**Urban Services Planning**
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**Lecture 33**
**Sanitary Landfill Design Part I**

Welcome back. In lecture 33, we will talk about Sanitary Landfill Design and this is part 1 of this lecture.

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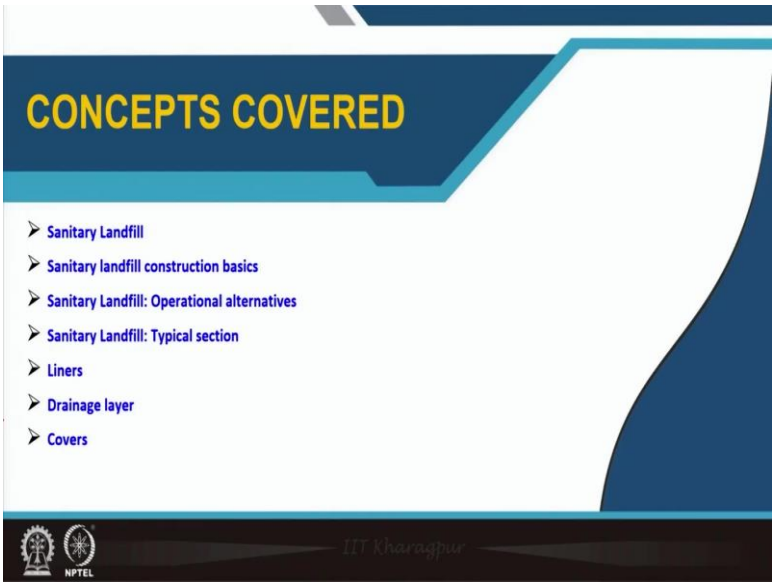


The concepts that we will cover are on different kinds of landfill construction, then sanitary landfill operational alternatives, sanitary landfill typical section, liners, drainage layer and covers.

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So, as we have learned earlier that when every you will be need to make sure that they have operational landfill site and a properly designed and engineered facility that is why we call them sanitary landfills and there are several laws and regulation in this regard what kind of waste should go to the landfill, what should be the design of the landfill and so on. So, some of this we have discussed earlier. Then we have talked about the landfill siting criteria that is how and where we should locate landfills, how should we select a particular location. And then in this particular lecture, we will start about talking about landfill design.

Now, landfill design and landfill area calculation are done together, why, because for different kinds of design will result in different kinds of area calculation and also landfill construction, landfill operation and eventually landfill closure, that is how is, complete the operation of landfills. This all needs to be discussed simultaneously when we discuss the landfill design. So, overall these the next 3 lectures will cover all these different components of landfill design as well as given certain aspects of this operation and the closure procedure in the next subsequent lectures.

So, when we talk about landfill design, these are some of the aspects that we need to cover. So, one is the geohydrologic and geotechnical assessment. So, that means, even before we start the design we have to conduct these kinds of assessments. So, last time when we were talking about landfill siting criteria, we have discussed about this kind of data collection, this kind of inspection that needs to be taken up and these are the things that need to be inspected, then waste stream categorization that is to understand exactly what kind of waste is coming to the landfill.

Now, even though we are only supposed to take waste which are non-biodegradable and also non-recyclable waste particularly inert waste to the landfills but as per different ULBs as per at what stage they will be is currently in terms of solid waste management, different kinds of waste reaches the landfill and sometimes we still receive mixed waste in the landfill, which means that there is still organic waste mixed with other waste that comes to the landfill.

So, first we need to understand what sort of waste comes to the landfill. Then what are the operational alternatives, what sort of designs we could think of in the landfill and within this they are put there according to that there will be designs for different lineups systems, drainage layer cover what are these, we will discuss this in detail but as you understand liners prevents the flow of leachate into the groundwater.

Drainage layer is one where we store the leachate so that it can be collected and covers our barriers which prevents water to get inside the landfill in the first place. So, these are the different things that we will discuss. Then we will talk about leachate management, landfill gas management, surface water management, groundwater management, water balance and this will be taken up in the next lecture.

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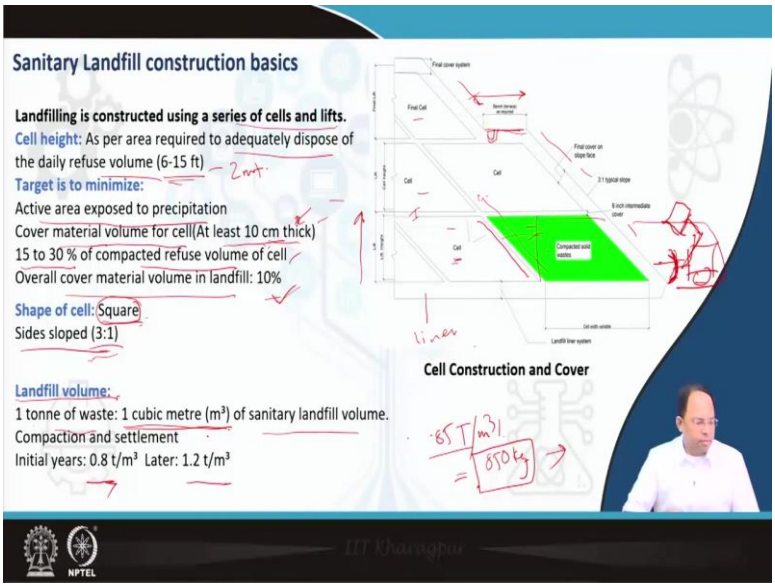


So, first we will start talking about the sanitary landfill construction basis. As you can see in this particular image, we have a landfill and at the bottom we have the landfill liner. So, this is the landfill liner. Liner is the one that layer which prevents water to flow the leachate to move below the landfill that is it prevents the landfill the leachate to mix with the

groundwater. And as you can see above the liner and as above liner, drainage layer and all these things that we will discuss in detail later.

You see that when we there is something called a cell and then each cell there is not only one cell there are multiple cells. So, each of these layers of cell that you can see in first cell second cell, that will be further cells over here as well. So, this is the first layer of cells. So, once the first layer is complete, then we move on the next layer and the under layer above it in so, in that gradually we go upwards. So, each of these is known as a lift. So, there are cells and then there are lifts.

Now, why do we need to do it in this way because, every time when we put garbage inside a particular area or inside this landfill, we have to do it in layers and once this layer is finished, then we move on to the upper layer. Now, the height of each layer is also the height of the cell. Now, how do I determine that? The cells height is determined primarily based on two factors. One is based on the amount of garbage that comes to the landfill site every day and also based on the physical the kind of equipment and kind of the process that we adopt to store this garbage or push this garbage into this particular landfill.

So, based on the amount the kind of equipment that we use, the height of the cell could be only as per the height of the equipment because we use mechanical equipment to lift the garbage and put it at a particular location. So, that means, if I am using a bulldozer like this over here to push the garbage inside, so, based on the height of the bulldozers, this face, it will determine the height of the landfill. Similarly, if I have a sort of bucket loader, which is like this kind of a system which lifts the garbage and places it in that case also we will see that based on the height to which this arm can move based on that we will determine the height of the cell.

So, various typical heights of cells that is possible and once this layer is finished one cell at a time we will finish this then we will move on to the top and what it helps is because we are moving on the top the vehicle has to move above this particular layer and automatically because of the weight of the vehicle the garbage will become further compacted and to facilitate movements above sometimes we have to give this kind of benches so, that which allows vehicles to continuously move and it allows the vehicle to gradually move to the top because we allow these surfaces where the vehicle can rest and the rest of the surface we will put we will give a slope so, that water can actually flow downwards.

So, this slope is given so that vehicles can climb along up this slope and also there is this slope allows water to come down from the top as well. So, and these benches helps for two purposes. One is it breaks the flow of water and we will use design surface water drains over here. So, that it will collect the water coming down along the slope, capture it because if I allow the water to travel for a longer distance, then it will gather speed and it will result in erosion.

So, instead we break it at the different benches and so, it slows it down. At the same point of time these benches could be used by vehicles to move as well. So, that is how we gradually build up a landfill. So, these are known as cells and these are known as in each cell layer of cell is known as a lift.

So, landfill is constructed using a series of cells and lifts and cell the height is as per the required to adequately dispose the daily refuse volume and maximum height is around 6 to 15 feet based on the general kind of equipment that we are using and so on. But primarily that size of cell is based on the amount of garbage that comes in. Now, why it is important? Because every day the garbage that comes into the landfill site that needs to be compacted, pushed and then placed at a particular position in the landfill.

And once we do that, we also covered that garbage because a layer of soil, so that what at least some amount of barrier is there so that the garbage cannot litter or because of weed it may not spread at the same point of time it is protected and there is smell and other things that comes out of garbage. So, if you give a layer of soil. It is protected from that and primarily we prevent water to get inside the garbage. So, that is why we give a little bit of soil and so, our target is to minimize the activity exposed to precipitation. So, that means the soil t, the layer of soil prevents water to get inside.

So, cover material volume that means we required some soil to cover this particular garbage, it should be at least 10 centimeter thick and we need to also determine what amount of soil is required. That means not only the quantity of garbage is important, also because the landfill is not only the garbage, it is also all these different layers that we construct liners, covers and all and also the kind of soil we use for cover.

So, it is 10 centimeter thick cover and it is given at every layer when one cell is done. So, you can understand there is a considerable volume of soil that is required. And based on this

volume of soil which is available on site or we have to transport it from somewhere else, we can even think that how much what sort of waste can be stored in this particular landfill.

If I have to import where soil from farther away, maybe it would not be possible for me to the cost would be exorbitant. So, maybe the life of the landfill will be less. So, it is based on the amount of soil which is available on site. And if we import soil, then automatically the cost increases. So, at one point, the entire operation may become infeasible. So, total around 15 to 30 percent of the compacted refuse volume that is, almost 15 to 30 percent of the garbage volume is the volume of soil. So, that is a huge amount.

And overall cover material volume in landfill is around 10 percent. So, that means because soil is, in some, like at the end of itself, it is only 10 centimeter, but in the liners, it is a little bit more so overall we say that around, even though at one cell level, the value is less at around 15 is a little bit more 15 to 30 person, but overall in the landfill, you will see that around 10 percent of the overall size volume of the landfill is what this kind of cover materials.

Now, the shape of the cell, it again depends what should be the size of the cell, the height is more or less 6 to 15 feet. So, roughly in standard operation, we can take around 2 meters because that is the human height and more or less the equipment can raise the garbage and then compare it to a height of 6 meter. You can also see it in 6 meter beyond that it is difficult to see. So, it is so more or less even though we are saying 6 to 15 feet. So, roughly 2 meters it is standard size that we use sometimes and more or less the shape of the sail is we try to keep it squarish.

Now, why square? Now, if it is square then what happens it is same on all sites and more or less it is easy to estimate that okay, how to cover it with soil and all these things. So, we keep a certain profile and the sites of the sailor also sloped at 3 is to 1, why, because this allows us for like if you see that this cell is sloped as 3 is to 1 which allows vehicle to pass above it and if not the next cell may come also in the same slope way and so on.

And because slope is required even for when the equipment is used to fill up the cell and all with garbage then also it does it is difficult to fill it up like a straight line. So, it will fill it up giving it a slope so, overall our slope is given in the slope of this the side slopes around 3 is to 1 and you can see that the same similar slope profile is maintained for the overall landfill, this

profile as well or for this particular landfill, the intersection would also have similar 3 is to 1 slope as well.

So, then, talking about landfill volume, 1 tonne of waste that comes into the landfill that roughly becomes around 1 cubic meter of sanitary landfill volume then it fills around 1 cubic meter of the typical sanitary landfill volume. Now, why 1 cubic meter? Because earlier we said the density of waste is around 0.85 cubic meters per meter 8.85 the density of waste is something around 0.85.

So, that means, that 1 cubic meter of waste will hold around 850 kilograms of waste, 850 tons per meter cubed. So, that means, this is the initial compacted density of waste and as you can see that is during the initial years if something around 0.8 tonnes per meter cubed, but in subsequent years because of compaction because of vehicles moving on top of it, it becomes around 1.2 tonnes per meter cubed so, it is during the final stages. So, roughly we can say during the average life of during the average period or during the middle years of the landfill the volume required is something around 1 cubic meter for every tonne of waste, so, that is the rough density of the landfill site.

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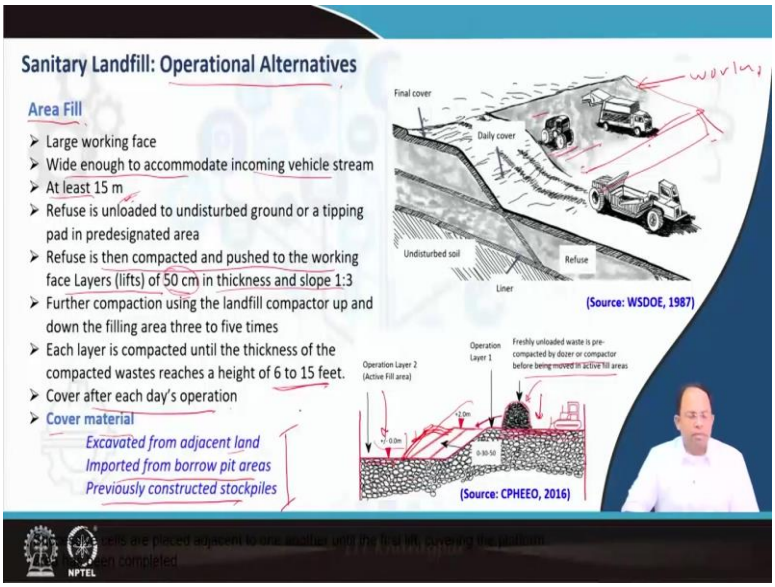


So, next coming to how we should organize our landfill, so, we will talk about the different operational alternatives for the landfill. So, the first method is called an area filled method as you can see, in this particular image, we have a large working face this is the working face of the landfill site. Vehicles can come directly over here and unload the garbage and then machines like this like a bulldozer and all can push the garbage into this particular face.

Now, what should be the size of the face? It is about the size of the cell. So, it could be like as we discussed like it is a squarish cell, but over here you can see it is a rectangular face sort of. So, or if this face is like this much, so, maybe the landfill cell size will be something like this eventually. So, that may be possible, like this.

Now, the size of the face should be wide enough to accommodate incoming vehicle stream. So, that means every hour garbage because coming and it is unloading garbage. So, at least in 1 hour, there are maybe 2 or 3 vehicles coming at least that area should be adequate for 2 to 3 meters, it depends on how many vehicles are coming. So, at least there should be around 15 meters. So, roughly it is 15 meters, but it could be even less, even though it is at least 50 meter, but sometimes we can even go a little bit lesser but we will try to stick to this particular value because it allows a few vehicles to come and stand and then dump garbage.

Now, sometimes what happens, these vehicles are not allowed at this particular face because of many reasons, because the tire and all these things for these vehicles does not allow them to move inside the landfill site. So, in that case, these vehicles will dump the west at this particular layer. And then compactor vehicles can compact it and finally push this vehicle or lift this garbage in some sort of loading bucket loaders and then carry it down the landfill site and then push it into the cell face and then make the next cell. So, in this way it can happen.

So, this is the active field layer that is going on and this part is already completed. So, this is fully covered. So, we are using this area to freshly unload waste in pre-compact and then pre-compacted by (())(16:59) or compacted before moving into that active landfill. So, both can happen that means we are not allowing vehicles to come to this area because of the nature of the soil or vehicles may get stuck so, instead they load it. They bring it down to this level and then we use this kind of bulldozers and bucket loaders to take it down and then push it into the face where we are actually filling up the garbage.

So, refuses then compacted and pushed to the working first layers of lifts up 50 centimeters in thickness and slope given is 1 is to 3. So, every lift is around 50 centimeters means one layer of lift now multiple of this actually makes the total layer of the lift which will come down to around 6 to 15 feet so, at every time a garbage is taken, approximately 50 centimeter of height. It gradually builds up on 50-centimeter height and finally it reaches a 6 to 15 feet and once and, and we compact that particular layer. And finally, that is the end of that particular day's operation and we cover and give a cover on this particular amount of garbage and so,

this cover that is given that is once the cell is finished, we complete putting garbage over here and then we will put cover over here.

So, this cover material can come from, that can come from adjacent land that is soil is excavated from the adjacent area and then we can use it. Imported from borrow pit areas, we can do pits in some other areas and we can import it from other areas as well. And also, it could be from previously constructed stockpiled. So, this is where we can get our cover material, but look what we have discussed earlier that, at the end of the day, the more material available at site with less than the cost of the overall landfill.

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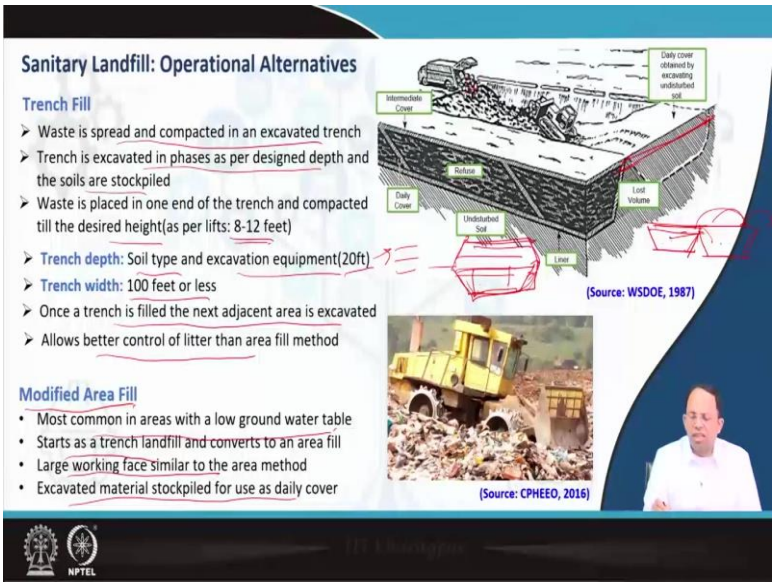


Then comes the trench fill method and as you can understand in this method, it is a little bit different where we first create a trench or that is a hole in the ground. So, that means, we first create a trench like this, we dig it up and we may stored the material over here or we stored the material over a little bit further away and then we put start putting garbage inside this particular trench and once this is filled before it even gets filled, we will construct another trench beside it and again we will start putting garbage over here and by that time when we start putting garbage here this will be covered this will be filled and this particular site is completed.

So, in this way we move from one trench to another and eventually the entire area is covered. So, waste is sprayed and compacted in an excavated trench like as you can see in this image, this waste carrying vehicle is bringing the waste over here and we are using a compactor to compact this particular waste. Trench is excavated in faces as per design depth and soils are

stockpiled. So, once we excavate, we can stockpile the soil and we can use it as cover and then waste is placed on one end of the trench and compacted till the desired height and this height is something around 8 to 12 feet. So, this is you can say it is similar to a lift. So, usually the trench, it depends on the trench depth.

Now, trench depth, again depends on what type of soil where is the groundwater layer, groundwater table, and what sort of excavation equipment that we use. So, it could be something around 20 feet or even sometimes beyond, but each cell is something around 8 to 12 feet. So, as you can understand over here we can fit roughly 2 cells.

So, roughly when a 2 lifts over here, one cell above another, and then trench with this something around 100 feet or less, this particular with that is a that that is less than 100 feet. And once a trench is filled, the next adjacent area is excavated. And this and as you can understand this is a method where we are creating a hole in the ground. And automatically it allows better control of data than the area fill method.

So, in area fill method, when wind comes lot of pollution happens, dust can litter, garbage can spread over an area, whereas in this particular case, it is a bit more protected. But as you understand this also has got some negatives associated to it whenever if there is a rainfall, then there may be chances of water logging and all so, that is a big problem. So, usually we do not find it in our country. And in most in our country, we usually go for something called a modified area fill, where it is a mix of both the area fill and the trench fill method. So, that means usually in areas with low groundwater table, we go for this kind of modified area fill.

It starts as a trench landfill that means we first create a hole in the ground. And then once this is filled, we start going up so, then we will go to the top. So, it has got a similar working faces the area fill method. So, eventually it becomes like area fill method. And excavated material stockpiled for users daily cover. So, this allows excavation of some amount of material which could be used as cover. So, actually the amount of material that we use that we require as cover can be excavated and that could determine the depth of this excavation as well.

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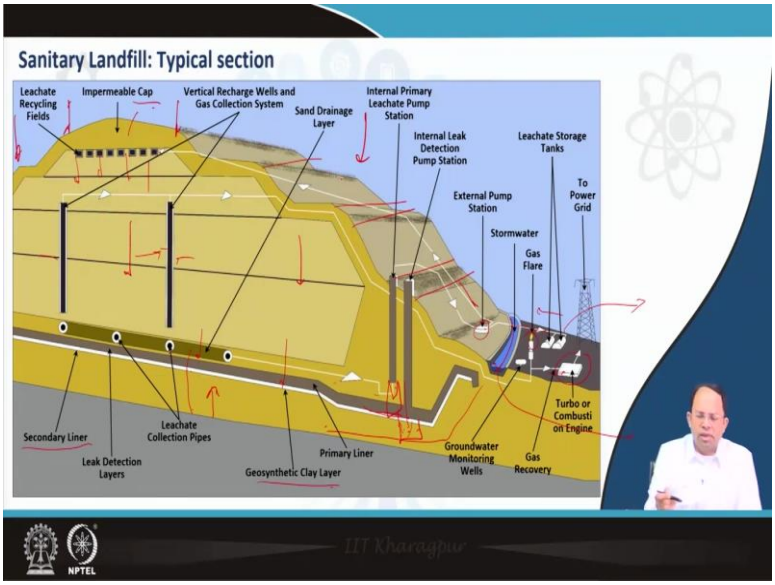


So, this is roughly the section of a typical landfill. So, you can see different components to it. For example, as you can see, this is sort of area fill method, but you can also call it a modified fill because obviously there is some excavation has been carried on over here. So, this is a drain given at this particular edge and these are those benches that we talked about. and these are the lifts you can see in each lift the landfill has grown up and this surface, this storm water drain is given so, that water is captured coming down the slope and also it prevents water from the surroundings to come inside and it gets trapped in this drain and the drain is diverted to somewhere else.

Then at the bottom you can see this bottom liner. So, this is the mineral liner of the soil liner, above it we can have certain other layers or secondary liner then you can have this geosynthetic clay liners we will discuss about this later. So, these are systems which prevents, leachate to go downwards because leachate is generated and it starts moving downwards. So, this is where it is it this is a drainage layer over here so, this is where the leachate drainage layer is made of gravels and all.

So, leachate comes and gets stored over here and it cannot go below because of these liners that are prevented so, the leachate will start accumulating over in this drainage layer and it will gradually go up. It then fills up these perforated pipes which are late which collects the leachate and it takes it away into some sumps maybe there is a sump over here and from here we can pump the leachate out or similarly at different from the layers also we can also the pipes could be also connected directly to some sump from where it could be pumped out or it

could be some amount of leakage can happen. And we can even have another layer to collect, leachate from that layer and also pump it out.

So, anyway so the leachate is pumped out from this particular layer is brought over here it is this is a pump house then it is brought to this leachate storage tank it could be again treated inside the site or it could be treated or it could be transported somewhere else and treated there as well. So, from over here, some amount of leachate could be recirculated back.

As you can see, this is where the recirculated leachate is taken from here the leachate is again allowed to pass through. Now, why it is done? Because in any radius and all, the moisture is less and we want moisture to be a little bit more in the landfill, so that it facilitates the degradation of organic matter and all. So, sometimes the leachate is circulated. So, that is what is being shown over here.

In addition to that, we can see this sort of vertical pipes or sort of wells you can say. These are filled with taking gravel and other material with pipes inside. These pipes are called gas connection. So, all the gas that is generated is moves into this particular these wells, gas collection wells and from there we can actually pump the gas out and this gas is also taken from using which we can burn the gas or we can also use it to generate electricity as well.

So, this is more or less the typical section of the landfill. And at the top we also give a imperturbable cap or a cover so, that water does not get inside the landfill. So, infiltration cannot get inside the land. Even so, some amount definitely will get inside but we will try to our best of our abilities not to allow water to get inside.

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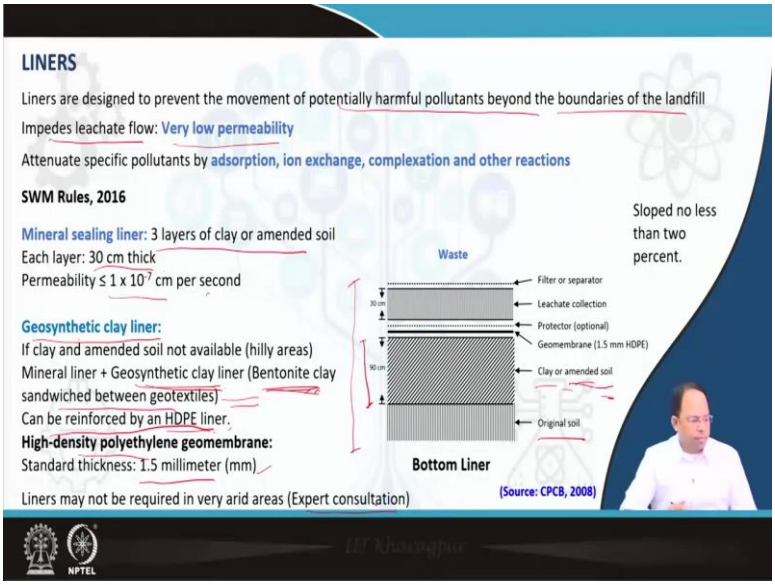


Then we will discuss about the a liners systems. As we discussed earlier liners are designed to prevent the movement of potential harmful pollutants beyond the boundaries of the landfill. So, that means it is a barrier layer which prevents movement of leachate outside the landfill site. And the idea is to collect the leachate within the landfill itself and then pump it outside and then take it for treatment or for transportation to a different treatment site. So, the liner should be designed in such a way so that it has very, very low permeability that is it is a layer of you can say a liner is nothing but a layer of soil, but the soil layer should have very low permeability.

So, automatically when the native soil does not have that much amount of permeability, we should have something extra to make it more non-permeable. For example, we can mix some cement as materials to make it more solid, so that we reduces its permeability. So, we can use clay or we can use amended soil, amended soil is soil mixed with some amount of cement as much material like bentonite clay and so on. And you can see that the system is designed, it has got several layers.

So, one is the bottom most layer which is the original soil of that particular place. And after that is the liner. Usually it is a 90-centimeter-thick liner, and it includes 3 layers of clay or amended soil and each layer is 30-centimeter-thick, and the permeability is 1 into 10 to the power minus 7 centimeter per second. It should be less than 1 into 10 to the power minus 7 centimeter per second.

So, that is the permeability allowed for soil in this particular case, but if the native soil is not that does not have it is more permeable that this in that case we may go for a geosynthetic clay liner which is sometimes we use a geosynthetic clay liner which is like a bentonite clay sandwiched between some geotextiles. Geotextiles are fabric material which allows passage of the leachate.

Now, what it says is why we do that, because sometimes what happens when we have 2 different layers of soil. One is very very highly compacted and the other is allows is allows it is a sandy soil allows passage of leachate. So, how do I differentiate these two? So, that means there has to be some form of barrier so, that water can pass but the soil materials will not mix with each other. So, or I have got the waste layer and then I have got the drainage layer. So, waste and drainage should not mix. So, there has to be something intermediate. So, that is where sometimes we use this geosynthetic liners.

So, sometimes the geosynthetic liners along with some amendment soil that is using bentonite clay we can create a layer which is like a sandwich layer in between which can prevent movement of leachate. So, along with that, we can reinforce this entire system. So, either we go with soil or amended soil or with geosynthetic liner and all. And along with that we can also put up plastic layer as well as sort of plastic. So, HDPE liner is also utilized so, HDPE is high density polyethylene plastic layer.

So, this kind of along with soil we can use this plastic layer which definitely prevents movement of leachate below and this is a high-density membrane and standard thickness is 1.5 millimeter and so, this prevents water to go down in case the soil is not good enough. So, liner sump is required in most sanitary landfills except in areas which are very, very dry and with expert consideration we can avoid also putting certain liners.

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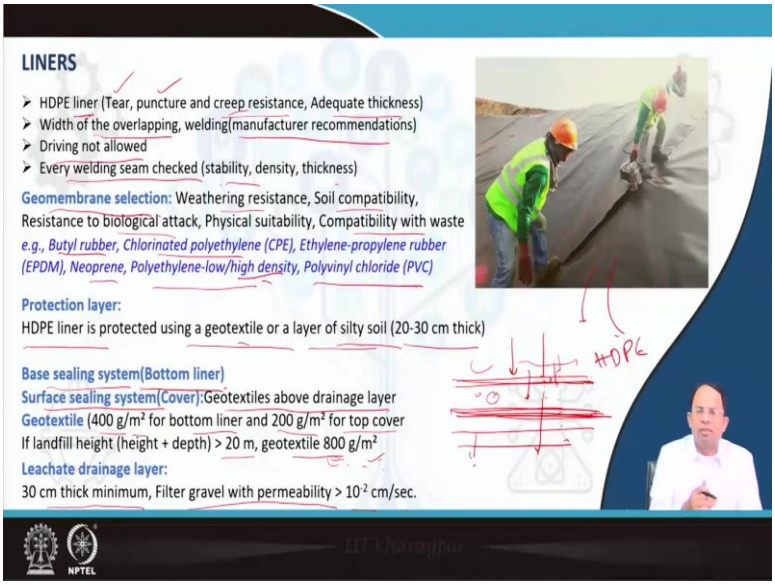


So, as you can see over here, this is that HDPE liner which is being given which has been laid on the top. So, this kind of liners are laid at multiple may be at the top as well. So, usually along with covers also liners are given at the bottom. At the top also, we can have some top liner which is also known as a cover system.

So, that means this kind of synthetic sheets are also utilized along with soil as well. So, HDPE liner, how do I decide on a liner on a particular liner. So, we have to understand some of its properties. So, will it tear, will it puncture, will it resist movement of vegetation that means some seeds and all are always there in vegetation can start growing. So, it should be creep resistance, adequate thickness and so on.

Then, we have to also be careful about the overlapping of the liners with the overlapping, welding we have to weld these two layers together so, that there is no movement through these two layers then this should be as per the manufacturer's recommendations. Then we should not be driving on this line is that is once the liner is laid it we cannot drive on it directly that is we cannot run the vehicles because it will tear the liner definitely. Every welding seam needs to be checked and for stability density and thickness so that there is no leakage.

Now, the membrane selection it could be HDPE which is very common in the Indian context, but based on weathering resistance, soil compatibility, resistance to biological attack, physical suitability, compatibility with waste we can select other liners as well. What are these? It could be butyl rubber, chlorinated polyethylene, ethylene propylene rubber,

neoprene, polyethylene low or high density in our case we use high density, polyvinyl chloride or PVC sheets. So, all these could become liners in a landfill.

So, directly HDPE liner is not provided on the soil or below the waste. So, it has to be protected using a geotextile or a layer of silty soil. So, that is it is a buffer layer between the waste and the liner otherwise, because of the pressure of the waste because of certain material in the waste, there may be a tear in the liners. So, that is why we require a protection layer. Usually this layer is 20 to 30 centimeter thick. And the base liner is also known as the base ceiling system.

Similarly, the surface ceiling at the top also we may sometimes use some one liners as well. Geotextiles are given above the drainage layer. So, we have the bottom liner, then we have that drainage layer and then above that we are given some geotextiles and then above that we have the waste. So, we allow water to go through the geotextile but we do not allow waste to mix with this particular barrier layer and then it allows the water to go inside the drainage layer finally, but the waste does not mix with the drainage layer. So, that is the purpose of this silty soil or the geotextile layer.

And once this is collected in the drainage layer, we can have our geosynthetic HDPE, or HDPE liner or some amended soil or clay below it so, that it prevents the movement of leachate from this drainage layer further down. So, that is how the more or less the system is designed.

So, this is some specifications for the geotextile like if you use a geotextile it should be 400 grams per meter square per bottom liner and 200 grams per meter square for top cover and if landfill height is both height and depth is greater than 20-meter geotextile should be at least 800 grams per meter square, why more because of the extra weight of the waste that falls upon it.

So, it should be of sufficient thickness and that is how thickness can be determined. Then leachate drainage layer is actually 30-centimeter-thick minimum and filter gravel with permeability greater than 10 to the power minus 2 centimeter per second is utilized to fill up this drainage layer. So, above the liner we have the drainage layer.

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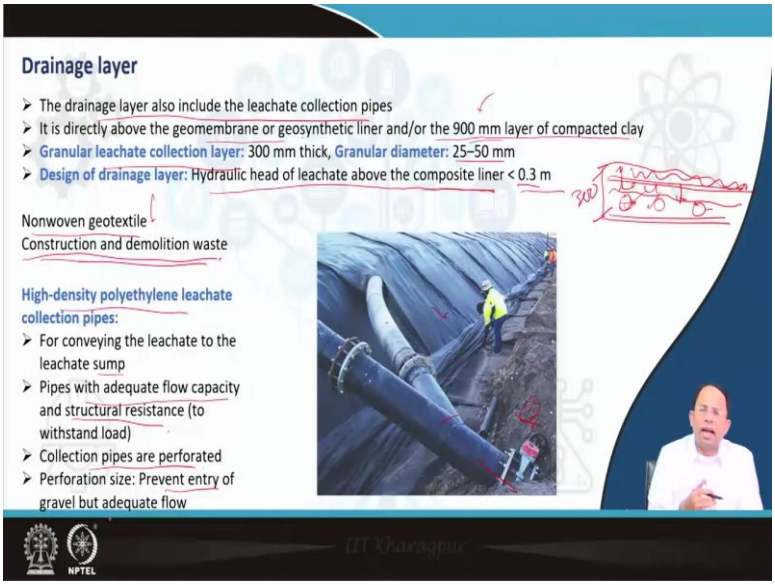


Now, coming to the drainage layer, so, as you can see that you can see these are the liners over here and we have over here the drainage pipes are coming. This is where it is entering into the this particular drainage layer and that so we have got this pipes, the drainage layer also includes leachate collection pipe.

So, these are the leachate collection pipes that is collected in the drainage layer. It is directly above the geo membrane or geosynthetic liner or the 900-millimeter layer of compacted clay. So, either it is the drainage layer is above the compacted soil of this 900 mm of compacted soil or it is above the geosynthetic liner whichever maybe the design of the liner of that particular landfill. So, a granular leachate collection layer it is 300 mm thick as we discussed and granular diameter is 25 to 50 mm and design of the drainage there is such so that hydraulic head of the leachate above the composite liner should be lesser than 0.3 meter.

So, that means above the liner that means above the composite liner we have the drainage layer and the drainage layer is something around 300 mm so, we should never allow more leachate to accumulate which should go above this. Then what happens? Then it will mix with the waste and it will create a sort of saturated situation which will create other problems. So, always the amount of accumulated this leachate should be less than 0.3 meter.

Now, this this accumulated leachate gradually enters into these particular perforated pipes and then is drained away. But the design of the density of pipes or the at what frequency we should give these pipes all depends on the pipe diameter as well as on the amount of leachate that is being generated. So, we can also use construction and demolition waste and above this

we also have nonwoven geotextile above the drainage layer so, that it allows passage of water inside and we can use construction and demolition waste to also instead of gravels we can use this (())(37:12) waste as the drainage layer as well.

So, HDPE pipes polyethylene pipes are also used for leachate collection and for conveying the leachate to the leachate sump as I was showing you in that image we create a sump where the leachate gets stored and from there we will pump it pipes with adequate flow capacity and structural resistance. Why structure resistance, so, that it can withstand the load above load of garbage above and collection pipes are perforated and perforation size should be such that it prevents entry of gravel but it allows adequate flow of leachate.

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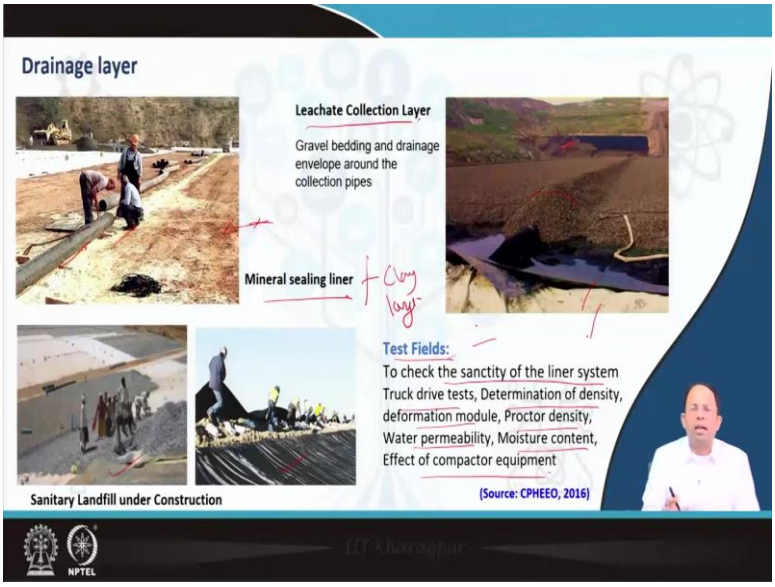


So, this is how leachate collection layer looks. You can see over here this is the HDPE membrane. This is the clay soil as you can see the base is created the mineral layer, sealing layer liner or the clay layer is first laid and then we are laying the pipes of course, we put some sand and then over that we lay the pipes and we have to weld the pipes together and these pipes are perforated and above the pipes we cover it with the drainage layer like this. So, this is how a landfill construction is going on. This is how this this is covered with these synthetic liners and so on.

So, before we even start construction, we have to create some test fields that means this is again the process of construction of a landfill. So, this test fields are created with the designs that we propose for the liners and the drainage layer and so on. So, that we can see that how it

performs in the local area because every area is different, whether it is different the soil conditions are different. So, we have to test it.

So, we check the sanctity of the liner system, we can drive trucks on this particular test field, determine its density, how much it is deformed, proctor density that is how much moisture and how much it can be compacted, water permeability, moisture content, effective compacted equipment, all these things could be evaluated in this test field and finally, we come with a final design accordingly we create the liners.

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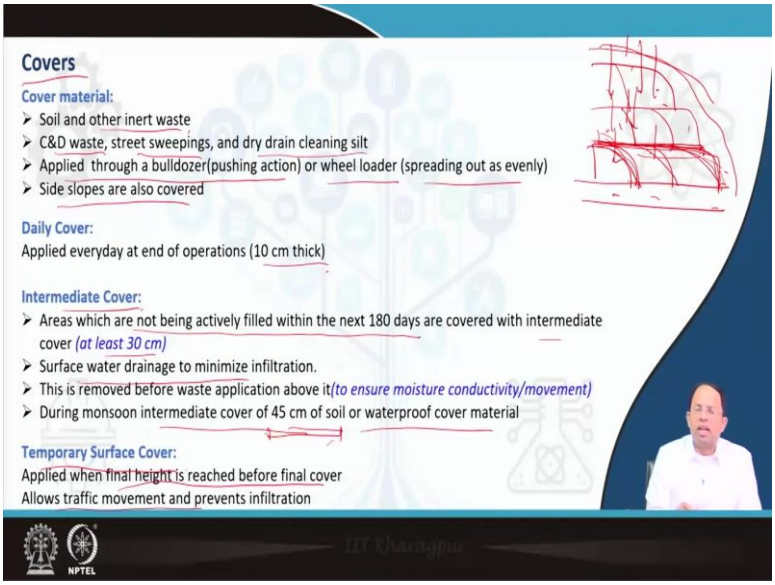


Then comes we have talked about liners which is at the bottom, but we also give sort of liners at the top which we also known as cover. So, we will call them as covers. So, cover material could be either soil and other inert waste, it could be CND waste, street sweeping waste or dry drain cleaning silt with this could be used as the top cover material.

It is applied through a bulldozer by pushing it or a wheel loader by spreading it out as evenly on that particular waste surface, side slopes are also covered. So, this is how the overall cover looks like. So, cover is done in many stages. As we discussed earlier that at each cell is done we put in soil cover, 10 centimeter.

Now, once a group of cells are done, and then we move on to maybe another area, so, that means we have to in that case provide an intermediate cover, why, because this area is left unattended, precipitation may happen and water may get inside. So, we need to instead of just attain cm cover, we know that we are giving 10 cm because the next day again we will work on it we will give another 10 cm. So, in that way it will go on.

But if I am leaving a space, this area alone that is more or less this work is temporarily done in this particular area. So, it is not being actively filled within the next 180 days. In that case, we cover it with an intermediate cover which is a little bit more so, that is around 30 centimeters thickness of soil is given on that particular area.

So, this reduces surface water drainage infiltration of course, and but again if this layer is again I am now starting the second layer of operations over it. So, in that case, we have to remove this layer first intermediate cover and then we have to again to the cells above it, why, because if I keep this particular 30-centimeter layer, it may prevent moisture to go down. We want the moisture to go down from the top of the waste once it enters into the landfill, we will allow it to go down even so, that it reaches the drainage layer.

So, if I provide intermediate cover that is temporary, so I have to remove the intermediate cover and then allow water to get inside it so, that it will allow water to get inside. Now, the top covered is the one at the top. So, we will get this top cover so that we prevent water to get inside in the first place but once it gets inside we should allow it to flow through.

So, during monsoon, the intermediate covered of 45 centimeters soil or waterproof cover material is given. So, that means normally it is a 30 centimeter, but for monsoon or where places of heavy rainfall, we can even increase it to 45 centimeter. So, temporary surface covers are also given when the final height is reached before the final cover. So, again the final height we have achieved in some locations other locations we have not so temporarily some cover could be given. So, that it will allow traffic movement as well as prevents infiltration.

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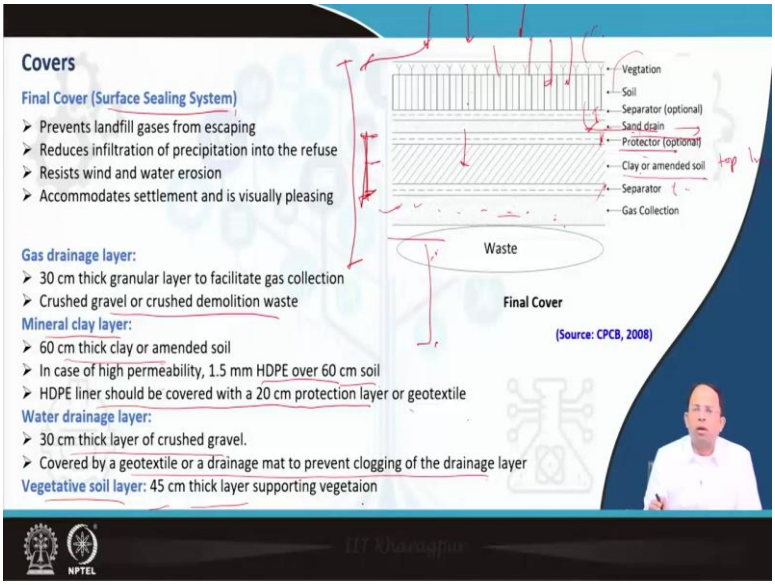


So, this is how the final cover looks like. It is now also known as the surface sealing system. So, we have waste at this layer. Then we have a gas collection layer. Again, it is made of some of gravel. Then there is a separator layer, separator layer could be geosynthetic. Textile, it with some amount of amended soil inside it sandwiched.

And then there is a barrier layer which is again made up place. So, this is also called the top liner also if you want to then there is a protector layer again there is it could be protector layer of some sort of geotextile or some sort of membrane is given. So, it prevents water to get inside. Above there, there is a sand layer which allows drainage of water then there is again a separator layer and at the top of it is the vegetation layer. Vegetation layer allows plants to grow.

So, at the top we allow plants to grow, why, because it will prevent erosion that means, that plant roots will hold on the soil and it will prevent erosion, because it continuously rainfall happens over it. It will flow what this particular soil so, it will erode. So, the plants actually prevent that, but because we are putting plants and trees and so on and water allows gets inside this particular soil because this soil is not that clay soil.

So, in that is why we are given a sandy layer so, that it allows water to accumulate and then pass out. Below it we give this top cover or you can the entire thing is the top cover, but here you can see this is the top liner and this is where we put this clays soil so, that water does not penetrate, but still of course some water will get inside and then we have the gas collection

layer and finally there is waste and below that again after different cells you will have the drainage layer as well as the bottom line.

So, the gas drainage layer is 30-centimeter-thick granular layer to facilitate gas collection this one and contains crushed gravel or crushed demolition waste, construction and demolition waste. The middle clay layer is this one, 60-centimeter-thick clay or amended soil. And if sometimes we use HDPE layer over 60 centimeter of soil in case it is very highly permeable and HDPE liner should be covered with a 20-centimeter protection layer or geotextile.

So, that it does not, there is a protection at both at the bottom as well as the top as I told that whenever we have two separate material in two layers to protect one from another we can give this geotextile layer which allows water to pass through but will prevent mixing. And then the water drainage layer is above a 30-centimeter-thick layer of crushed gravel covered by geotextile or drainage mat to prevent clogging of the drainage layer and finally vegetative, so, a layer of 45 centimeter thick layer supporting vegetation at the top.

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So, these are some other images, these are some of the designs you can take a look. So, this is one design, this is another design, this is another design. So, we can have different designs of top layer. It depends on what varieties of cover we give. Over here you can see that a topsoil layer is given which is around 0.5 feet and then 2 feet of barrier layer with 60 mil or thicker flexible liner HDPE liner substituted for soil barrier layer. So, we use some amount of soil and some amount of HDPE layer. And so this is a very, very simple cover. This is a little bit

complicated as we have discussed and this one is even further complicated. This is another design.

So each layer is different, we have to give a slope of course so, that we allow water to flow down. We do not allow water to stagnate on this particular layer and in this image you can see this is being constructed. So, again HDP layer is the top layer, top liner that has been given HDPE layer is given and above that we fill it up with soil and this is the vegetation layer over which eventually trees will grow.

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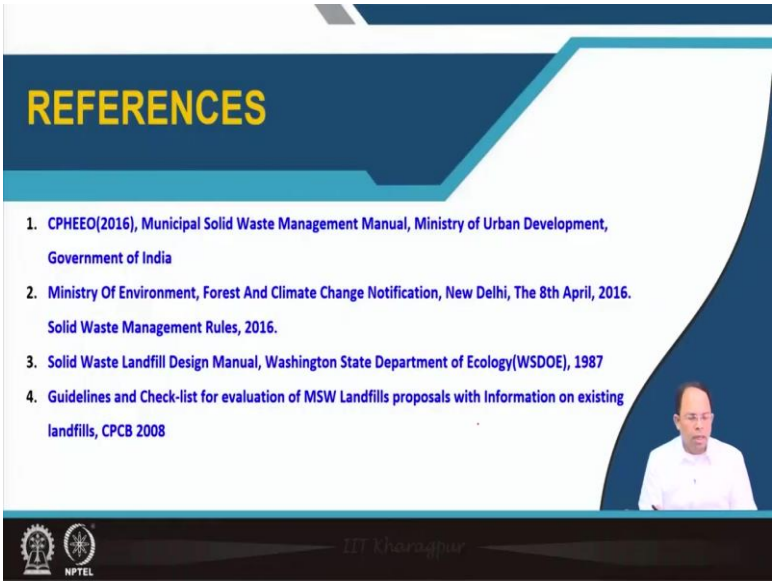


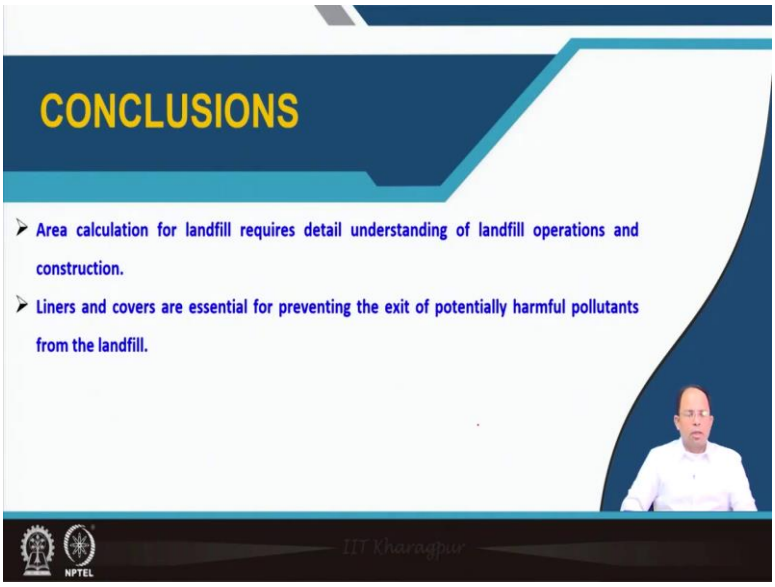


So, these are some of the references you can use. To conclude area calculation for landfill requires detailed understanding of landfill operations and construction, and liners and covers

are essential for preventing the exit of potentially harmful pollutants from the landfill. Thank you.