is very less we look at alternate covers, but wherever there is greenery in the natural environment; that means, there is some self-sustaining vegetation in that environment. So, we must have a similar situation as far as the landfill is concerned the covers must withstand long-term settlements now when we talked about liners we were talking about the fact that clays are flexible and membranes are flexible and they would be able to overcome the settlements in the soil, but covers if they have biodegradable waste have much larger settlements.

So, the cover should be able to withstand large settlements, if there is organic waste or biodegradable waste covers have long-term slope stability problems. If you look at this cover or this cover this slope is going to be exposed for the design life 50 to 100 years, there should be no erosion.

There should be no slope in stability the hydraulic barrier should not get exposed same thing here liner gets buried. So, their slopes are temporary. So, therefore, slope stability problems are much more in cover systems and when you are exposed on the surface for years and years design life 50 to 100 years then you should be able to withstand, if there are any vehicles which are going to move on the cover.

These may move for maintenance these may move for other purposes, extreme winds, extreme sun extreme hurricane, extreme tornados, what else; extreme earthquakes. Everything for which your building should be stable these covers should be stable as well. Liners are now buried and they are not being subjected. They have been subjected to leachate which is very different issue than for the covers

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So, can the following perform satisfactorily one of the ongoing practices in municipal solid waste disposal is to put a soil cover. These old waste dumps in the soil cover are often referred to as sanitary landfills, but soil cover is not necessarily impermeable, but it does allow you to get some vegetation to grow on it.

So, does a soil cover meet all that we are trying to say in the earlier slide? A soil cover a local soil cover a local topsoil cover will support vegetation if there is vegetation in that city, but it will not perform much of the other much of the other functions it will not be a hydraulic barrier it will not prevent the gases from going out. So, a soil does not work satisfactorily.

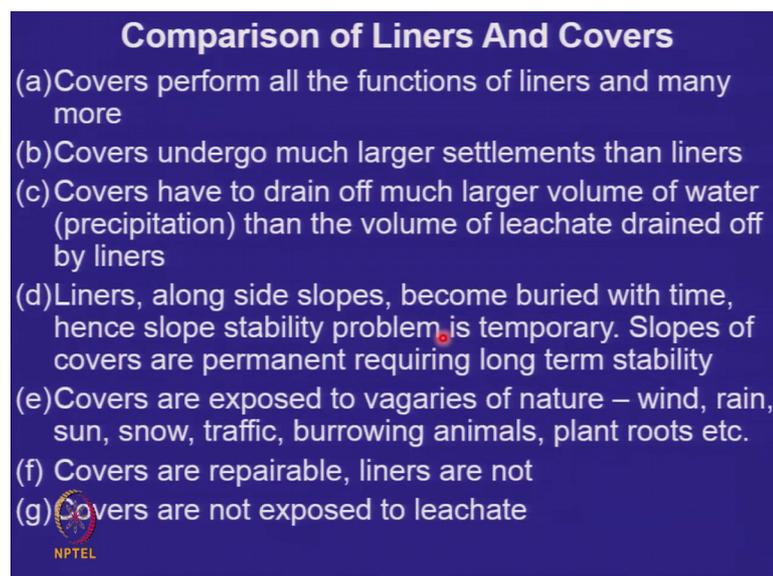
It may work on a horizontal surface purely for aesthetics, but on the side even the soil can start to get eroded. Concrete will not work on waste if you look at concrete that is it is a rigid system and therefore, it will not work on a large settling mass. So, immediately the thought comes maybe what we used in the liner. Can we use that in the cover? And did you when you when I showed you the geomembranes what was the color of the geomembrane that I showed you.

I showed you the geomembrane smooth and textured what was the color. What are the color of most of the overhead tanks?

Student: Black.

Because, if their carbon black is used in all the polymers to withstand ultraviolet rays. So, typically these polymers are black in color. You can make them colored as well, but the issue is if you use a geomembrane and clay it will be a good hydraulic barrier, but if it has to remain exposed for 50 to 100 years one is the esthetics issue that it is a black tomb the other is a open to vandalism, it is open to vandalism children will come and play on it and the people will drop something on it. So obviously, just by itself the geomembrane and the clay can be a good barrier, but it is not suitable for long term stability for 50 to 100 years the way concrete is when you can leave exposed concrete and that will survive 50 to 100 years, but you cannot leave geomembrane and clay.

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Comparison of Liners And Covers

- (a) Covers perform all the functions of liners and many more
- (b) Covers undergo much larger settlements than liners
- (c) Covers have to drain off much larger volume of water (precipitation) than the volume of leachate drained off by liners
- (d) Liners, along side slopes, become buried with time, hence slope stability problem is temporary. Slopes of covers are permanent requiring long term stability
- (e) Covers are exposed to vagaries of nature – wind, rain, sun, snow, traffic, burrowing animals, plant roots etc.
- (f) Covers are repairable, liners are not
- (g) Covers are not exposed to leachate

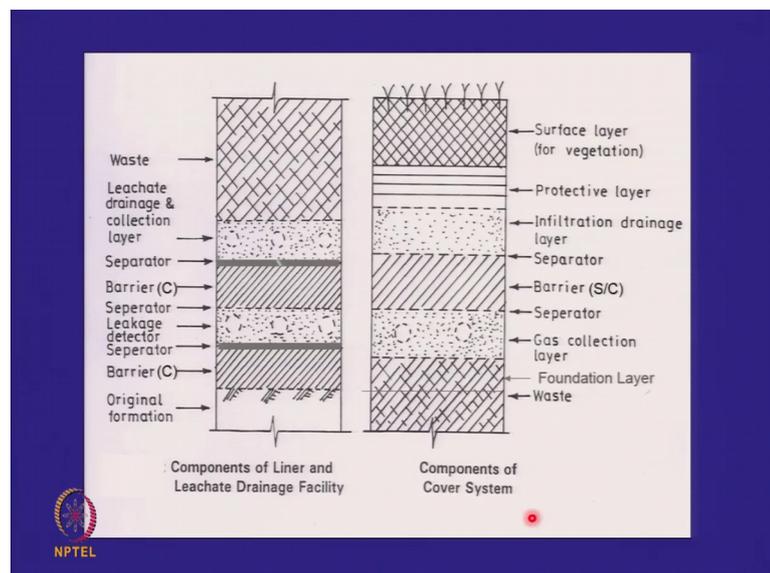
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Obviously, we need to look at this a little more carefully. So, first issue is that covers have to perform all the functions, which are performed by the liner, except that they do not come in touch with leachate. If you have designed your system well you will not have leachate coming in contact with your cover, but covers undergo much larger settlements.

So, they will be different covers have to drain of much larger volume of water the leachate that is generated is the amount of the squeezed liquid which comes out and part of the precipitation which gets into the waste the leachate quantities are smaller what falls on the cover has to be handled by the cover it is the full peak rainfalls. So, covers have to handle much larger volumes of water liners alongside slope become buried with time hence the slope stability issues are temporary, but slopes of covers are permanent and require long term stability. And as I said the covers are exposed to wind rain sun snow traffic burrowing animals plant roots etcetera the advantages covers are repairable they arrive at the top.

So, you can dig them up and repair them the liners you cannot repair especially, if a lot of waste has come on top of them and covers are not exposed to leachate.

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So, if I look at a liner let me look at the liner here first waste, separator leachate collection system, a composite barrier, then the separator on top of this if required then another separator then the secondary leachate collection system composite barrier and

the sub grade. So, that is a cover typically sorry that is a liner system which we have saw and this is a double composite liner for hazardous waste. I am going to look at a typical elements of a cover system. Because cover must have green look and vegetation on it needs to have a top soil layer, then there is something called a protective layer we look at the functions of each of these layers. If any water goes in which it will because you want to keep the grass green, if you want to keep the grass green you have to irrigated if you irrigated some water will definitely go in.

So, there is a lateral drainage layer that if any water infiltrates through this it drains out. So, that it should not stand on top of the barrier. The barrier here shown does not have a geomembrane it says S oblique C S is for single barrier C is for composite barrier liners will always be composite covers can be single barriers or composite and this we will try and understand a little more. The waste is at the bottom gases are emanating from the waste if I put a barrier here, if I put a barrier here then the gas pressure will build up. So, there is a gas collection layer above the waste there is a gas collection layer above the waste.

And there is a foundation layer what is the foundation layer between the gas collection layer and the waste is a little bit of material which is put to smoothen out the surface and to give you a strong surface for the other components to come on top, it is basically compacted local soil it may or may not be required sometimes what you may do is you may put a little bit of extra gas collection layer and say this will take care of my foundation layer.

So, in some countries this is essential in India this is optional. If your waste is soil like if your waste is soil like means what.

Student: (Refer Time: 16:09).

If the particles are not very large and protruding and furniture components; and construction and demolishing blocks, then there will be no protrusions from the waste, if it is soil like sit is in sand and size below then the waste itself can form the foundation layer, but if there are big particles heterogeneous material then you will need to put extra material on it to cover it. So, that is the foundation layer

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- Surface layer: for erosion control and vegetative growth
- Protection layer: to protect underlying layers from desiccation, frost, root penetration, burrowing animals, accidental human intrusion
- Drainage layer: to reduce head of water on barrier layer, drain water from overlying layer
- Barrier layer: to prevent intrusion of water, prevent escape of landfill gases
- Gas collection layer: to vent or collect gases generated from waste
- Foundation layer: smooth & a-grade finish on top of waste, strong subgrade for placing cover layers.

So, the surface layer the surface layer, which we saw on which we grew vegetation is predominantly for a green look for erosion control and vegetative growth. So, vegetative growth means green look erosion control means you do not want the soil to erode right. And the can we put a soil which will not erode, can you put a soil which will not erode any thoughts on soils which do not erode.

Student: Grapple.

Typically grapple will not erode, but you will not get a green look. So, you will get a huge mound with a gravelly gray look and that is the issue, but in arid climate you may have no other option because you may not have sufficient water. You are not trying to create a green park in a desert. So, we can have an ocean control other than vegetation, but wherever we have can grow vegetation that is one of the ways we do it what is the protection layer.

So, typically the how deep should be the surface layer, what would govern the depth of the surface layer, I said the surface layer will be made of local top soil on which vegetation grows. So, how thick do you think it should be 10 meter one meter 10 centimeters?

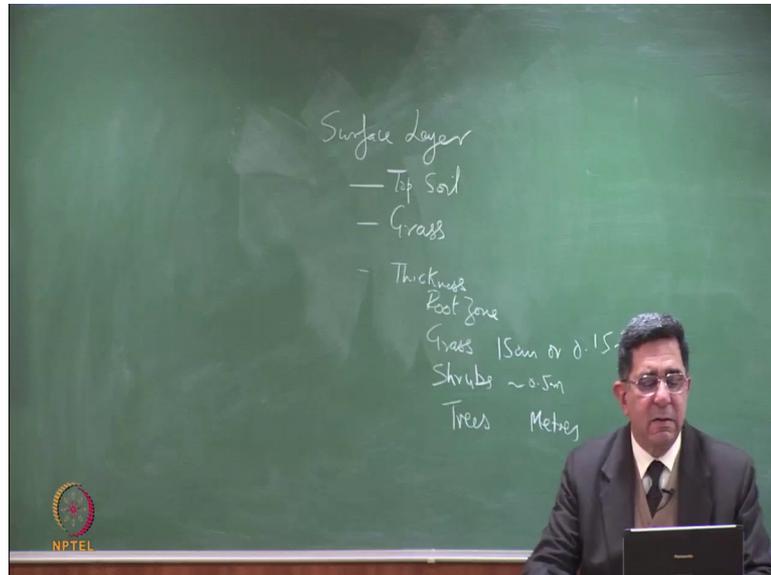
Student: (Refer Time: 18:12).

Depends on the type of vegetation; why what is vegetation got to do with.

Student: (Refer Time: 18:18).

Depends on the size of roots, so that is carry this discussion forward.

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Surface layer thickness, I said it is made of topsoil. I want to grow vegetation on it, do I want to grow grass or do I want to grow local vegetation. I want a green look let us start with grass not it is not inexpensive the kind of grass you have in lawns gariepy lawn it is not inexpensive you have to maintain it. So, we said that the thickness will depend on the root zone one of the concentration is root zone. So, if I have grass what should be the thickness?

Student: (Refer Time: 19:37).

if you say 6 inches 15 centimeters hundred and 50 millimeters right because the grass itself is not going to be taller than 6 inches. So, the grass roots are not going to be avoided, but you have been told to restore the land to it is original condition is that right.

Student: (Refer Time: 19:58).

Is that what we said that whenever we walk off after 50 years there should be original vegetation? And original vegetation can only grow if it has sufficient drool depth; so if original vegetation is a tree or is it a shrub. So, if you look at your hometown and think

about when you are traveling on the highway out of your city what do you see on the roadside shrubbery more or trees more.

Student: Trees more (Refer Time: 20:30).

So, you do not have anything on the ground it is only a tree and a brown patch beneath that. What covers most of the ground other than the agricultural field?

Student: (Refer Time: 20:41).

You have trees they are more visible because they are larger, but you will not have a canopy of trees. Some places nothing may be growing, but most places you will have local shrubbery. Shrubby may be either in the form of a little tall grass or shrubs which may be a foot high a wild some kind of a wild growth right. I do remember that I went to the Jim Corbett Park and they have a grass which is taller than me. So, so there are different types of grasses and different types of shrubbery. So, if you walk in that grass, you are always worried that there is a tiger on the other side a few meters away right. So, anyways most of the places we will have local shrubbery. If you want to grow a tree on a landfill what is the root penetration depth zone, you need sorry let us end the discussion on this. Suppose you say I want to grow trees on my landfill.

So, what is the root penetration depth that you need tree may be, how high it can be very high, but let us take a normal.

Student: (Refer Time: 21:45).

So, 3 4 meters high; a greed maybe little taller, then what do you think will be the root depth of a 3 4 meter high tree.

Student: (Refer Time: 22:03).

1 meter; so immediately please see what is happening the moment you go from a grass to a tree the surface layer is becoming very thick. So, first remember it is not easy to grow trees on landfill services because you need to put in a lot of soil. And that is a challenge because, the moment you make it very thick you have to get the material from somewhere and you have to lay it and compact it, but if something is in your mind that I want to put trees then you will need several meters if you want to put shrubs.

Student: (Refer Time: 22:40).

About half a meter 50 centimeters; so I am just giving you some figures. So, grass 15 centimeters or 0.156 meter shrubs and trees. So, trees we said in meters 1 to 2. Some people said shrubs will be about. So, now, you have got an idea as what it should be at the top let us come to the protection layer the second layer that we are talking of protection layer.

So, why do we need a protection layer below, that is going to be the barrier layer what is it about the barrier that we need to protect. So, we had all these issues can we have a geomembrane and clay at the top. I mean that is the discussion you want green finish I will give you green geomembrane. Is that fine or you do not like look of green plastic. So, green geomembranes are available and they have been tried, but eventually are you going to say nobody can walk on this, are you going to fence it off and put a and have a security guard there that see that no animal well you will prevent children from coming your fence side will put a gate, then somebody will hop over the fence then you will make the fence higher than the birds will fly from the top and then what will you do.

So, you have to protect your barrier. So, what can trouble your barrier if what is happening in Srinagar? Today lots of snow, but cars are buried. So, you have to protect your barrier from snow from rain from burrowing animals. And if you grow shrubs at the top you do not want them reaching your barrier and going through them. Because then when the shrub will die it will become a preferential seepage path. So, you have put root penetration.

By mistake somebody may start digging, somebody wants to run a telephone cable right, but now everything is mobile, but somebody wants to run a any line any utility line and he starts digging. So, we do not want the it to be damaged. So, the function of the protection layer as you can see is protect the underlying layers from desiccation frost root penetration burrowing animals accidental human intrusion or others.

And these may also be half a meter, typically half a meter. Is sufficient you know unless you are belong to a cold country they have a frost penetration depth curve in for the various regions. So, you will know that. So, much of the ground freezes, below the ground level and that is called the frost penetration depth. So, you would have to have your protection layer more than the frost penetration depth.

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So, you have to put a protective layer, and after you have come below the surface layer. And the protective layer you can put your barrier layer, and if I trying develop this now surface layer for vegetation, protective layer to prevent anything. And let us say for the simplicity of argument that my barrier layer is simple clay compacted clay. So, we will have a barrier layer. Here now your design must be like the roof, minimize infiltration by having a sloping roof. So, the philosophy is that whatever is falling should run off the best way to run it off, is to pave it if you pave it. Then the infiltration will be less than 10 percent of the precipitation, but what is the problem with paving? You can not pave it with concrete maybe the road engineers will say we can pave it with bitumen.

But do you remember what is the kind of settlement that we have in municipal solid waste landfills. I said some percentage of the weight, we had done it while planning landfill capacity do you recall.

Student: (Refer Time: 27:56).

Padarn?

Student: one point (Refer Time: 27:56)

0.1 percent of the.

Student: (Refer Time: 28:01).

No I think I said 15 percent.

Student: (Refer Time: 28:02).

15 percent of the weight; so if you have a 10 meter high landfill. So, it will settle by 1.5 meters. Now bitumen is not going to take that kind of a settlement, in any case bitumen is going to be black. So, if you want a black top coal tar pavement that is an aesthetics issue again. So, we must have a material which can take large settlements.

So, we come back again that the barrier layers have to be flexible. And on the top if you have a good vegetative cover your infiltration is going to be low. So, your inclination has to be there and a good erosion control measure also gives you low infiltration, but some water will come true because you are going to make the grass grow.

Once you are doing irrigation water is coming through and it will come and sit on top of your barrier layer. Now what you are doing at the top you again do it on top of the barrier layer, if some water comes through the grass surface layer and through the protective layer remove it. So, therefore, you have a drainage layer you do not want any water to pond up on the barrier layer the moment the water to pond up on the barrier layer what is the problem it will go through the barrier eventually.

So, therefore, you have a drainage layer which again removes the water precipitation runoff some infiltration and some lateral drainage. So, in a sense water does not stay on the roof and it goes to the toe. So, that is the function of the drainage layer to reduce the head of water on the barrier layer 0 head, and the drain away the water which is coming from the overlying layer and that brings us to the discussion on the barrier layer.

What kind of barrier layer do you want? One which allows 0 water to go in or one which allows some water to go in. 0 water is ideal in the sense there will be no leachate or only the leachate from the products of reaction and what is squeezing out. And therefore, leachate treatment costs will be a minimum, but if you want your landfill to stabilize the municipal solid waste you stop water, it will stop biodegrading. You have already stopped oxygen. Please understand when the waste is lying on the roadside at least is a it is in contact with the air shallow depth the moment you put. So, many layers of waste and you put a daily cover at the end of the day.

There is no oxygen which is inside the waste. So, it is be coming from an aerobic condition to a anaerobic condition. If I make the dry tomb landfill, then no water goes in and the biodegradation even becomes slower I can not stop biodegradation, but it becomes slower it the more the moisture, the faster it degrades the more the oxygen the faster it degrades aerobically. So, there are 2 schools of thought, for the hazardous waste landfill which does not have biodegradable which is mostly sludge and in organics most of the time, you will have a composite barrier similar to the one that you have for liners, but for municipal. But for municipal solid waste landfills you may have a single barrier.

The idea as most of the water which falls and comes through will go to the side and some percentage of it will go into the landfill. That is not a huge amount it may be 10 percent or 15 percent or lesser of the total precipitation may be 5 percent the leachate will be formed, but it will also biodegrade; so the 2 philosophies. One allows municipal solid waste landfills some water. So, that they stabilize the other is allow no water. Now if your waste is becoming totally segregated at the source and the biodegradable component is going to the composting plant, then what kind of a cover video adopt composite because there is nothing biodegradable here then you can keep it to composite. Totally as another thought maybe I would like to wash my waste, no if there are some leachable soils in it something that dissolves.

So, maybe my bad degrade levels will gone, but let me wash my waste. So, that it becomes stable. So, I had this discussion with you again this is only at a philosophical level that when the leachate comes at the bottom, you have to treat the leachate to treat the leachate you have said to send it in an effluent treatment plant or just conceptually into an evaporator let us say. So, in an evaporator the liquids will be evaporated and some solids will be left, but these solids will all be soluble.

At the moment these solids are brought back to the landfill. So, if they are brought back to the landfill the contaminant is just going round and round; if we have a technology that the solids come out of the effluent treatment plant or from an evaporator and we classify them or we do something such that they become non leachable. At the moment it is a salt when you evaporate something it is a salt you put water in it again it will become into a solution.

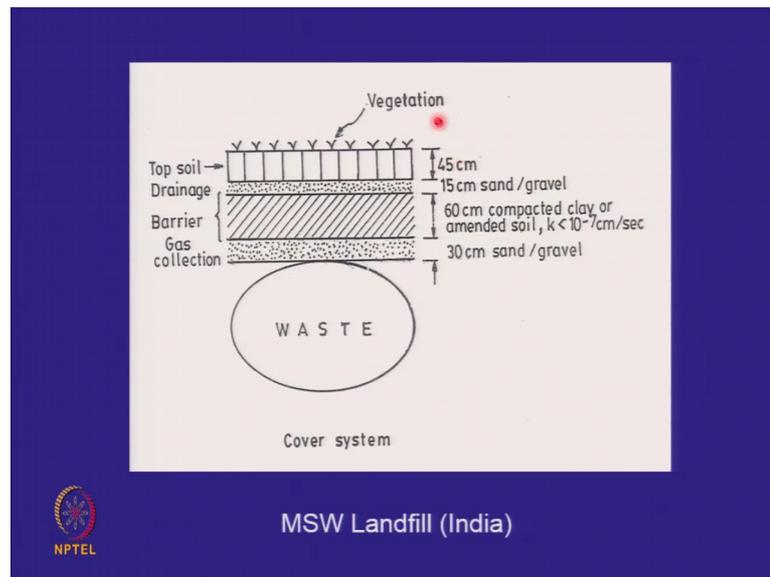
So, that we have not changed the solubility of the contaminants and I am not only talking of heavy metals I am talking of contaminants like chlorides and sulfates which will precipitate out, and the moment you bring it into the landfill then again come into the leachate; so till there is a strategy of entrapping them. So, one of the thoughts which goes on is let us put them in concrete building blocks building blocks are inert and if you put them in building blocks they will be held inside, but you can not prove to me that if you put them inside a cement block that after 100 years they will not be released.

See classification means putting them inside a matrix where they will be there for thousands of years. Manmade materials are typically there for 100 of years. So, that is the issue you remember that movie at the Jurassic park? In the Jurassic park how did they create dinosaurs? There was a mosquito inside a golden glowing resin blob. So, what had happened was that the mosquito had bit a dinosaur it had the blood of the dinosaur inside it.

So, he had the DNA. And while it was sitting on the side of a tree it rains it got stuck to the resin and the resin interrupted. Consequently, it became entrapped in an inert matrix, and you could go and take out the DNA from inside, but then this survived for thousands of years. Whereas, we have concrete, which I do not know whether it survives for thousands of years rock does. So, anyways the point is the philosophy of whether this should be impervious totally or have some little bit of allows some little bit of water in the debate which goes on infinitely.

Currently the state of the art is if you want your municipal solid waste to, if you want to municipal solid waste to stabilize allow some water. So, therefore, you have single liners typically a compacted clay liner in municipal solid waste and you have a composite liner in a hazardous waste cover. Then just like you have a drainage layer at the top you have a gas collection layer at the bottom to collect the gases. And below that you have waste. If the waste is such that there are no protrusions and no non uniformities and a dozer can make it plain and it can be compacted, then you do not need a foundation layer, but just suppose if it is your food waste. We wet soggy non soil like. Then before you put your gas collection layer which is also sand and gravel you would like to put an intermediate soil layer on it

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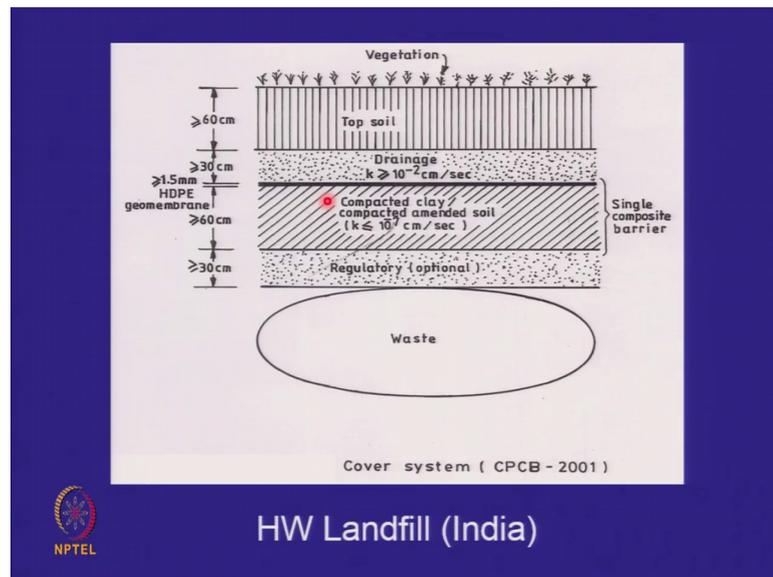
So, there is a foundation layer which comes up optional which you have. So, that is your cover system as it is adopted. So, if you look at the municipal solid waste management rules in India, here is what it has. It says 45 centimeters of top soil on which vegetation will grow 15 centimeters of sand as a drainage layer. 60 centimeters of compacted clay as was the case 10^{-7} centimeters per second. 30 centimeters of sand gravel. So, does not seem to have any protective layer, and does not seem to have any foundation layer.

So, that depends on the designer that depends on the designer please understand a protective layer. If it is made of the local soil, let me again say you are going to grow grass. So, 15 centimeters of surface layer is fine and the protective layer is also of the local soil that is 45 centimeters both things put together is called a top soil layer and here they have given 45 centimeters.

Student: (Refer Time: 38:26).

It could have been 60, but it is 45, it works both as a surface layer and a protective layer. We have top soil is very limited, there you will have a separate top soil and a separate protective layer.

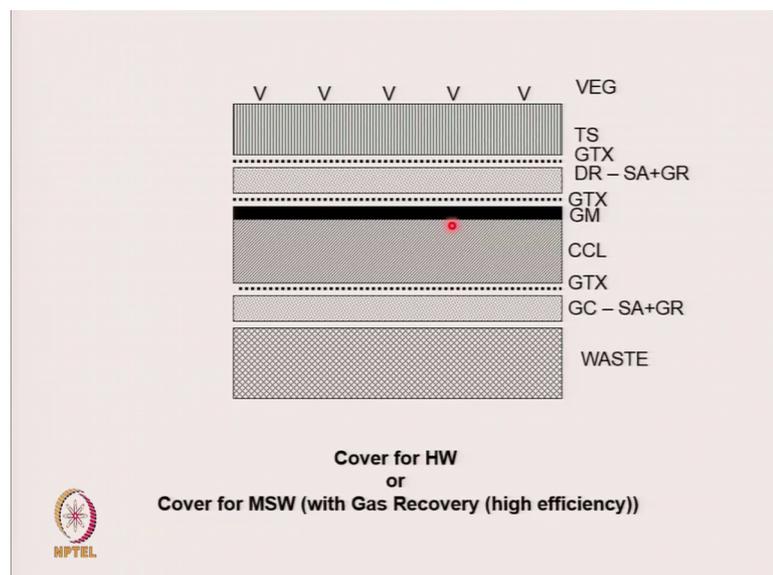
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Student: (Refer Time: 38:41).

And for the hazardous waste landfill the following other, specification now you have a 60 centimeter top soil the surface layer plus protective layer, and drainage layer of 30 centimeters a geomembrane and compacted clay liner. This is called a regulatory layer. Now why is it not called a gas collection layer there may be no gas coming out of a hazardous waste landfill? There may be some volatile organic compounds. So, it can be a gas collection layer or it can be a foundation layer or it can be both.

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So, this word regulatory layer I think comes from Germany, which they put here. So, that is for a hazardous waste cover system. And if I go back to our discussions on separators and filters vegetation, topsoil you will need a separator between the drainage layer and the topsoil right. And it should be a separator come filter it can be a geotextile it can also be soil. Then between that drainage layer and the compacted clay liner you need another separator. Compacted clay liner it is sitting on the gas collection layer another separator in the filter. So, many interfaces have to be taken care of and when you come for hazardous waste you have more interfaces; the same number of interfaces except now the geomembrane is in intimate contact with the compacted clay line.

And the important thing here is that, in this system something else is also written at the bottom this is a cover for hazardous waste landfill or cover for a municipal solid waste lands fill with gas recovery. If you are going to design a landfill to extract the gas and generate power from it, which is what in many landfills in the US you will find that they are extracting the gas and generating power we do not want to lose any gas to the atmosphere. Now if you have only a compacted clay liner please understands that for gas the permeability is higher than for water typically.

So, compacted clay liner will not be effective incur holding your gas if you are intending to have a municipal solid waste landfill with a gas collection system please put a geomembrane here because the geomembrane is much more informal to gas than clay alone. And therefore, you should have a geomembrane at the top, but if no biodegradents (Refer Time: 41:40) are going to come to your municipal solid waste landfill no significant gas not required, but if your waste stream is not segregating itself out composting plants are not able to take the waste because it is too mixed then it might reach your landfill and if it reaches your landfill. And if you want to extract gas for it please have a geomembrane in the cover system though it is not prescribed in the minimum rules.

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So, we can have a different alternatives for the various components we talked of a surface layer, it is a top soil with grass is what we have talked about. If grass will not grow maybe you will put artificial turf on it you want a green look like a hockey field artificial turf, there are artificial turfs which exist you can have geosynthetic mats. You can have cobbles, if you are in an arid climate you can have cobbles or gravel if it is available nearby. You can have paver blocks.

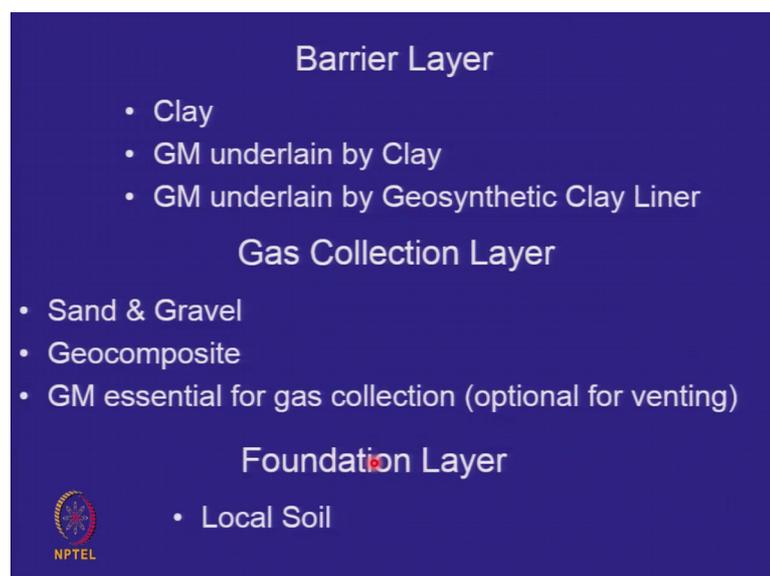
You can have rubble masonry some rubble is discarded construction and demolition waste you can put some cement and make a rubble masonry from it. Or you can have geocells with soil etcetera. So, there are a lot of our options which exist this is the most often used, because in the end you have to make your cover for restoring the land to it is original condition. If you are making a short term cover, then you can do all the other things right.

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Similarly, for the protection layer as I said mostly you have only the same alternative used local soil. Local soil can be different from local top soil. Top soil is the one on which the vegetation grows if you dig a little deeper you may not have soil on which the vegetation grows, but you can use it on the protection layer. For drainage we are going to talk about we have talked about use of sand and gravel just like the leachate collection layer above, but we also have other geosynthetics which we also have other geosynthetics which we use and we will discuss this in the next lecture.

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I will show you some of these materials. Barrier layer for municipal solid waste compacted clay for hazardous waste geomembrane underlined by compacted clay. Even when you want to have municipal solid waste with gas collection you will need a composite liner geomembrane underlain by compacted clay if clay is not available there is a tendency to replace the clay with a geosynthetic clay liner at the top gas collection layer sand and gravel a geo composite.

And I have already said geo geomembrane is essential for gas collection. If you do not want to collect the gas the gas gets vented out you can still collect it, but you are not taking it you do not want high efficiency to make energy out of it. If I am making energy, I am the owner I want 100 percent of the gas collected right. If I am just venting it, I can send the gas through vents where 50 60 percent efficiency is also acceptable the rest will go out through the through the soil layer on top.

So, remember gm is essential for collection for energy not necessary for venting the foundation layer is made of soil. So, these are the alternatives which exist. We will stop here at this point and in the next lecture we will take up what are the non man made materials, which are used to replace some of the layers that we have seen. So, far all we have done is added a geomembrane in a composite liner as an add-on to a compacted clay liner, but now more and more we attempt is to make the cover lighter less thick by putting in thinner elements. If I look at the thickness of this cover, 60 plus 30, 90 plus 60 150 plus 30 180 it is more than 2 meters thick if I look at the separators as well. So, that is a huge thickness; so known landfill owner watch to lose 2 meters of thickness in a 10 or 15 meter high landfill. So, can we make can I put something else? Can I put something else we will look at it in the next class, thank you; any questions which come to your mind at this stage?

No questions, but do remember the ones you put man made materials you have to be very sure about the life of the manmade materials, in comparison to natural soils which we can be sure, if I put sand in a drainage layer how long will the stand last what it is life generally see in discussion what is the life of sand particles 5 years, 10 years, 100 years, 100 years, 10 thousand years take a pic. At least a 1000 if not 1000, at least a 1000; if not 10 thousand geomembrane take a pic 5 years 10 years 100 years thousand years 10000 years.

Student: (Refer Time: 47:39) 100.

100 to 200 even the manufacturer will say sir this will last of to 2 100 years plus. Our design life for the whole system is 50 200 years. So, manmade materials will not last for 10000 years. So, if you are bringing back landfill to it is original condition you have to take into account. That after a certain point of time the manmade materials will not be there that is fine, if the race has become stable if the emissions are within limit is it is fine it is now harmonized with the environment, but otherwise man made materials are not going to survive in a geological time frame, whereas the natural materials well. So, we will carry on from there in the next class.

Thank you.