Urban Services Planning
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Lecture 34
Sanitary Landfill Design Part II

Welcome back in lecture 34 We will continue with Sanitary Landfill Design, this is part two.

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So, we will cover different concepts in this lecture. These are leachate management, then we will talk about the leachate collection system network, then the quantity of leachate that is collected, transmission and holding treatment of leachate, then we will talk about the gas management system, where we will talk about the passive system, and the active system, then the gas purification system, then we will talk about surface water management and, eventually groundwater management.

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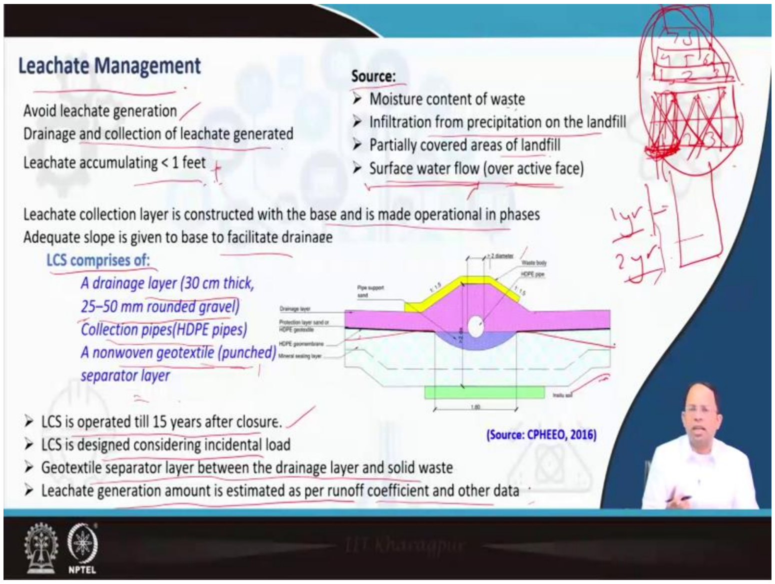

We have already learned about the different liners, we have learned about the covers. We have also learned about the drainage layer that is constructed in landfill sites. Now, leachate management obviously is the management of leachate within the landfill site. And it involves we have to understand that the leachate is collected from the drainage layer itself using HDPE pipes which you have discussed earlier. But how the pipes are laid, how what we do with the leachate, that is what is leachate management system.

So, our primary goal is to avoid leachate generation in the first place. And our goal is to, drainage and collection of leachate generated, the amount of leachate that is generated, we have to, drain it to certain point and then collect it and we should not allow accumulation of leachate more than one pit as we have discussed otherwise it will mix with the waste and also this is the height of the drainage layer so we cannot exceed it.

And where does the leachate comes from, we have also discussed this earlier moisture content of waste, that is the waste itself has got moisture, so, this moisture may gradually travel down because we are pressing on the waste, the waste is compacted. So, moisture will all obviously ooze out. Infiltration from precipitation on the landfill. So, some amount of water will definitely get in whatever amount of cover during the time the landfill is active, we are only giving intermediate covers or daily cover so obviously water will come inside so that generates leachate.

Partially covered areas of landfill and surface water flow over active face. In case surface water moves over the active face then also it will result in a lot of wasted water infiltration, of course, we will prevent we our goal is to prevent surface water to flow or come or the water should not be drained on the active face of the landfill.

So, leachate collection layer is constructed with the base and is made operational increases. So, landfill the entire landfill is not constructed together we construct it in phases, we will show the designs in the next lecture, but what it means is that means we only what once a small area at a time and the phases are designed either for one year or for two years that means one year of waste generation or two years of waste generation, why because the waste generation changes the amount the quantity of waste that is generated by an urban area changes every year. So, we can say that for two years this may be stable.

So, that means the quantity of waste that comes during these two years every day is more or less stable. So, the cell size and all these things will be also stable. So, we should design one cell at a time and then gradually we move so, if I have a large landfill site, I can fill up this area first, then move on to this area and then move on to this area.

Now, after that, once this entire is filled, I can go to the top again I can fill up another layer above it, another layer above it, another layer above it. So, that is the that means after one layer I can go and do another layer and then another layer. So, this could be phase 1, this is 2, this is 3, this is 1 2 3 and then 4 5 6 7 8 and so on.

So anyway, so we will show you different designs of phases later on. But the idea is that means one when one phase is done, depth the bottom or the base of that phase is first prepared and then we also comes once the base or the bottom line is prepared then also we also create the drainage layer for it.

And because it is done in phases, the drainage network of, this HDPE pipes also has to be designed in such a way so that it is adequate for this particular area it is complete for this area. So, it would start operating it will start collecting leachate and it could be operated even this phase is also in operation. So, that means it is fully operational system. Adequate slope is given to the base to facilitate drainage. So, obviously the base, the soil, the liner that we have to give it a slope so, that the drainage layer also has a slope.

So, there is certain slope given to it and as you can see that this LCS comprises of a drainage layer 30 centimeter thick 25 to 50 millimeter grounded gravel again this values if you can use C and D waste also to a certain extent but better to use gravel and all, then collection pipes and HDPE pipes are there inside and a non-oven geotextile punch separator layer. So, that means at the top of this we have a, above the between the waste and the drainage there, there is a non-oven geotextile punch separator layer punched because it allows flowing of water inside.

Now, you have to understand this. So, this is the drainage network has to be constructed and this drainage network is operated till 15 years after the closure so, that means once the landfill is fully completed, we put a cover above it after that it keeps on operating for the next 15 years. So, that means there will be infiltration during the next 15 years and that also needs to be collected and that means that leachate management system has to be kept operation for the next 15 years after closure.

So, it is designed considering the incidental load the compaction that will happen and so on. So, that means the layer is at the bottom, so, a lot of load will come on that so, that has to be considered geotextiles separator layer between drainage layer and the solid waste so, that it prevents mixing up waste inside the drainage layer.

Leachate generation amount is estimated as per runoff coefficient and other data. So, there is a detailed analysis that needs to be done to determine what amount of leachate is generated, but we will do a very using some thumb rules, we can also do some basic estimates but usually we need to do very very little calculations when the as per engineering design is concerned.

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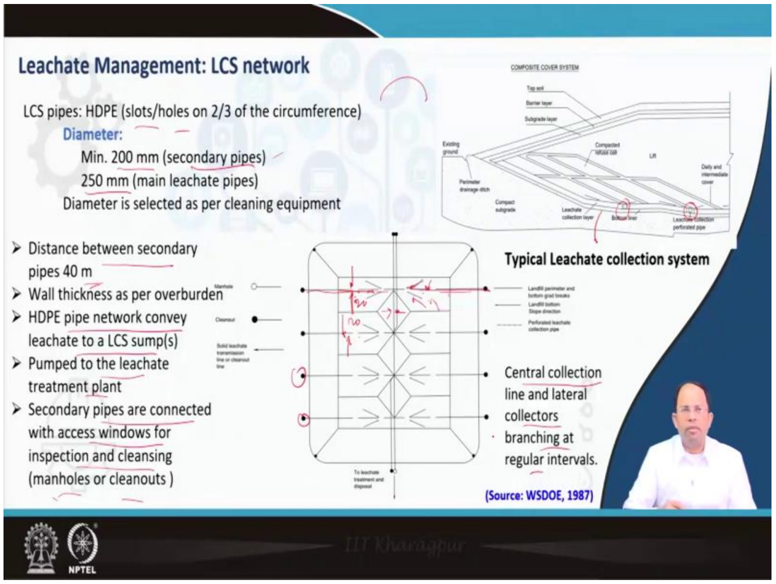

Now, LCS pipes are slotted pipes or pipes with holes and two thirds of the circumference of the pipes will have these particular holes which will allow this leachate to come inside, diameter of the pipe minimum is 200 millimeter, this is particularly for secondary pipes, whereas the main pipe is around 250 millimeter. And as you can see in this particular landfill site, this is the section of the landfill site and this is the bottom layer, this is the liner, above that there is a drainage layer and here you can see these pipes. So, at certain intervals, we have put pipes, which allows collection of drainage.

Now, once these pipes are put as you can see these are those pipelines. So, this is the main pipeline goes at the center and these are the secondary pipelines, the secondary pipes, now, these pipes are designed in such a way so that from the surrounding layer, water will surrounding drainage layer the water will move into this pipe. So, this slope of this particular zone is towards this pipe, slope of this side is towards this pipe. So, this is one layer and similarly slope of this area is here slope of this area is here.

So, we give the bot, we designed the bottom liner in such a way we give certain slopes to it and the slope profile has to be designed prior before we even start construction. Accordingly, the drainage network also has to be designed and pre-designed and then we will lay it or do the construction accordingly. So, this is how it looks. Now, distance between secondary pipes roughly is around 40 meters but it could be even less as per requirement but the standard design is around between two pipelines is around 40 meters. So, you can see that this is around 20 meters and this is 20 meters. So, from the so the slope is given over here.

So accordingly, but this could be even less even 15-meter as well. So it we have to design our slopes as per the distance between the pipes. So, both this this pipe will get leachate from both the sides so accordingly we have to give slopes to both the sides. So, HDPE pipe network conveys the leachate to the leachate sump and pump. Then from there it is pumped to the leachate treatment plant and secondary pipes are connected with access windows for inspection and cleaning the manholes and clean out so as you can see, at the end of the pipes, there are clean outs.

So, if the pipe gets clogged and all we can actually clean it using the different systems we can clean it. We can use these robots which can go inside they can clear some amount of clogging and all this sometimes we can use some other sorts of cleaning like vacuum, we can create vacuum or we can, do our sort of wash out. So, those kinds of things could be done. And so, then the, this sometimes we also provide manholes, so that we can inspect what is the condition in the line.

So, the manholes is of course comes from the top. So, from there we can see what is the so, we so, we have also give accesses access to this pipe network. So, as you can see in this image, there is a central collection line and lateral collectors branching at regular intervals. So that is how the leachate collection network has to be designed for landfill.

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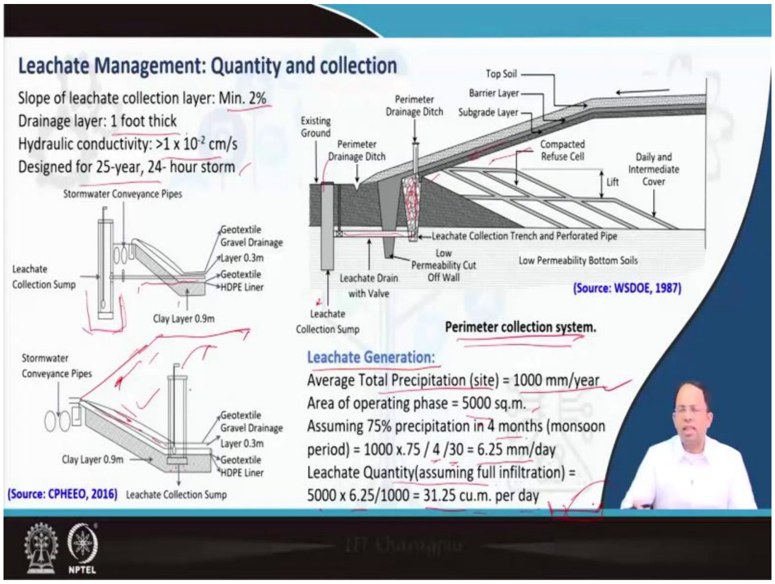

Now coming to quantity and collection, first of all, there has to be a minimum slope given to allow the leachate to flow. So, the drainage layer is one foot thick and hydraulic conductivity of the drainage layer is less than 1 into 10 to the power 2 centimeter per second, this we have discussed in the earlier lecture as well. And this is designed for a 25 years considering a 25 year 24 hour storm, that means in the last 25 years the maximum storm intensity for a 24 hour period is considered while designing this leachate layer, so the considering this drainage layer sorry.

Now, as you can see over here, the pipes are actually coming out, and then it comes to this particular sample which is outside the landfill site. So, the sum could be outside the landfill site, or the sum could be even inside the landfill site as in this particular case. So, the leachate comes to the sum, it is corrected in the sum as if it is inside you can see that we can also collect the leachate coming down from the sides as well. And from here we can pump the leachate out.

Now, that now some amount of leachate like over here if the slope of the landfill is like this, the landfill is like over like this, then some amount will also come from the side as well. So, for that we have a perimeter collection system as well. So, the leachate which flows from the side it comes to this particular layer where it is stored. And from here we can collect the leachate via pipe where it is taken to a sump and from there again it is pumped out. So, there is this is the perimeter collection system and this is the standard collection system for leachate.

Now coming determining leachate generation, as I said, it is a very, very complicated calculation, we need to do detailed water balance analysis of the landfill site. But in general terms, if I just want to just determine what is the rough volume of leachate that has been produced, so that we can create some ponds and all these things. As planners, you would be able to estimate the area required for a landfill which includes also the area required for that leachate collection pond and as well.

So, in that case, we can go like this, where average total precipitation of a site is 1000 millimeter per year. So, this kind of data is available from IMD and if I know the area have one operating phase, whatever is the area of that particular operating phase in this case 5000 square meter, and we assume that roughly 75 percent of the precipitation happens in the 4 month period or it will be 80 percent even. So, in that case, we and then I divide by 4 months divided by the number of days we get around 6.25 millimeter of per day of rainfall that will be converted into leachate.

So, that means total leachate quantity is 5000 multiplied by 6.25 divided by 1000 which is 35 1.25 cubic meters per day. So, this 6.25 millimeter we divide by 1000 to make it meter so, it becomes 31.25 cubic meter of leachate is collected by per day. So, if I design a transportation system, or if I design a pumping system, so first we have to store this leachate for a day and then we have to pump it out throughout the day.

So, we can design this storage for one days of leachate or it could be for multiple days of leachate depending on how much amount of leachate I want to transfer or via some vehicle to the leachate treatment plant or the existing sewage treatment plant or how much we can treat it in that particular site, based on all this we can decide on what should be the storage volume of our leachate pond or leachate collection area.

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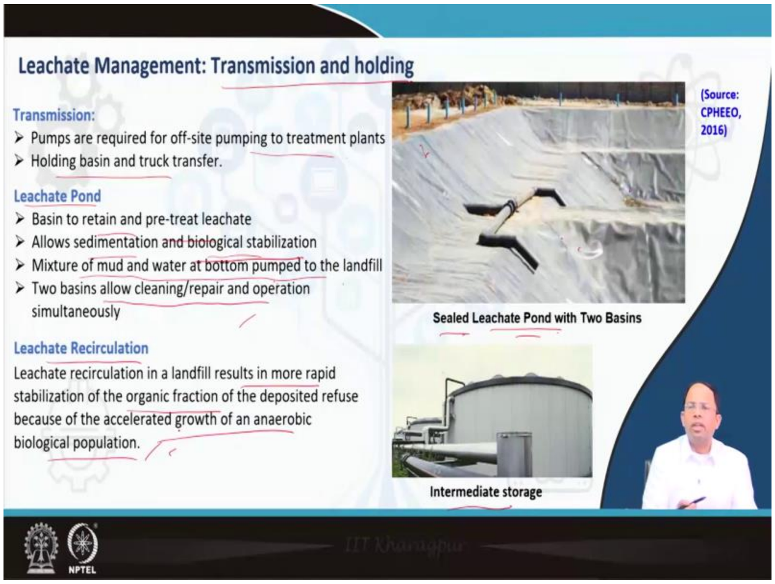

So, of course leachate before transmitted it has to be hold held also for some time, so for transmission and holding we create this leachate ponds these are sealed ponds as you can see, these are this this HDPE layers are given so that it does not mixes into the surrounding soil. And usually, two basins are created so that at least one is always operational. So, we can clean or repair one whereas the other could be kept operational. So, this is what is being shown over here or we can store the leachate in some intermediate storage tanks as well.

So, pumps are required for offsite pumping to treatment plants, or we can hold the leachate in some holding basin, for eventually transfer transferring it via trucks to the treatment plant. So, the leachate pond, this is for retaining and treat and some amount of treatment is can happen in this leachate pond. Now, because we are holding leachate for some point of time, it allows sedimentation and that means will allow the heavier materials to fall down. So, and there we by obviously, when this kind of a material with some organic matter is there biological stabilization will happen or decomposition will start happening.

So, this mixture of mud and water at the bottom which gradually accumulates this is again pawned back to the landfill because that is we that that is not what we transport we only transport the water part the liquid part the solid part is again put back into the landfill site, two basins allow cleaning repair and operation simultaneously. So, this is how leachate ponds are designed.

And then coming to leachate recirculation as I was saying that some amount is pumped back into the landfill.

And if we do that, then some moisture also goes back and leachate recirculation or landfill results in more rapid stabilization of the organic fraction of the deposited refuse, because of accelerated growth of anaerobic biological population or bacteria inside the landfill site. So, this is a again, if organic waste is there, this is fine, but if organic waste is not there, then there is no point of doing this kind of recirculation.

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Now, in the leachate treatment plant or if it is locally at the site or it is done outside, so, usually we employ biological processes where we use aeration, active sludge processes, similar to water treatment and nitrification and denitrification, so, these are the processes which are taken up. Chemical processes like oxidation, neutralization, these are taken up, or physical processes like air stripping, activated absorption, ultra filtration, these are the different processes. I am not going into details of this. But if you are interested in sewage treatment and all you can look into our NPTEL lecture also on sewage treatment.

So, there we have discussed many of this process in detail. And so that is the similar process that also adopted in that leachate treatment plant. Then co treatment can also happen that is instead of having individual leachate treatment plant, we can use the existing sewage treatment plant to treat this kind of leachate, but the idea is the STP should have the capacity to handle this extra leachate and this capacity is form of the biological, BOD are the biochemical oxygen demand or biological oxygen demand load.

So, that means, whenever a leachate is brought for treatment, it has extra, it has got, organic matter and all, so obviously, the BOD will increase. And similarly, the nitrogen load would also be increased. So, this extra BOD and nitrogen load that has to go it through this particular has to be taken care by this sewage treatment plant.

So, the capacity has to be already existing. So, when we design the sewage treatment plant in adequate in addition to designing it for the normal, urban sewage, we also have to consider the extra nitrogen load and the biochemical oxygen load which has to be taken care of because of the incoming leachate as well.

One very basic process of leachate treatment which could be done on site itself is by, spraying the leachate along the lined ponds for evaporation. So, we can spray the leachate along the lining of the pond. And when we do that, the water evaporates, the remaining solid matter can be collected and again taken to the landfill site. So that is how it is a very basic system for treatment as well. So, this shows the leachate treatment plant over here with intermediate storage as well.

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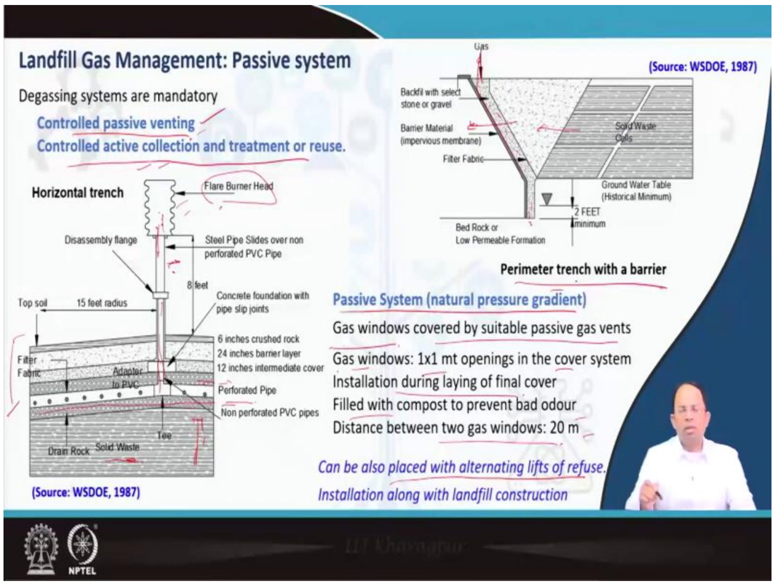

Then we come finally to the landfill gas management system and here instead of leachate we are collecting gas because gas is also which is generated in landfill particularly we generate CO2, CH4, a lot of greenhouse gases are being generated which needs to be captured. So, there are different ways to do that. It could be a controlled passive venting system and also a controlled active collection and treatment or reuse system.

So, primarily it could be up passive system or active system. Now, in future landfills the mandate is to go for active collection system, but for existing landfills there are passive systems or we can also design passive system for already, existing dump sites and so on. So, in passive system the idea is the gas will move as per the natural pressure gradient of the gas. So, we are not creating additional pressure by creating vacuum or so, on.

So, that means, we are allowing the gas to move. So, for this we create some windows or we know we call them gas windows covered by suitable passive gas vents. So, that means gas windows and nothing but opening in the liner system that means, in the top liner system or the cover system we create some openings, so one meter by one meter and through which we can allow the gas to come out.

Now, there is some designs for it, I will show it one by one and this is done during installation of the final cover, of course, we have to create some holes in the final cover to allow the gas to come out and fitted with compost to prevent bad odor. So, we sorry filled with compost to prevent so, we filled this particular opening with compost so, that it odor is not that much odor does not it does not result in odor.

Distance between two gas windows is around 20 meter. So, I will show you a image of this in the in one of our case studies later on. So, this 2 we can fit this kind of gas windows inside and sometimes you can see there as you can see over here that is we have a solid waste the layers, the cells you can say, above that we have this gas collection layer we have shown this in the design of the final cover that there is a gas collection layer over here we have laid a pipe which is a horizontal pipe and this is has got perforations which allow gases to move inside and then it is at certain intervals, we have this gas windows through which we can take this pipe out or the gas can be taken out.

And above there is this metal pipe fitted with a layer or a burner head, where the gas could be burnt. So, that means the gas is allowed to come and get stored, then we, what we can do we can ignite this gas and we can burn it in a controlled fashion so that this fire does not goes below so that is how it is controlled, and this is called flaring of the gas. So, we burn the gas so that it does not mixes with the atmosphere. So, when burning will convert this gas into CO2 and CO2 is much less harmful compared to CH4 in terms of greenhouse gas, in the implications in regards to greenhouse gas emissions.

So, that is why we burn the gas converted it from CH4 to CO2 and automatically, this is a better process than releasing the CH4 directly into the atmosphere. So, the design is more or less given and again these are technical designs, some variations of it will be there everywhere, but this kind of gas collection layers can be also placed with alternating list of refuse and that means the installation is not only happens at the end, when the final cover reconstruction cover is the final cover is done, but also in the intermediate stages as well.

So, that means it can be paid after two layers of refuse is done we can place once this gas collection layer and then we can move on and put other layers as well. So, that can also happen and in that layer, we can also have this horizontal perforated pipe which is again connected with this gas layers. So, in addition to this there could be a perimeter trench with a barrier. So, over here you can see at the barrier to prevent gases to move from the sidewalls also, there is a barrier layer and we have a gas collection layer over here as well which will allow the gas to be collected from that top. So, this kind of system also exist.

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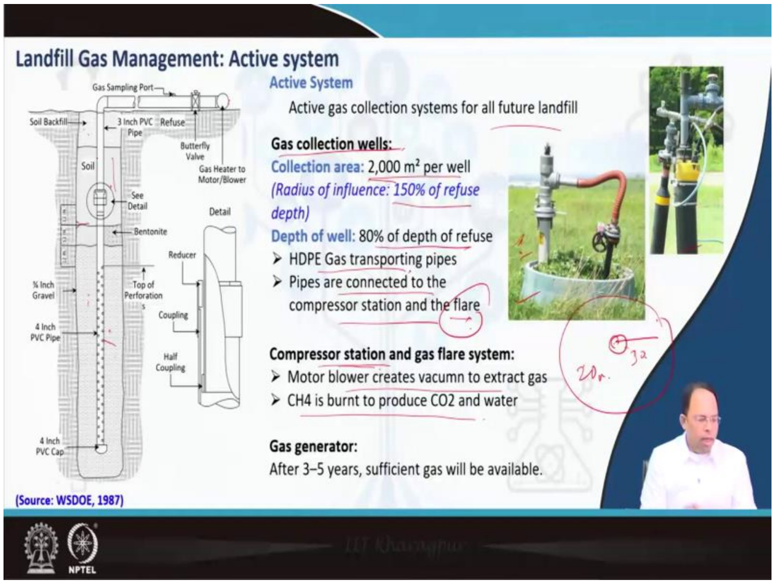

So, next comes the active system in active system as we were saying that all future landfills in India should also have active systems. Here we construct gas collection wells, that means we create some to at least 80 percent of the depth of the diffuse we will create some wells and we will put this HDPE pipes covered by of course, this granular material is to, collect the gas and then it will be transported to the top.

Now, pipes are connected to the compressor station that means there is a compressor pump which creates vacuum it will suck the gas inside and this gas could be again because we are actively controlling this collection of gas. We can we can either flare it as far as the gas collection schedule or we can, take it or transport it to a station, where we can, we can we can collect the gas we can clean the gas and we can use it for electricity generation.

So, the motor in the compressor station the and the gas flare system that is installed, the motor blower creates a vacuum to extract the gas and CH4 is burn to produce CO2 and water. So, as you can see that this is more or less that design of the system. So, we have this gravel layer it is it is a hole in the ground, approximately the collection area for each of these well is around 2000 square meter or we can say that around 150 percent of the refused depth. So, that means, if the refuse depth is 20 meters, so, that means 150 percent of this that is 30 meters should be the radius of the collecting area.

So, for each well on the landfill, we can have a radius of these 30 meters, and this is the area commanded by this particular gas collection well. So, roughly over here it says for every 2000 square meter, we can have one gas collection well, and you can see the gas collection wells in this particular image. So, this is about the landfill site. So, the top cover of the landfill has the vegetation level, where grass is grown and you can see the gas collection layer sticking out this gas collection wells sticking out of it.

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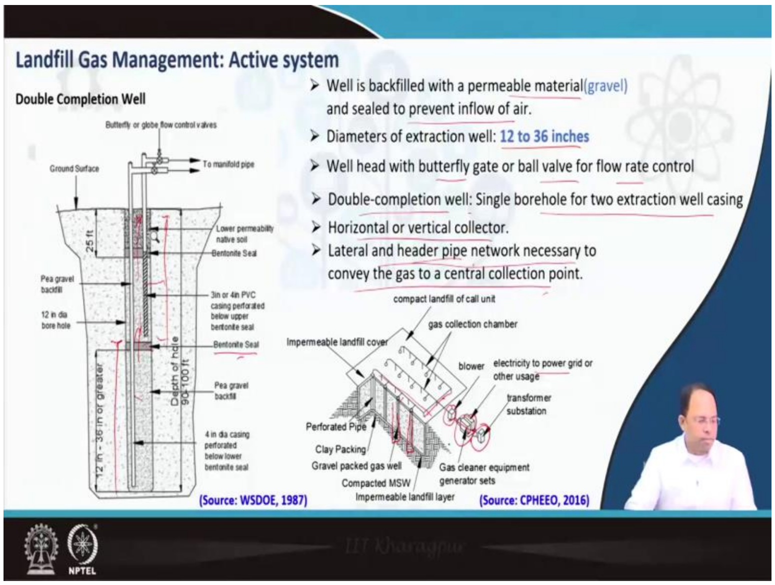

So, the well is backfilled with permeable material gravel and sealed to prevent inflow of air, so we seal it so that air does not move inside to prevent and also gas does not move directly no above it has to come through the pipe. So, in the earlier image also you have seen that there is a sealing done. So, there is a soil sealing there over here and over here you can see that there is a bentonite seal and here instead of one pipe we are using two pipes, because we are using one well but because the depth of the landfill is quite significant instead of having one pipe we are having two pipes.

So, this pipe is collecting from these upper layers and this pipe is collecting from the bottom layers, so that is why there is a seal over here and then there is the top seal over here as well. So, this seal prevents gases to pass directly outside and whereas the gas is collected inside these perforated pipes and then using any active system or this compressor we can suck the gas outside. Diameters of extraction well ranges from 12 to 36 inches and well head is with a butterfly valve or a ball valve to flow so that we can control the flow rate of gas and double completion well where single borehole, for two extraction well casings can be utilized.

So we can use the single well for two disc pipes, it could have a horizontal or a vertical collector network of pipelines, lateral and header pipe network necessary to convey the gas to a central collection point as you can see over in this image, these are the gas collection wells. And from here there is a pipe network of lateral and header pipe network which will bring the gas to the blower which actually sucks the gas, then it is transported to this particular station where electricity is produced and transported to the power grid via transformer. So, that is how the overall gas management system works.

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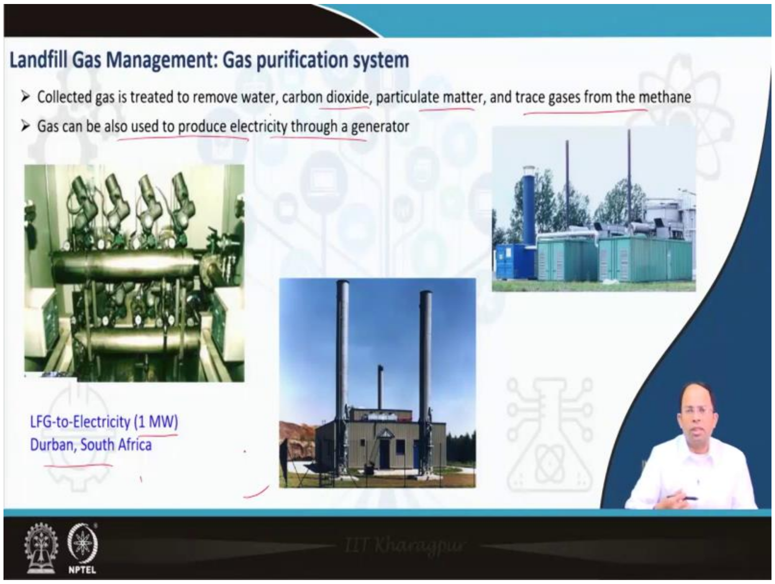

So, once the gas is collected, either I can burn it and we can clear it or we can burn it to generate electricity, but sometimes we can also clean the gas first before we burn it and all we clean it the gases treated to remove water, moisture, carbon dioxide, particulate matter, and trace gases, from the methane. Gas can be used only to produce electricity through a generator. So, as you can see that there are several examples of it one is this landfill gas to electricity power plant a 1-megawatt capacity in Durban, South Africa. So, this is how the overall the gas needs to be first clean and then it will be incinerated or burned so that we can produce electricity.

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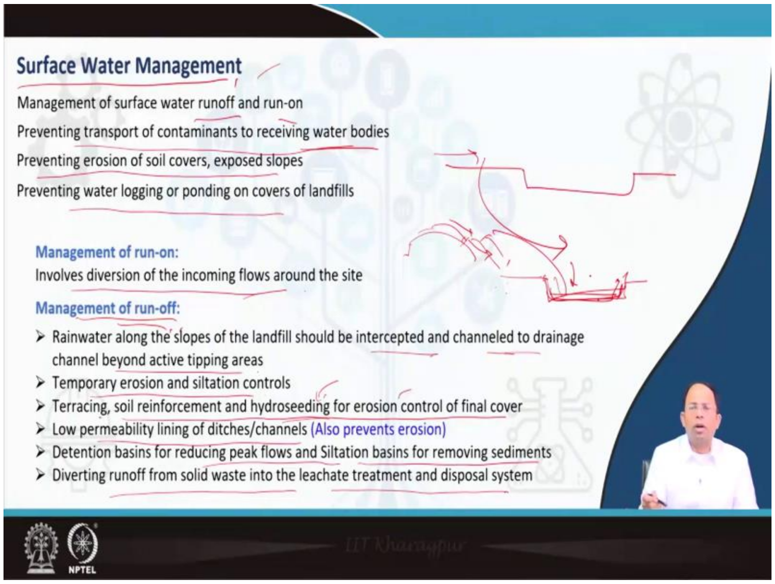

Now we come to surface water management. So we have got landfill gas management, landfill leachate management, but we also need to manage the water that comes into the landfill. So particularly we are concerned with the surface water and the surface water could be both run off and run on. Run on is the water which is moving from the surrounding area over to the active landfill site. So, we want to prevent that.

So, to prevent that, that means if we that means we have to divert the incoming flows around the site. So, we cannot allow the water to if I have got my landfill site, I cannot allow water to move over here so I have to divert it around the landfill site. The other is of course, we have to prevent transport. The other is of course, the management of the runoff part, which is more important, because this is where the water is going inside we have to prevent the water to go inside.

So, we have to prevent transport of contaminants to the receiving water bodies. So, that means, what happens even though we are putting a cover, intermediate cover still there is a lot of, toxic material in or, the waste material is sprayed over the landfill and when water comes in contact with it, it is becomes polluted or contaminated.

So, we cannot allow this water directly to flow over the landfill and then go into a water a body, receiving water body like a pond or surface water stream and so on. So, some amount of treatment has to be done. So, we also need to prevent erosion of soil covers and expose slope slopes that means the water will travel along the slope of the landfill site. So we need to prevent erosion and we also need to prevent water logging or ponding on the this top cover of the landfill site.

So, these are the primary goals of surface water management. So, we are not talking about the water which infiltrates inside there, we have to control it by the leachate management system, this is the water which flows over the site first of all, we will prevent water to flow over the site, but the water that falls on the site that we can have to take it over the site of course, so that is one where we are concerned about. So that is how we manage the runoff.

The rainwater along the slopes of the landfill should be intercepted and channeled channel to drainage channel beyond the active tipping areas. So, that means we should make sure that the water which is falling on the landfill it is not flowing uncontrolled. So, that means it should be intercepted at certain distances using some drainage system as I was explaining earlier, that in the benches, we have to create those drains where we can collect the water and we have to also do temporary erosion and siltation control that means the water that is flowing from the surface has to be held for certain amount of time maybe in detention or retention basins.

So, that sedimentation happened we collect the soil back and we can use it back as cover as well. Terracing soil reinforcement and hydroseeding for erosion control or final cover, terracing, of course, we have discussed soil reinforcement, we have to put some amended soil, clay soil and so on. And hydroseeding is we put mix grass seeds with water and spray them over the cover. So that is hydroseeding that will result in growth of grasses uniformly over the entire area which will prevent erosion.

Then low permeability lining of ditches and channels. So, all that the drains that we will create in the site they should have low permeability and detention basins for reduced peak flows and siltation basins for removal of sediments. So, this could be the same thing detention or siltations or it could be different ponds designed for different purposes. Diverting runoff from the solid waste into the leachate treatment and disposal system. So that means either this could be treated through the leachate collection system as well this water or it will be treated separately.

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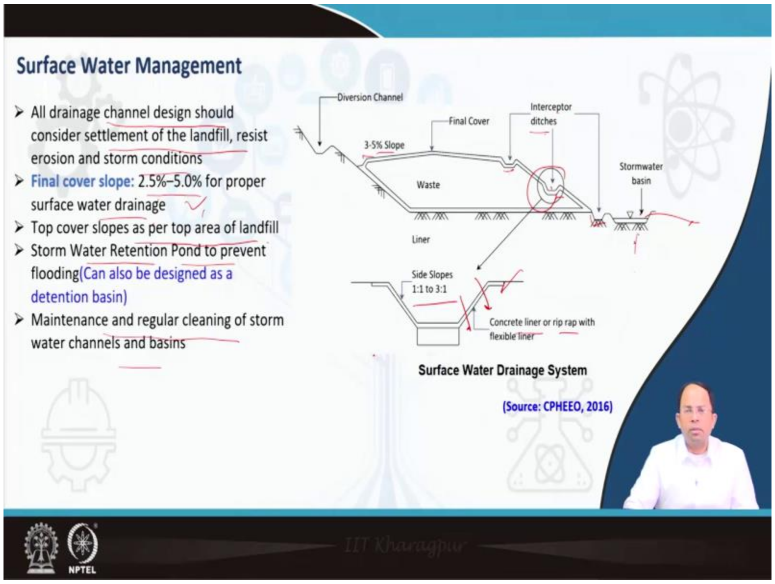

This is how it looks our 3 to 5 percent slope is given on the final covered at certain distances we have this intercepted ditches. So this could be also along that benches and there we collect it, this is the design of this particular ditch where the side slopes are given 1 is to 1, 2 3s to 1 and there is a concrete liner or rip rap so that this does not allow infiltration through this particular ditch and eventually it is collected over here and then there is a storm water basin where we can retain some amount of it or we detain it for something before we allow it to pass out.

So, few considerations, all drainage channel design should consider settlement of the landfill and it should resist erosion and storm conditions and should consider the storm conditions for this particular area. The final cover slope should be 2.5 to 5 percent, like 3 to 5 percent 2.5 to 5 percent of the proper surface water for surface water drainage. Top cover slopes as per the top area of the landfill but of course it has to be aligned with this. Storm water retention pond to prevent flooding can we also designed as a detention basin, maintenance and regular cleaning of stormwater channels and basins. So, this is how we go about surface water management.

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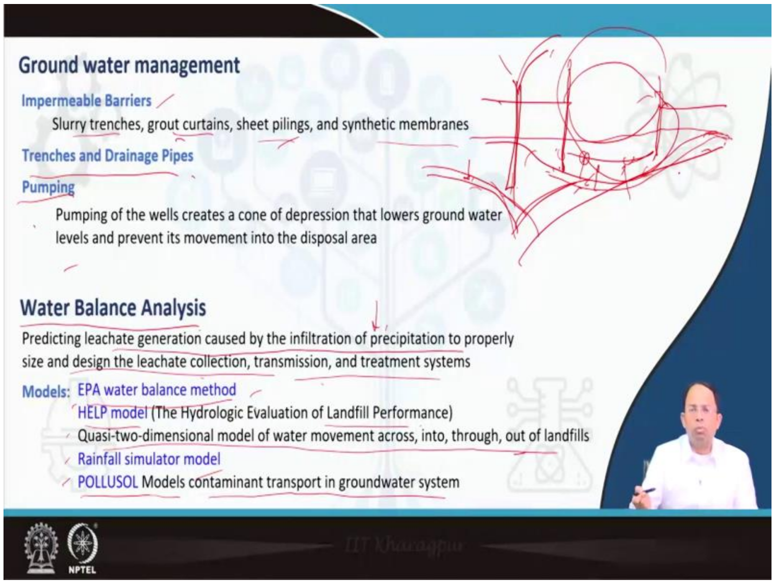

And then we also sometimes we need to go for groundwater management as well. But this is rare because we will try not to design landfills at areas with the high-water tables. But sometimes we cannot avoid that. There are different seasons maybe the water table comes up. So, there we have to create some protective, we have to take some protective measures, what are these measures? One is measures like putting some impermeable barriers that means we put some slurry trenches, grout curtains, sheet pilings, synthetic membranes to prevent water to mix from or water table the water from the groundwater to mix with the waste or to, if it is aligned system also to mix with the liner systems or to influence the liner system.

So, that kind of protective measures are given. Sometimes what happens I have a landfill site like I have a dump site like this, waste is dumped. Now, the groundwater table is comes along here. So, I can put some barriers over here by putting some piles, putting some grout curtains and all this will make the water to go like this. The aquifer to bend like this or you can say that this will allow the movement of water below this some amount will come try to come up but still it will not mix. So, this is how we prevent.

Trenches and drainage pipes we can also put in some trenches inside and we can put drainage pipe, so that the water that comes inside can be eventually drained. Then the final method is pumping. Earlier in maybe in my other NPTEL course, we have learned about pumping that means, whenever we pump water what happens that groundwater table bends so that this is called a cone of depression.

So, the groundwater table bends when we pump water from a particular using a deep tube well or so on. So, here also we can pump water that will make the groundwater table bend and that will not influence my landfill site. But this is a active measure and it will take both energy electrical energy to keep the pumps running and it requires a lot of additional investment. So, we need to do a very detailed water balance analysis for a landfill site.

Again, we will not go into the details for this but understand predicting leachate generation caused by infiltration of precipitation to properly size and design the leachate collection transmission and treatment system that is the goal of water balance analysis. So, to design the leachate collection transmission treatment system, we need to estimate how much amount of leachate is generated. So, it is not only the water that goes into the moisture outside, but also what amount of waste moisture is there already in the waste, many other parameters has to be estimated.

So, for this we have the EPA Environmental Protection Agency USPA, water balance method. So that can be utilized. There is something called a health model, which is the hydrologic evaluation of landfill performance model also developed by EPA it is a quasi-two-dimensional model of water movement across into through and out of landfills. So that means what water moves from outside to inside, inside to outside and through within the landfill how much water moves that could be estimated.

A rainfall simulator model for that particular area and POLLUSOL models which can model the contaminant transport in within groundwater system. So different people have used these components to design what sort of movement happens in terms of, this leachate inside a landfill, as well as how much amount of contaminants can move into the groundwater. So, all this could be modeled and determined and accordingly the leachate collection system can be designed.

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So, these are some of the references you can study.

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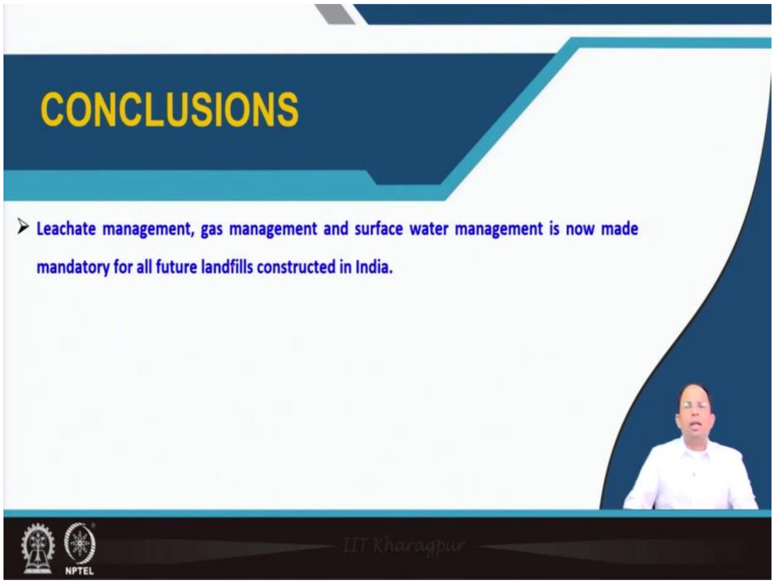

To conclude, leachate management and gas management and surface water management is essential and is now made mandatory for all future landfills constructed in India. Thank you.