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

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Lecture - 16
Generation and Control of Leachate

Good day, and welcome back to this class on which we will focus on generation and control of leachate. In the last 3 4 lectures we have done a lot about liners and something about covers. So, we have got the envelope now, we have got the whole waste in an envelope of impermeable barriers, which is the philosophy of dry tomb landfills. Now how are we going to handle the 2 emissions which are formed inside the leachate, which is formed inside and the gases. So, that is the going to be the next 2 3 lectures. And today we look at leachate.

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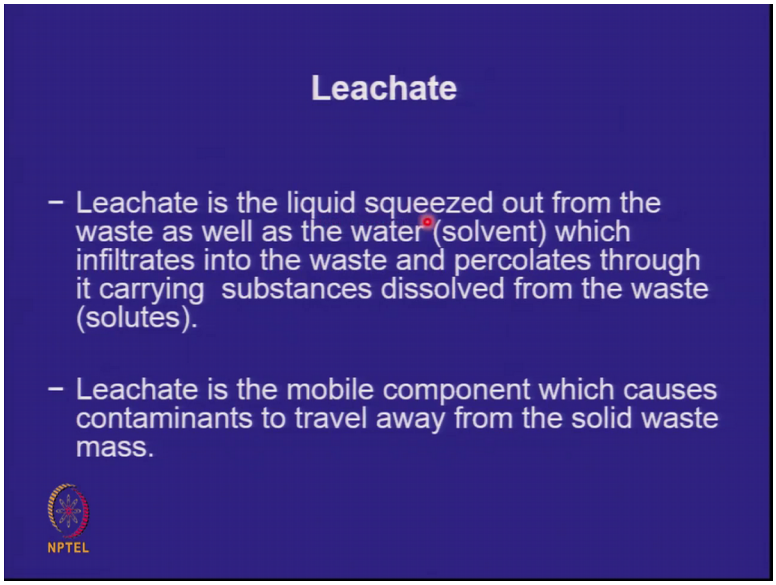

So, leachate is the liquid which is squeezed out from the waste, that is one part as well as the water which infiltrates into the waste and percolates through it carries carrying substances dissolved from the waste. So, water becomes a solvent, whatever is soluble will get into the water and we will come down with the water. So, the leachate is the mobile component which causes contaminants to travel away from the solid waste mass.

So, if there was no leachate, then at least in the liquid phase nothing would move out it is still there could be dust it could be particles which could move out there could be gaseous emissions, but as far as the liquid phase is concerned, whether it is polluting surface water or whether it is polluting groundwater it is the mobile component. And let us go back to this diagram which we have been working with.

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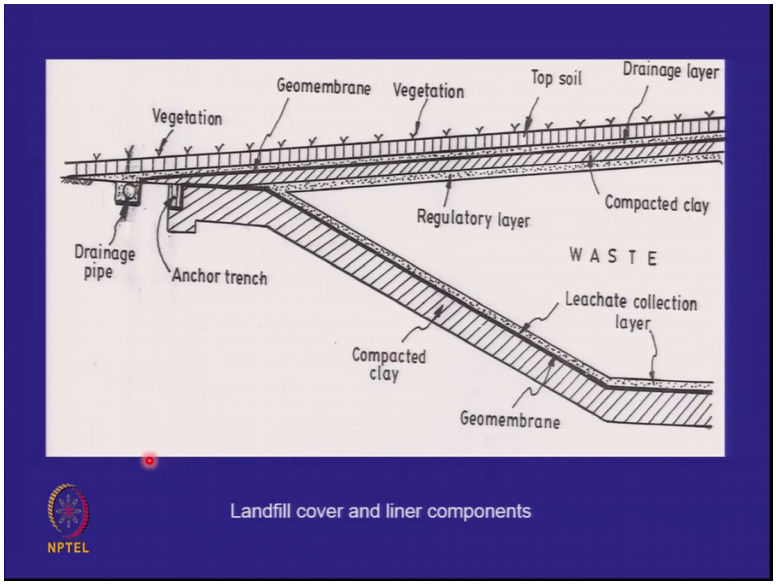

We have talked about liner, we have talked about cover, and today we are going to talk about that, if you have infiltration and if your barriers do not work some water will come down or if this is a perfect barrier the waste itself may be wet and as you build up the waste it will squeeze the poor liquid out. So, how do we handle this liquid which is coming at the base? And you would recall all the diagrams, we have we have a composite liner here and top of the composite liner we have a 30 centimeter thick layer where the leachate is collected.

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So, we are going to talk about leachate generation and control. First we will talk about quality then we will talk about quantity, and how the liners and the drainage and the collection system help us to collect this leachate. We do not want it to go out in an uncontrolled manner. And then what do we do with the leachate that we have collected that is going to be the summit substance of what we are doing today.

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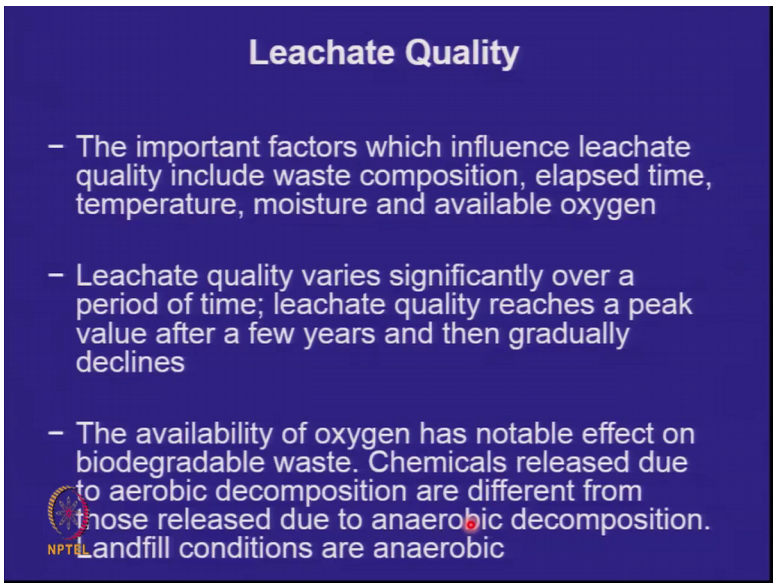

So, it is very difficult to predict what will be the quality of leachate. So, suppose I was to ask you please predict what will be the quality of leachate, how would you go about it I

could give you a lot of waste, but I want to ask you what will be the quality of leachate. So, those two issues in the quality of leachate one is the constituents right and second is their concentration. So, we need to know what will come out and what will be the concentration and how would you go about it.

If I was to ask you to estimate the quality of leachate in advance you are going to make a landfill, you know this waste is coming the waste is available from an old dump how would you estimate the leachate. So, if there is no old dump which is available then quality would have to be necessarily simulated in the laboratory. And the simulation will be what you will put the waste in a column, and you put some water on top and you will collect the water at the bottom.

So, you may get the constituents in it. You may not because this may be a 15 20 minute one day test whereas, leachate may be generated over years. So, you could do a column test by leaching water through the waste you get some idea of the constituents, and the concentrations will what about the concentration concentrations will depend on what is the height of the column.

In the field the height of the column may be 15 20 meters. So, water is traveling to 15 20 meters of waste therefore, the concentrations may be high in your lab you cannot make a 15 20 meters high column. So, the concentrations may be different plus inside the waste mass lot of reactions may be occurring if it is a biodegradable component is high or if it is municipal solid waste.

Therefore, now the factors which will influence the leachate quality will be the waste composition, the time, the temperature, the moisture, the oxygen and other factors. So, it is complex leachate quality varies significantly over a period of time, but broadly speaking leachate quality will reach a peak value; that means, the concentration of the contaminants will first reach a peak value, and then it they will gradually decrease as more and more water comes in they will gradually decrease after the peak value is reached.

In biodegradable waste, in municipal solid waste available that you of oxygen has a huge effect, whether the reactions which are taking place inside the waste mass are in aerobic condition or anaerobic conditions, because the contaminants of the chemicals released

during aerobic decomposition are different from those released due to anaerobic decomposition.

Landfill conditions are by and large anaerobic in the lower portion of the landfill, but when you are depositing fresh wastes there is oxygen in it. So, they gradually change for aerobic to anaerobic.

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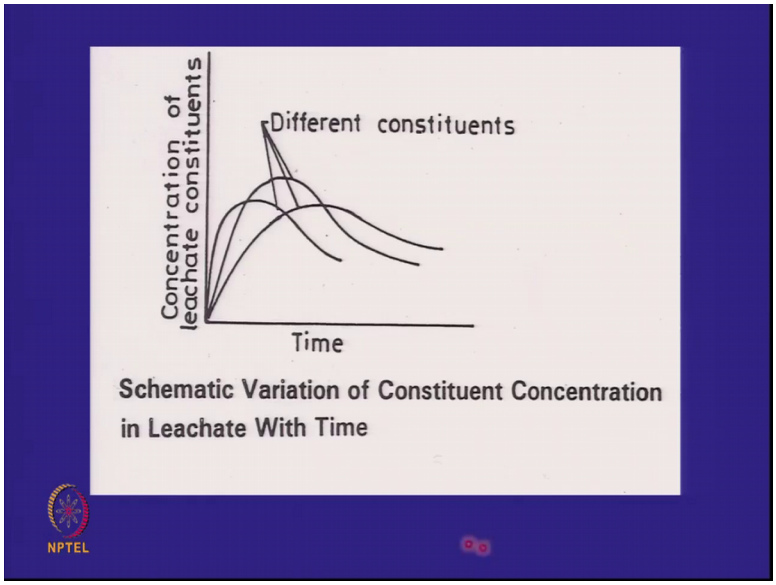

So, these are the complexities that are involved, and if you look at the concentration of the leachate constituents and if you look at time from a landfill many constituents may come out. So, they will reach a peak value this could be chloride this could be something else this could be heavy metals and then they will tend to decrease.

It is almost as if the waste is being gradually washed off of the contaminants which will be carried away with water. Not all contaminants will come with water some will be the poor squeezed liquid also there may be a production of reactions, which may not dissolve in water, but they are liquid themselves right.

So, if you have organic waste and some reactions are taking place and the outputs are immiscible liquids, they will come out by themselves which will not ride as a solution in the water and just to give you an idea of the complexity.

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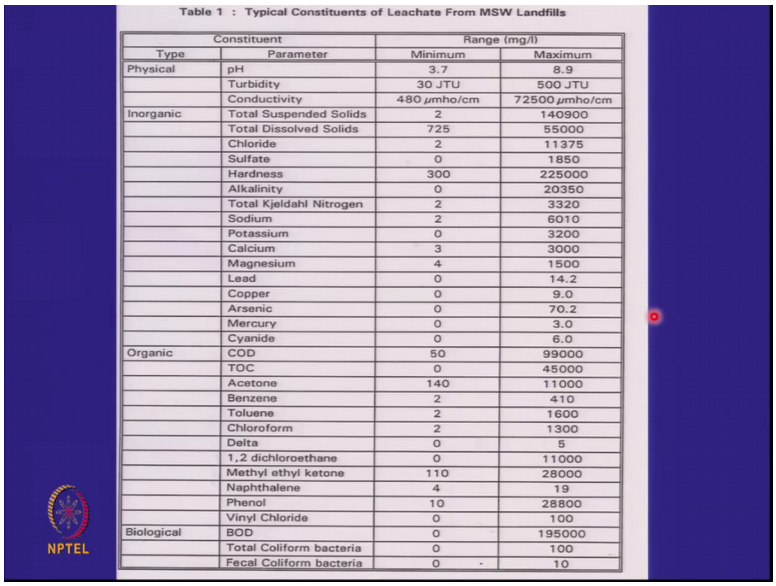

Constituent		Range (mg/l)	
Type	Parameter	Minimum	Maximum
Physical	pH	3.7	8.9
	Turbidity	30 JTU	500 JTU
	Conductivity	480 μmho/cm	72500 μmho/cm
Inorganic	Total Suspended Solids	2	140900
	Total Dissolved Solids	725	55000
	Chloride	2	11375
	Sulfate	0	1850
	Hardness	300	225000
	Alkalinity	0	20350
	Total Kjeldahl Nitrogen	2	3320
	Sodium	2	6010
	Potassium	0	3200
	Calcium	3	3000
	Magnesium	4	1500
	Lead	0	14.2
	Copper	0	9.0
	Arsenic	0	70.2
	Mercury	0	3.0
	Cyanide	0	6.0
Organic	COD	50	99000
	TOC	0	45000
	Acetone	140	11000
	Benzene	2	410
	Toluene	2	1600
	Chloroform	2	1300
	Delta	0	5
	1,2 dichloroethane	0	11000
	Methyl ethyl ketone	110	28000
	Naphthalene	4	19
	Phenol	10	28800
	Vinyl Chloride	0	100
Biological	BOD	0	195000
	Total Coliform bacteria	0	100
	Fecal Coliform bacteria	0	10

I do not know whether this slide is very readable, but if I take a municipal solid waste landfill, then if I go to literature and see the kind of contaminants that we can study.

So, there will be some biological contaminants. There will be some organic contaminants, there will be inorganic contaminants. So, here is a list of parameters pH, turbidity, conductivity, suspended solids, dissolved solids, chloride, sulfates, hardness, alkalinity, nitrogen, sodium, potassium, calcium, magnesium, lead, copper, arsenic, mercury, cyanide, inorganic; and organic cod, toc, acetone, benzene, toluene, chloroform and other compounds; and biological BOD coliform, bacteria, fecal, coliform, bacteria.

So, really to be able to characterize a municipal solid waste landfill leachate, you have a large number of parameters. And what bothers us, I mean if I have leachate coming out, what is bothering you. The concentration of the constituents should not be very high right. If I take ordinary soil, if I take ordinary soil and run a heavy metal analysis on it, there will be some heavy metals in it.

But they will be very low and if I take some groundwater which we are using for drinking purposes, and if I run some I mean groundwater quality analysis we will get chlorides, but again there will be lower than the acceptable limits. So, what bothers us about the leachate? As long as everything coming out is within limits no problems, but if it is more than the limits then there is a problem.

So, when I say we should test. So, many parameters what do we compare them with I mean. These are all the parameters of contaminants in the leachate. I need to compare them with some limits. So, what limits should, I compare them with. So, I have leachate constituents, should I compare them with drinking water standards? Why not?

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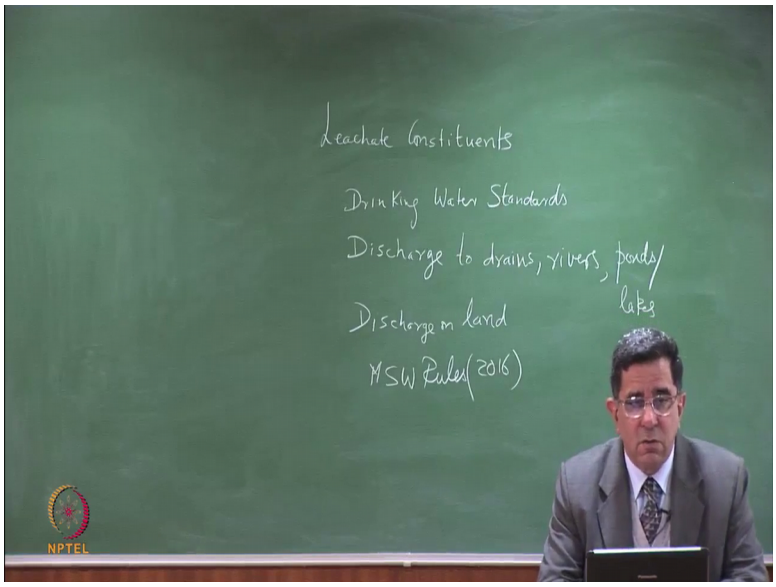

Eventually, if the liquid is going from the waste mass into the ground into a groundwater which are using for drinking water purposes, then should I compare it with drinking water standards. Well one of the set of standards which are available in the codes is the drinking water standards are there other standards which are available. So, this is the acid test, if the leachate is meeting all the standards great you can drink the leachate.

No do not be scared about it you will be very confident of your testing. You be very confident of your testing, but do not be scared about the fact that I cannot drink my leachate. Is there any other standard by which we can say all right our leachate should meet, the standard what are the standard do we have in the IS code?

Student: Dispose on or pound.

So, I also have pollution control standards of you know, this is like the landfill is treated like a factory. So, the effluent coming out of a factory is subjected to the pollution control mode norms right. The pollution control board officials will come once every

month. Randomly and take your sample. So, there is there are standards for discharge to drains. What can come out and go to a drain?

So, you will have to check this out in greater detail, but there should be standards for discharge to drains. Discharge to rivers and discharge to pounds or lakes. If the drain is going to a affluent treatment facility, then it will have some pre standards about what the affluent treatment plant will accept. If it is going to a river and if it is going to a pond the standards will be different, why? River is flowing.

So, whatever mixes the river it gets diluted more fresh water comes from behind, but in a pond or a lake the water is not flowing. So, the water is not flowing the standards will be more stringent and of course, drinking water standards will be the most stringent. Over and above that we have more standards, I understand discharge on land, discharge on land. So, do you think the most stringent standard of course, is the star is drinking water standard right. And discharge on land and I have not looked at the standards in great detail, but it presupposes that there is an attenuation capacity of the soil right. It presupposes that.

So, maybe it is different from the drinking water standard, but for me from a long term perspective, if leachate is going to come out for the next 20 to 50 years then the attenuation what have you understood attenuation capacity will.

Student: Deplete.

Deplete with time and if the water table is high, then you are and if you are using your ground water for drinking water purposes then you are back to the standard. If your ground water is already polluted, it has some high constituents not because of your landfill. Then at least you cannot go above the background levels, you understand you know salty water and if you have then your means there is some high amount of total dissolved solids right. So, then your benchmark becomes that what you are putting on the land which will go to the groundwater, I should not exceed the what is already existing higher than the background level.

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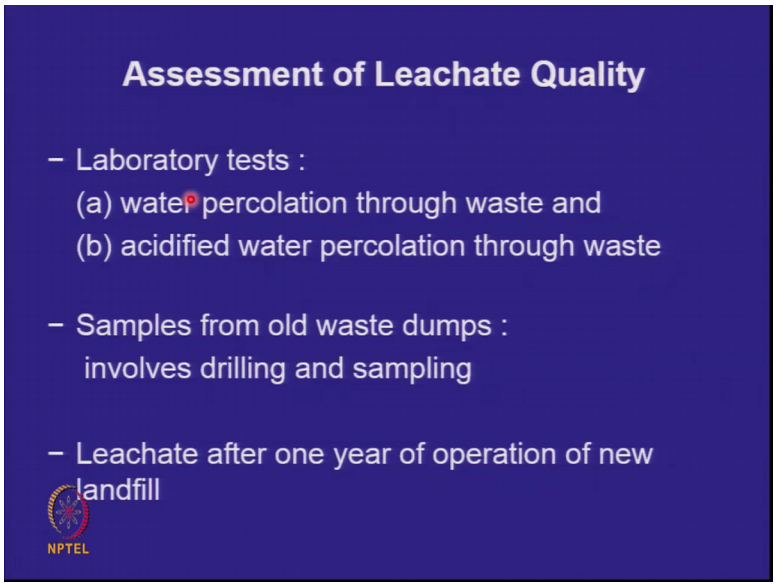

So, how do we assess leachate quality I have began this debate, you can do laboratory tests you can do water percolation through the waste, but I told you the limitations. You cannot simulate long term percolation of several years. And the height of the column is less right. So, what do you? So, usually look at the second one acidified water percolation through waste what does it mean we just trying to accelerate time.

We say that if the acidic environment more leachate will have more heavy metals more of the constituents will be released. So, if I have to do something very fast in the laboratory I have to model it in something. For example, how do we test durability of a construction material, in the laboratory were 2 cycles which are perform at a very rapid rate which simulate what happens outside very slowly would you have any idea.

I give you a concrete sample, a new concrete sample I have made this new material. Can you just check with me whether it lasts for 15 years or will it become will sort of disintegrate in 15 years? So, how can you do a test in the laboratory? Well there is a freeze and thaw cycle, there is a wet and dry cycle and there is a heat and cool cycle. So, what are the heat and cool cycle is simulating summers to winters, summers to winters, summers to winters right. And wet and dry cycle is simulating rain and no rain and no rain and no rain.

So, in the lab I can do the wet and dry in 24 hours. Whereas, in the field one wet and one dry cycle maybe taking a few days or a few months, I can accelerate the process in the

lab and I can estimate the number of cycles which may come in a lifetime of 15 years or 20 years and I can do the tests in 6 months. This could be the durability tests. So, these are accelerated tests.

So, when we study durability or geo membranes which you will do in geo synthetics there will be accelerated tests when I study leachability of constituents. I talked about the TCLP procedure something called the toxicity characteristic leaching procedure; there we are working on a pH of 2. So, everybody ask me why do we do this test at 2.

Whereas in the natural environment you are not going to encounter highly acidic of acidic environment that is just an accelerated how much is the total heavy metals which can come out leachable heavy metals which can come out from the waste. So, here also you can do acidified water percolation this way, but the secret is and this is not written in most of the textbooks, that if you have an old waste dump nearby what you are trying to simulate in the lab is already happening in the waste dump.

So, go to our waste dump and drill a hole suppose the waste is 5 meters high drill the hole to 3 or 4 meters, see if you get some leachate inside the waste dump that is the starting point. If you go into the soil beneath the waste dump and try to get may be already some attenuation is taking place. So, get the waste were stuff and maybe that waste dump came up in 3 4 years. So, what you are trying to do in the lab is already been done.

So, if you can get an old dump, take samples from the old waste dump I mean no it is just come from a couple of waste dumps and it says all around the waste dump you finds black leachate, I said go very nice go collected it, let us at least see what is there what are we dealing with is it just that it is black color is there some contaminant in it and he keeps on doing testing for heavy metals and heavy metals and I said no test for salts test for dissolve salts. And suddenly he will give me sir heavy metal is 4 PPM and the limits 3.5 PPM is it dangerous, I said what about the total dissolved salt sir the limits one thousand and we are measuring 20,000. So, get the right constituent. Please look for the right constituent I may have given you a list of 30 40. So, sampling from old waste dumps you can drill in sample or if there is a natural path by which it comes out, then it is accumulating it someplace.

No I am not saying that it is the worst feature it might have rained yesterday therefore, the leachate might have been diluted, but that that is going to remain there. So, go at the end of summer before, it dries out and pick up that leachate to see what are the kind of constituents that you are going to get. So, this gives you why is this important because we need to treat this leachate in the end.

If I do not have a handle on what are the constituents what treatment plant am I going to make right. So, I am going to treat this in the end. Otherwise that you make a landfill you do not have the waste dump you are not confident of your lab results make the landfill store the leachate for one year leachate will come out this is on as is coming out basis store it for 2 years.

If you operate a landfill well you are not going to get that much of leachate which you can not store. If you operate it badly then of course, you will have a problem because you can not store it, but if you cover it with temporary cover during the monsoons and ensure that very little rain goes in it you can have leachate that you can test after one year and then you can do design any facility for that purpose.

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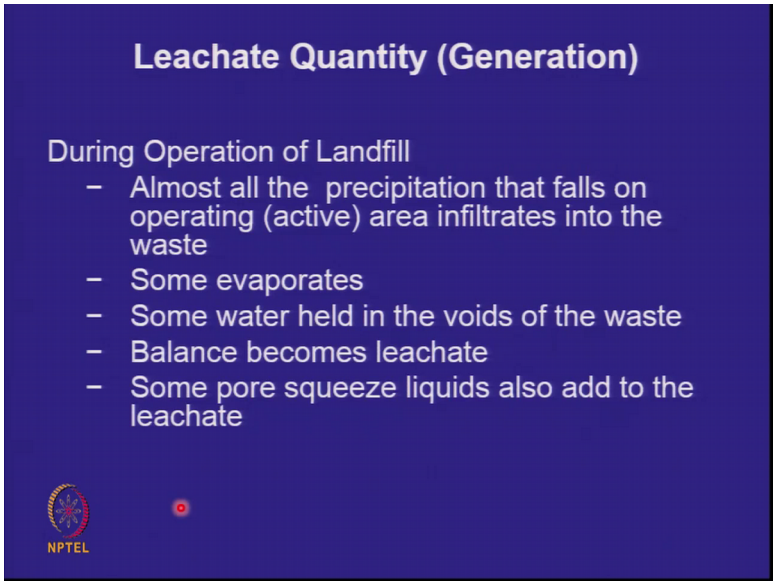

Let us look at the next aspect that is generation. And I tell you this topic is important because again you will find that a lot of discussion on the model rain falls, let us let us just go back to our cover and we will understand what are the I really want to bring the diagram.

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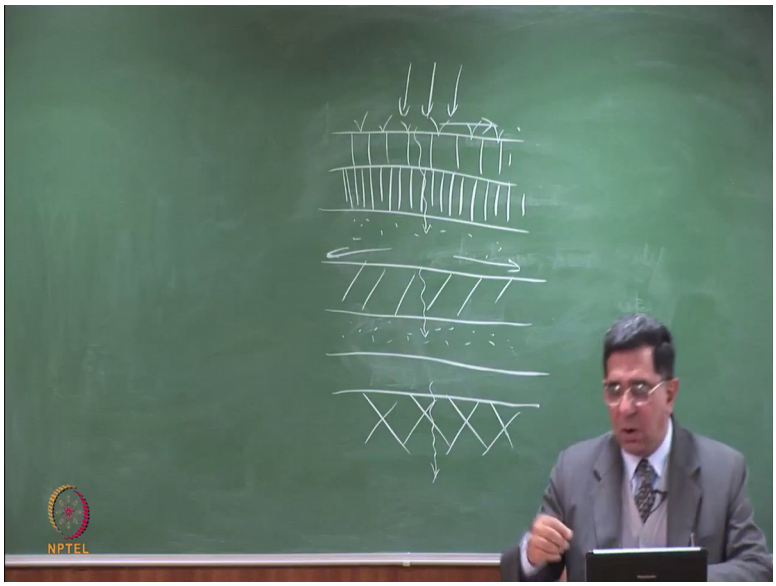

So, I will come to the diagram, but if you recall our cover, I will not put the separators and I am just putting a municipal solid waste cover.

So, this is the top soil in which your vegetation will grow right. This is the protector layer drainage layer, barrier, gas collection layer and a foundation layer, if you need one and then the wastes you all remember this. So, we are now trying to estimate the quantity of leachate which is generated. And if you look at this diagram it says precipitation, runoff, evapotranspiration, change in moisture and then leachate.

This is bulk large grass processes. Rain will fall, if this is sloping rain will runoff some of it will come in what will happen here at the barrier we have put a drainage layer with a very specific purpose, that this will also runoff. We have clay barrier something will go through what we may call leakage or we are designing it that something should go through. This will percolate through the wastes and this waste may be several tens of meters thick and then it will come to the bottom.

So, to simulate all this how much is falling what is the infiltration coefficient; what is the runoff coefficient depending on whether it is grass or not. A lot of mathematical models have been developed a lot of mathematical models have been developed and one is listed here it is called help it is USEPA. It is available free on the net. You can use this for the purpose of computing how the nature is generated.

But the larger picture is lost because everybody starts to work with this model. And let us first understand; what is the larger picture where is the leachate coming from in a landfill, bulk of the leachate. The bulk of the leachate comes from the active phase. This is what you have to fundamentally understand. If I am taking out 100 units of leachate every day bulk of the leachate in that 100 units is from the active phase.

Why because in the active phase this does not exist, why active phase there is no cover it is you are adding you are adding waste every day right and you are adding waste every day and it rains. So, there is no cover in the monsoon you can say I will keep it covered because I am expecting rain, but where 2000 tons of waste is being disposed every day for example, in one of the landfills of Delhi 2000 tons of waste comes.

How many trucks are coming 2000 tons of waste?

Student: 500.

400 500 trucks are coming in 20 hours how many trucks in an hour.

Student: (Refer Time: 25:10).

20, 30 trucks a truck every minute or 2. What are you going to cover these trucks are just coming and you have to spread the waste and there are 5 dozers and the trucks are coming and the waste has to be spread and it rains.

So, you say no rain is coming professor Datta gave a lecture key no you shouldnt allow the leachate to form trucks will start by lining up you can stop it. You cannot stop putting your waste and you cannot have a temporary cover on the site all the time. In the monsoons you can be actively geared for this right, but. So, what I what I am trying to say is it is the active part of the landfills which creates the leachate and that is what you have to understand.

That is the message which is normally lost in this water balance which we talk about. And let me see if we can quickly capture that. So, in leachate generation, the main thing is during the operation of the landfill almost all the precipitation that falls on the active area infiltrates into the waste.

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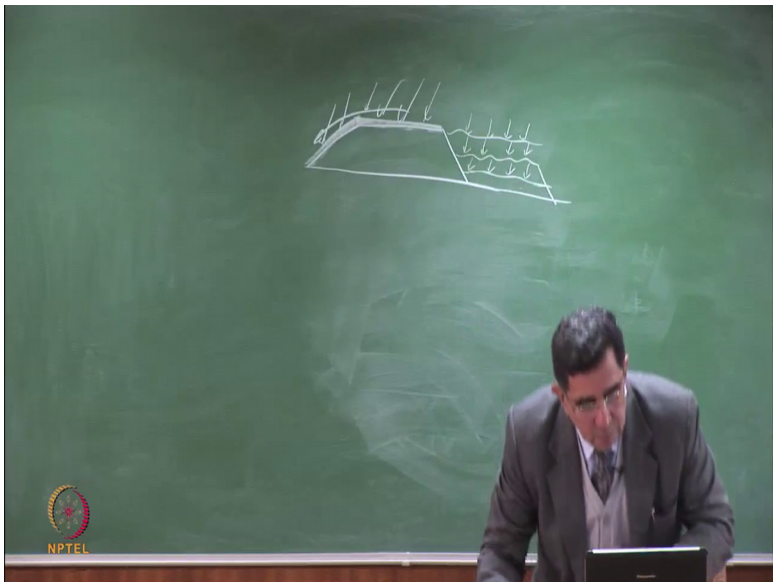

So, I am going to compare 2 areas of a landfill, again it depends on how you are operating your phase, but if that is my landfill this is covered.

This is intermediate cover and this is your active, if rainfalls on this will it run off in any direction. If it is undulating at the top if you do not finish it off and put a daily soil cover will any rainwater runoff. I can tell you if rain falls on this 100 percent of the precipitation will go inside some of it may be stored in the waste, but if waste coming itself is moist then there is going to be no storage inside the waste.

So, this part of the landfill is going to create the maximum leachate. And that is what your design is for if the design is not with cover whereas, everybody starts to use the help model the design is not for the cover. Because here ninety percent of your water if you have any well designed cover with proper slopes and an internal drainage layer ninety percent of more of the water is going to go of the rainfall.

Here hundred percent of the rainfall is going to come in though it is a much smaller area. That is the this is the area for which you do the design, how much leachate can you handle at, what rate is it coming, and what kind of quantities can you handle. The rest of it produces very little leachate. So, almost all the precipitation that falls on the operating area. So, after looking at this do you want to improve it you would like to put a daily cover.

A daily cover because if the rain comes on the daily cover, and if it is sloping sixty percent of it will go in 70 percent of it going because this only a soil there is no there is no vegetation on it, but still 30 percent of it will runoff. So, how you open it? And the smaller, you make this area the smaller you make this area the less because what is falling outside is not coming into the leachate.

So, all the precipitation falls some may evaporate some water is held in the voids balance becomes the leachate some pore squeeze liquids are also added.

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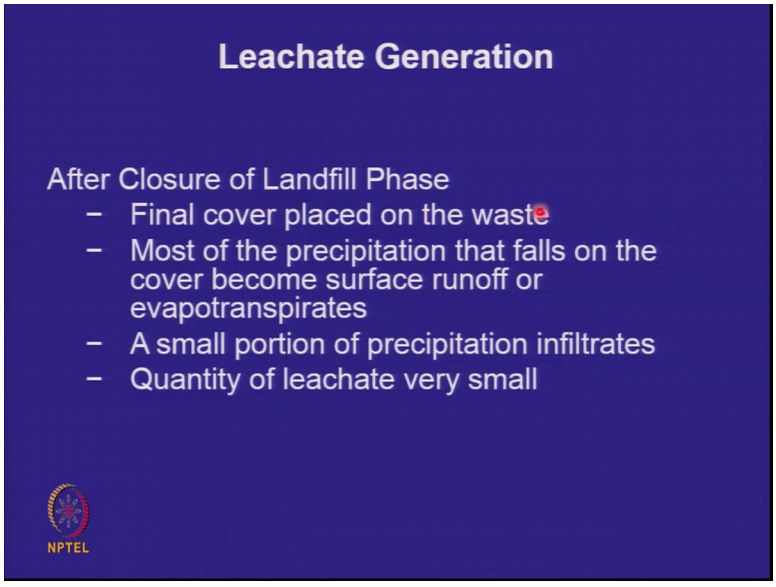

So, this is main thing. After the closure final cover is placed on the waste most of the precipitation becomes surface runoff or evapotranspiration. Small portion of precipitation infiltrates. And what that infiltrates again the internal drainage layer takes it away and quantity of leachate is very small. And I come back to this diagram, what I have put on the board.

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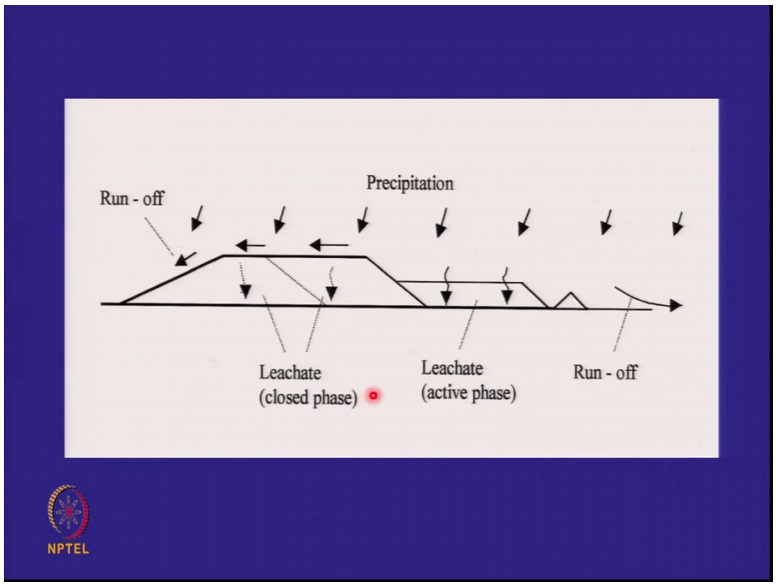

These are the closed phases this is the precipitation and that are the runoff. So, this will go to a surface water drain here. That is the active phase and what falls on it will give you the main leachate right. You have to have a bump here you do not want the water which is falling here to come here and start coming down. So, you have to prevent any water from any side coming into the waste.

So, this is the leachate which is the active phase and this is may be giving you large quantity. And this may be giving you much smaller quantity of leachate. And how you operate this whether you put a temporary cover whether you make it smooth whether you have a separate monsoon cell all that determines the way now how does it make a difference every amount of quantity of leachate every unit volume of leachate which comes out has to be treated and then the treatment costs.

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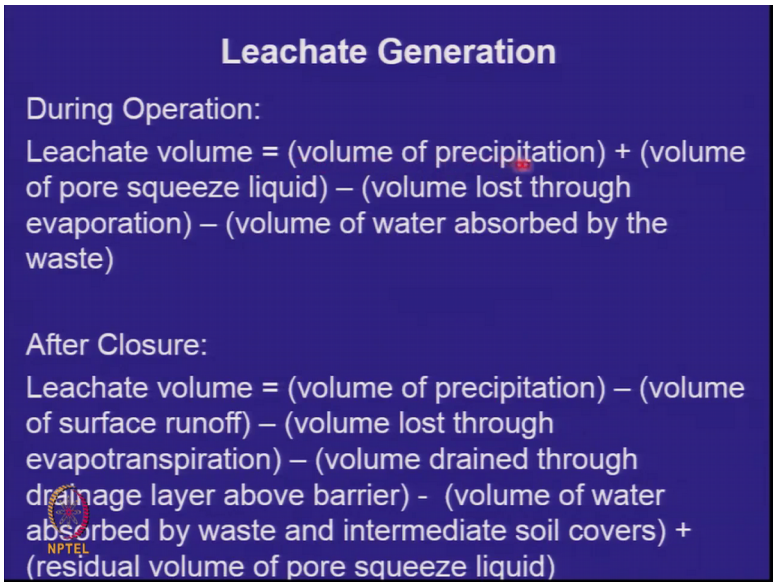

So, you have to offset the measures which you take for reducing the leachate versus the treatment cost. So, let me again put this during operation, leachate volume is equal to volume of precipitation plus volume of pore squeezed liquid, minus volume lost through evaporation minus volume of water absorbed by the waste. So, please understand there is no surface runoff presumed in this equation.

After closure volume of precipitation, volume of minus volume of surface runoff minus volume lost to evapotranspiration in the cover, minus volume drained through the lateral drainage layer above the barrier, minus volume of water absorbed by the waste and the intermediate soil covers plus some residual volumes of pores squeeze liquid. Mostly pores squeezing would have finished as the phase builds up, but there may be some pores squeezed liquid or some products of reaction taking place in a municipal solid waste landfill.

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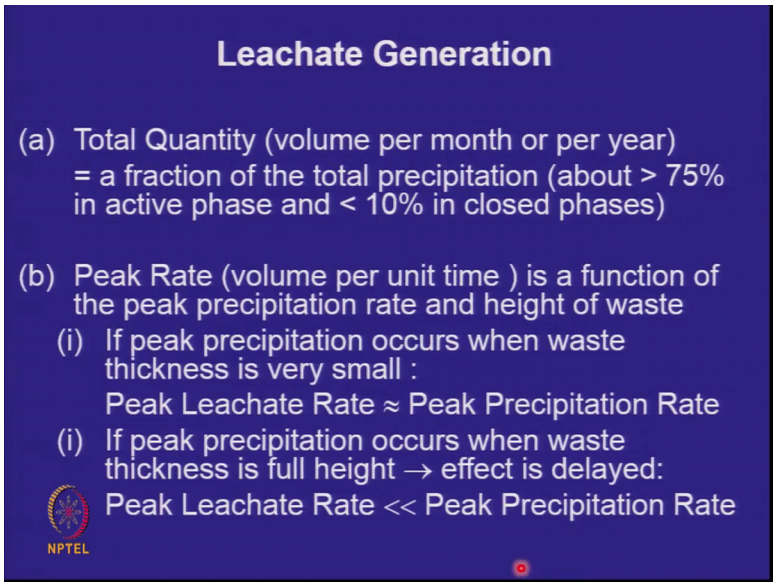

So, leachate generation, total quantity and peak rate; now when you are going to design a leachate collection system at the bottom what are you bothered about. What is the total quantity of what you have to take out or total quantity of leachate and at what rate do you have to take it out? Let us take the example of a football field right. We want the football field to drain out very rapidly two designs are done both designs can handle the same quantity of water which fall on the football field in a year right, but it is not the quantity of water which falls on the football field in a year that is important.

It is handling the peak rainfall which occurs for that 15 20 minutes, when the game was interrupted, it is like the cricket field you want to come back and play to be able to handle that peak rain what are the what do you want. You want that your pipes and your pumps and the surface water drains should be able to handle that peak rate of water which is coming into the collection system.

So, peak is different from total. So, the cricket field which has larger lateral drainage layer at the bottom, with higher permeability thicker has larger surface water drains at the sides and huge pumps. And which actually tilts the field a little more because the more the inclination the faster the runoff. That cricket field will drain up faster; of course we do not want to make it. So, inclined that you know the ball runs to the boundary every time on it is own and the batsman says no this field is tilted like this.

I do not want to hit on that side because there is an up gradient, I will hit on this side because there is a down gradient, but sometimes if you are listening to the commentators of the cricket match very carefully, why the bowlers change the ends. There is always the gradual inclination in the ground. They will talk about it sometimes that when you deliver the ball from this end, it is better or from that end it is better and when they are talking of uphill and downhill they are talking of one percent slope or a half a percent slope they are not talking about climbing a hill right.

So, total quantity volume per month or volume per year is a fraction of the total precipitation. Please understand about 75 percent from the active phase more than 75 and less than 10 percent from the close phases, that is the total quantity that you going to handle in that year. So, you are effluent treatment plant or whatever system that you are going to set up must be able to treat that much leachate every month or every year.

But the peak rate is going to be governed by our rainfall. And under what condition is your peak rate going to be the highest tell me. You have 2 situations. Peak rainfall occurs here or let me take 3 situations. Peak rainfall occurs here and peak rainfall occurs here which is the most critical rate, when the waste thickness is small or when the waste thickness is large.

When the waste itself has some absorbing capacity, even if it does not have some absorbing capacity it has some permeability. So, what falls on the top takes some time to come down. If it takes some time to come down the peak will be gradually spread over a period of time, when the waste thickness is large, but when the waste thickness is small then the time lapse between what is falling and coming to the pipe is very little.

So, actually this is the worst case. Of course, the leachate will be diluted the leachate will be diluted. However, you still have to handle it. So, the peak rate expressive, peak rate is a function of the peak precipitation rate and height of waste. If peak precipitation occurs when the waste thickness is very small then peak leachate rate is almost equal to peak precipitation rate. Whereas, if peak precipitation occurs when the waste thickness is almost full height the effect is delayed. That is why I mean we are going to get peak rates in the monsoons, remember that.

So, our phase how which month does the phase started our phase starts post monsoon. So, if let us say if Delhi has July august September. So, my land filling will start in

October god forbid if the peak rainfall occurs in October, but from October to June, I would have built up my waste right. And I would like to cap the waste before the monsoons come with the full cap.

That is the correct way of operating the phase. It is not that I operate a phase of January to December and during the operation of the phase for 3 months in between I am getting or I operated from financial year you know lot of things are going by financial year. So, if you are (Refer Time: 37:50) an academic year. So, you can always say I will I will do it academic year, but financial; that means, you start the landfill in April and immediately 2 months afterwards or 3 months afterward you start having your monsoon it does not work well close your phases before the monsoons. So, that you have least amount of leachate. This I have already discussed whatever we have talked, but a lot of people work on help you can also work on help, and you can also for your cover simulate.

You can simulate different thicknesses of the waste how much leachate it will come out in an active phase. Always the active phase is the determinants do not start with the covers because that is bringing out a very little leachate. And let me give you an example here. This is an example which is modified from one of the papers

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Example

Annual Rainfall :600 mm/yr, Annual Waste 30,000 to 70,000 t
Infiltration:Active phase 619 mm/yr; Capped phase 20 mm/yr
Absorption : 0.010 cu.m per cu.m

Year	Active Phase	Active Area (sq.m)	Capped Area (sq.m)	Active Infil. (cu.m)	Capped Infil. (cu.m)	Total Yearly Leachate (cu.m)
1	1	17,000	0	10,200	0	9,900
2	2	28,000	12,000	16,800	240	16,540
5	3	27,000	34,000	16,200	680	16,180
10	5	30,000	76,000	18,000	1520	18,820
20	8	27,000	133,000	16,200	2660	18,160
25	Closed	0	160,000	0	3200	3,200
30	Closed	0	160,000	0	3200	3,200

So, in a place the annual rainfall is 600 millimeters per year, and this much waste is coming annually.

Infiltration active phases 600 this is wrongly written please. Annual precipitation is 600 millimeter per year and therefore, the infiltration in the active phase is taken as 600 full capped phase only 200 millimeter per year how much percentages of this. Capped phase only 20 millimeters per year sorry not 200 20. So, how much percentage 3.0?

Student: 33.

3.33 percent. So, only 3.33 percent is coming out.

So, let us say first year active area 17000 square meters. A full rainfall is taking place this is the amount of leachate which is produced. And some of it is absorbed by the waste only 9900 is reaching out. In the second year active area is 28000 capped area is 12000, from the 28000, 16800 is coming hundred percent precipitation. And from this capped area only 2 40; that means, 1200 into 20.

If I looked at the twentieth year 27000 is my active area, and 133000 is capped, but from the active area I am getting this much. Leachate from the capped area I am getting this, am trying to tell you is that as long as there is one active area operational, the amount of leachate coming out is very large. Though the capped area is very large the moment the active phase finishes the landfill produces much smaller quantity of leachate, because now this is the full landfill area, and you have to multiply it with this.

Because that is the infiltration assuming that your cover is working satisfactorily. So, during the phase when waste is being actively filled you having this. Suppose notionally I could reduce see what you are what you are saying is each active area is about 27 28 27 28 right. This is just starting to take off in the beginning.

Suppose I could have reduced this area I have to accommodate the same volume of waste how do I reduce the area which is exposed.

Student: (Refer Time: 41:26).

I mean volume is area into height. So, if I had this each phase was 10 meters high. Suppose I had made a phase 20 meters high then the footprint of the waste would be smaller. If the footprint of the waste is smaller than the amount of rain falling on that footprint is smaller, and therefore the amount of leachate coming out is smaller.

No it may not be possible to do this, just I am saying, but keep your active area small keep everything else capped. And please ensure water is not falling inside from outside I just take an example of a below ground landfill if you do not operate it properly.

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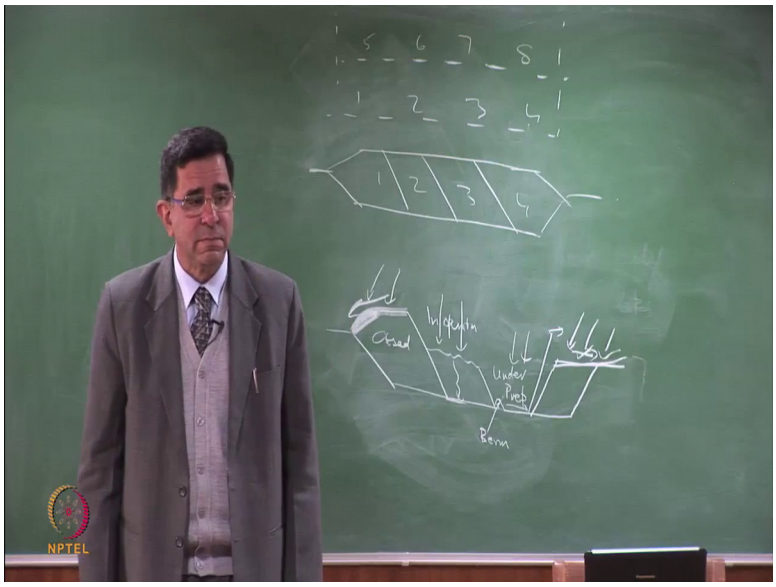

And I am going to come back to that question which I gave you in in the first minor below grounded and above ground landfill if you recall right. And there were 16 phases remember 1 2 3 4 5 6 kept going behind and behind and behind.

So, I said we should operate it like this if I look at it in plan. So, it will be 1 2 3 4 I could do 5 6 7 8 or 5 6 7 8 either way like that you remember this. So, can you give me the picture after 2 years of operation, third year is active first and second have closed. So, we said you should go up; so after 2 years of operation.

Now, after sorry after one year of operation is over you have closed it, and I am now operating the second phase. Is this fine? First year has been capped, I am into the second year second year filling is going on. All that falls there will go; I want to ask you to make the next line. Does the line go forward have you excavated the full have you excavated the full landfill is this how you are working yes or no?

Is there any other way you would like to do it, becoming a little tilted. Let me instead of see what I am trying to say is if you excavate the whole thing. When it rains this will runoff. This water will also point at the bottom and you will have to take it out with the

pump if you want a separate surface even if you make a bump here. So, how should you operate this?

May be I should have operated it like this. Nobody asked me to make this investment I mean excavating is putting money and you are the owner who, why do you why would you make such an investment, you will do it next year. Or even this is not correct because you should have said closed in operation and then under preparation. This is under preparation the liner is being put. So, that next year when you finish you can come in do the same, but in any case do not do extra excavations please. Whatever falls here you can grade it away.

So, that if the rain fall comes this does not come in and this also does not come in the problem is that if we operate like this and if this water also starts to come here. Then you have a lot of leachate not only from the precipitation falling from the top, but also from this and if this is sloping inside and I have seen this happen below ground landfills actually becoming ponds, because not enough precaution was taken to taken to keep the water out. Any questions? Keep excavations to a minimum. So, let me wait closed in operation under preparation.

So, this rain will go down into the leachates collection system and what rain falls here it should go this side and it should be taken out as surface runoff and put it to the storm water drain. The moment it becomes leachate you are prevented by law to put it into the storm water drain. And this bump is very important. It separates the leachate keeps it inside this and surface runoff on the other side. Any confusion?

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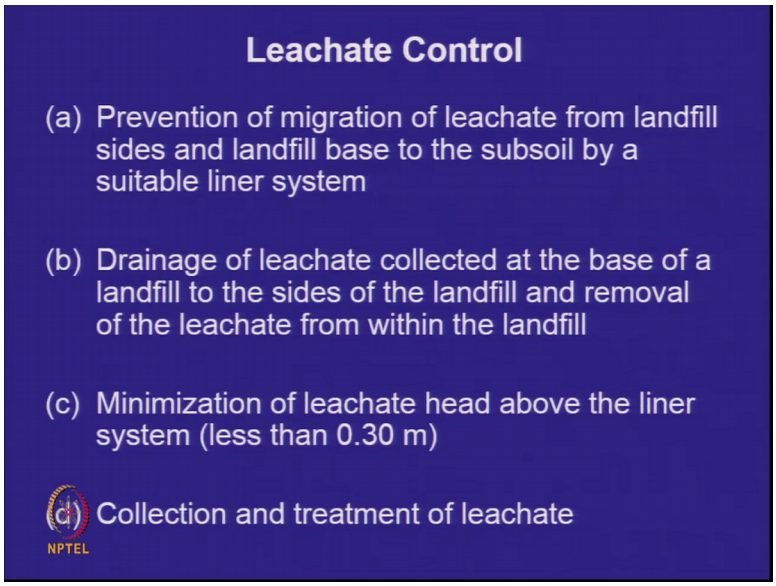

So, the next having kept the leachate to a minimum, leachate is still going to come out. So, what? So, how do we control this leachate? We have to take the leachate to the sides. The leachate should not point up into the center of the landfill. So, we first you have a liner which prevents this leachate from going down into the soil. Drainage of leachate collected at the base of a landfill to the sides of the landfill. And then removal of the leachate from the sides that is critical.

So, you have to have a convex shape at the base of your landfill or at the base of your phase and I will show that the, second is our leachate collection layer is 30 centimeters thick typically that is the minimum specification we have done that. So, our leachate head should not be more than 30 centimeters thick; that means, when I design the pipes inside the leachate collection layer my design head is 30 centimeters or one foot. And then I have to collect and treat the leachate.

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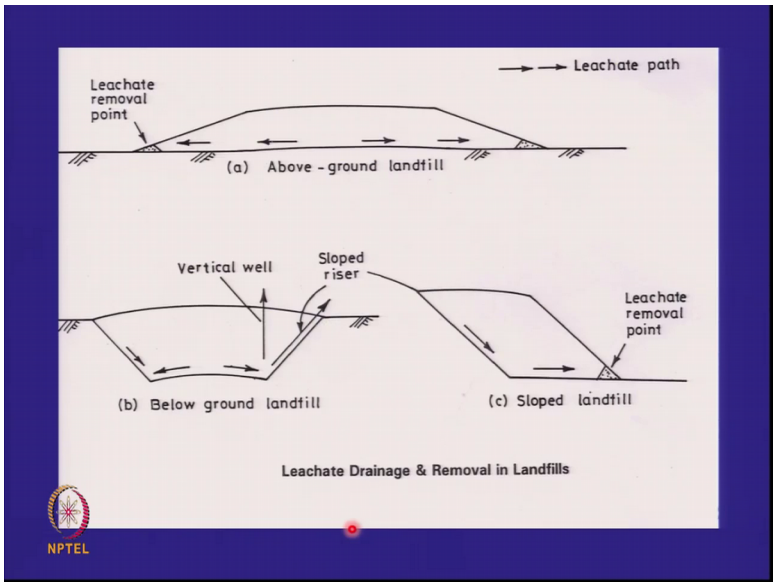

So, let us just see this. I have an above ground landfill, if I do not do the proper grading at the base suppose the above ground landfill has a base like this going down and coming up all the leachate will come to the center and you will have to pump it out, it cannot come up by it is own because this is low line, but if I fill it up and make it convex then the leachate can come out from here and the leachate can come out from here and the good thing is you do not need electricity you do not need a pump.

So, in above ground landfills with properly designed base, you can allow the leachate to come out through gravity. So, it is visible to you it comes out through a rock toe and you can collect it outside. And what are these slopes these slopes are 2 percent the ground slopes are 2 percent. If you have below ground, the little that you can do the leachate has to come out through pumping.

So, you can shape the base of your landfill such that leachate comes here and leachate comes here. And then you can remove it you can either have a vertical well or something called as sloping well a side slope a riser pipe is like a well pipe. So, you can have 2 options a vertical well or a side slope riser. If you have a landfill on a slope again lucky for us if I do this properly and the leachate does not flow backwards to this corner.

Now, you have to keep the slope outwards then the leachate can come out by gravity again. So, it is the below ground landfill in which the leachate has to be pumped out.

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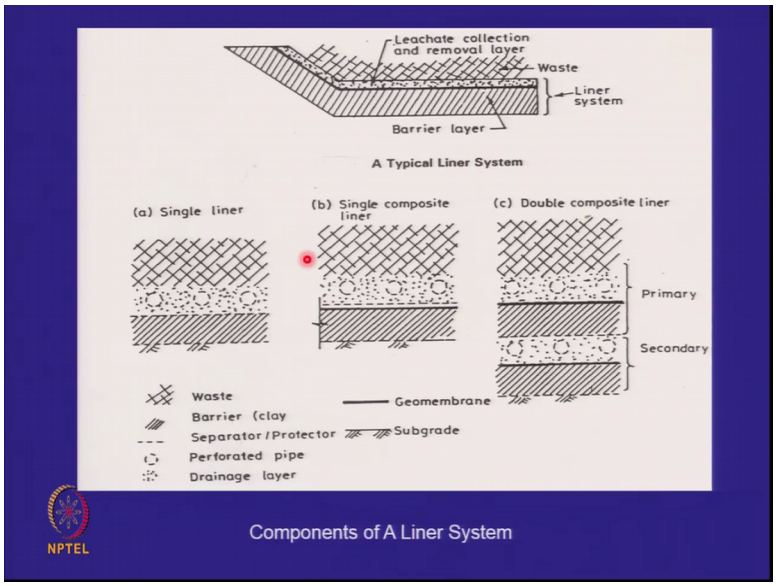

And let us go back to the liner system that we talked about. So, that is the this is a single composite liner the barrier layer the compacted clay the geo membrane and on top of that; that means, any leachate which comes to the side slope comes down and any leachate which comes there comes down and this is where it is collected.

You make a sump here for collection of your leachate and I can see some pipes when high flows are expected then you have a 2 percent slope you have to be able to handle the high flows. So, perforated pipes are put within the 30 centimeter sand gravel layer. So, leachate travels at 2 percent slope and in that 2 percent slope are perforated pipes which are typically 15 centimeters in diameter and leachate travels to this pipes to one corner where there is a pump to pump out the leachate.

So, let us say I have a 400, 500 meter wide base. And if I give a 2 percent slope what will be the difference in elevations of the 2 sides.

Student: (Refer Time: 52:51).

500 meter wide base and I say I will give a 2 percent slope.

Student: 10 meter.

10 meters that is a huge elevation difference percentage is only 2, but there is a huge elevation difference.

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So, then you see what will happen is when the width is very large, if this is 500 meters in a 2 percent slope will give you a 10 meter trop. So, in such cases the base of a landfill starts to look like this with the drainage pipes. So, you make the leachate flow in short lengths you have to keep the earthwork to a minimum you do not want a very elevated difference in the facilities and then in this perpendicular direction you take out your leachate.

Is sometimes called the accordion arrangement, but it goes like a corrugated base.

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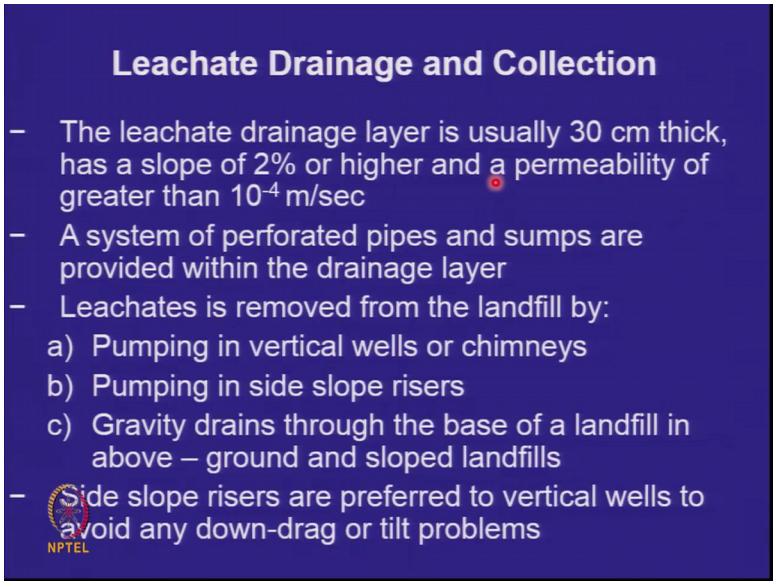

So, the leachate drainage layer is usually 30 centimeters thick has a slope of 2 percent or higher and a permeability of greater than 10 to the power of minus 4 meters per second, or greater than 2 to the 10 to the power of minus 2 centimeters per second a system of perforated pipes and sumps are provided within the drainage layer.

So, becomes like a hydraulic design you know flow in a pipe. So, leachate is removed from the landfill by pumping in vertical wells or chimneys pumping through side slope risers or gravity drains to the base of a landfill in above ground and sloped landfills. Side slope risers are preferred to vertical wells to avoid any down drag or tilt problems you know if you have a vertical well and the waste is biodegradable it is settles this might cause the vertical well to tilt.

If you have a side slope riser it is resting on the ground on the side slope. So, side slope risers are typically preferred to vertical wells to avoid any down drag or tail problems.

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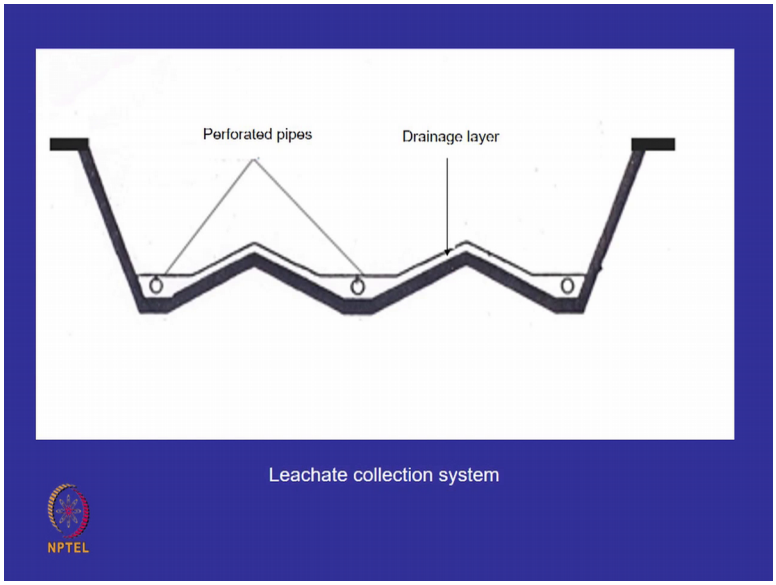

So, I just shown you this leachate collection layer, where this kind this is vertically exaggerated diagram.

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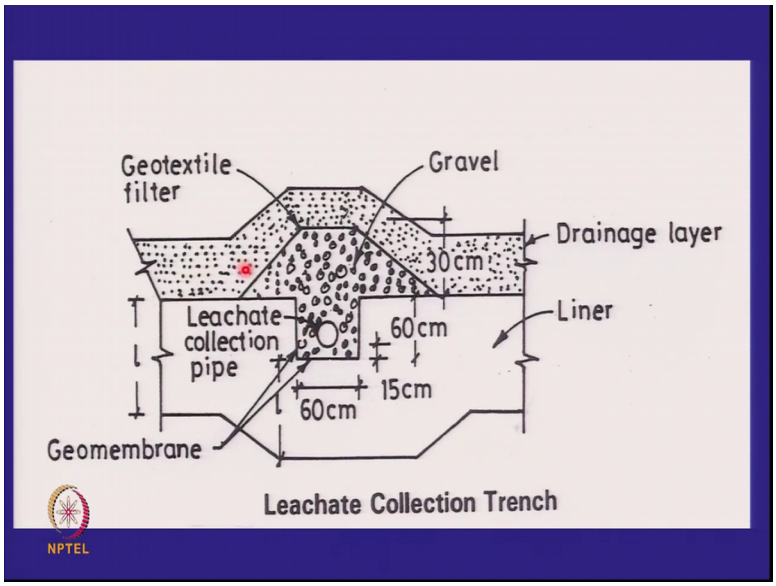

And again please understand that, this is the leachate collection pipe and it should be surrounded by gravel and the size of the gravel should be larger than the size of the perforations.

Otherwise the soil will go into the pipe right. And around this is your sand gravel mixture that is the leachate collection layer and there has to be a geotextile or a filter between the gravel and the sand.

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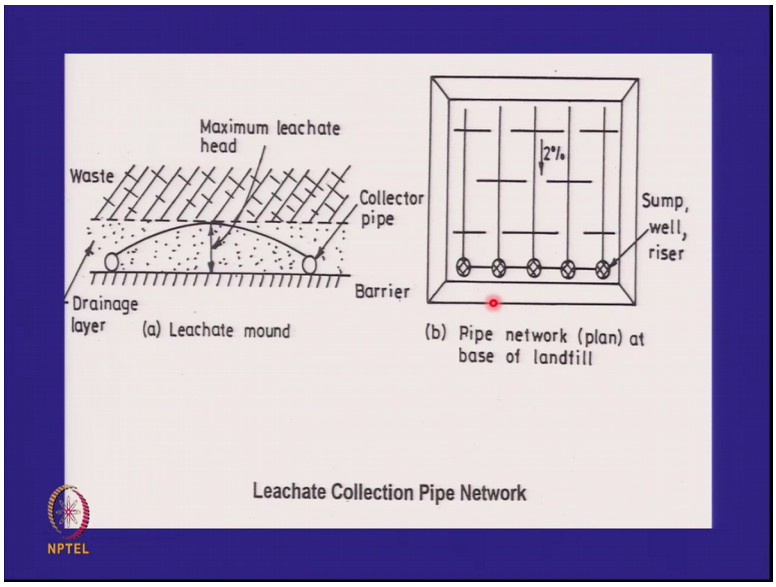

So, that the sand does not come and fill up the voids. So, this is a typical leachate collection trench and the base of a landfill.

So, if I look at the top, if I look at the top, you will have main leachate collection pipes. And then you will have cross pipes if required and all of them will go and connect to a one sump in one phase, this is one phase and you will take out the leachate through this phase. The design of these pipes these pipes of 15 centimeters this layer 30 centimeter thick. So, you have a hydraulic design that you know the rate at which your peak leachate is being generated so many cubic meters per hour. You do not want the head to be accumulated.

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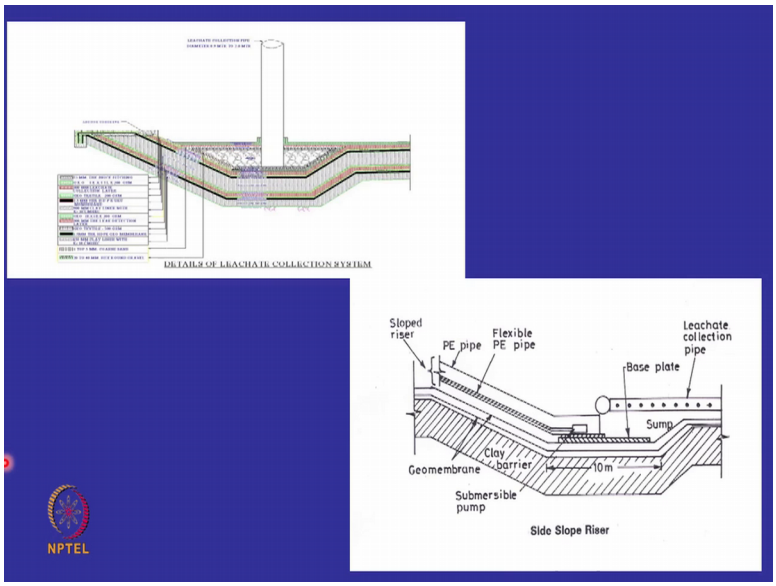

So, with this head these pipes must be equal to match the q which is coming down. If more q is coming down put more pipes; that means, you have to reduce the spacing of the pipes if less q is coming you can spread them out; typically, this pipe 50 to 75 meter spacing hundred meter spacing. And these are the 2 diagrams this is a vertical well. So, this is your sand drain.

The well will have gravel at the bottom and this is at HDPE pipe. Typically, you tend to avoid RCC pipes because the leachate can attack the concrete. And this is a side slope riser. So, this is also an HDPE pipe. This is your leachate collection pipe this will fill up with the leachate. There is some submersible pump here there will be some submersible

pump and a pipe here and this will send up the leachate through the HDPE pipe and through this HDPE pipe.

Here other cells they can be tilting problems as the down drag occurs whereas, here this HDPE pipe is sitting on this and, but I have a double liner at the base of the sump double composite liner because this is always going to be filled this is going to be your weakest link the sump is always going to be full of leachate. So, all this is all this area is not going to have the leachate is all going to come here similarly all this is not going to have leachate. So, it is going to come here.

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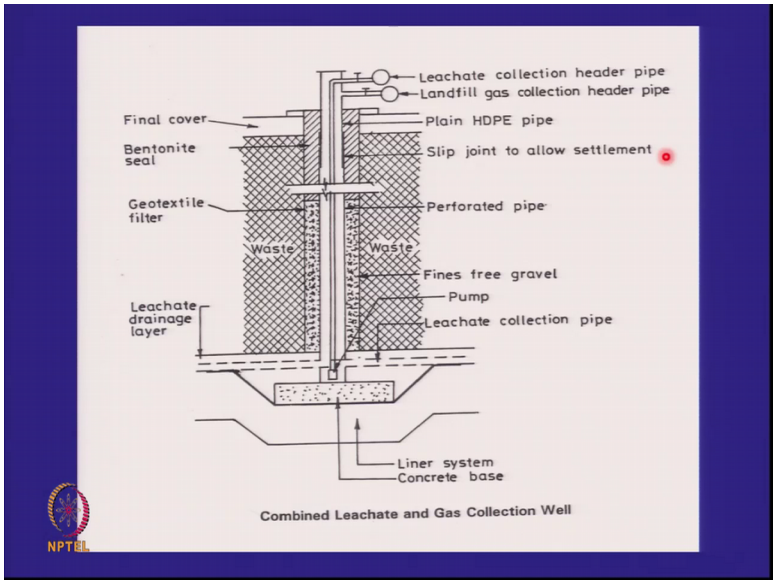

So, your sump should have a double component liner. This is a combined leachate collection and gas collection well we will probably look at this at a later date, but the idea is from the same well you can have a submersible pump.

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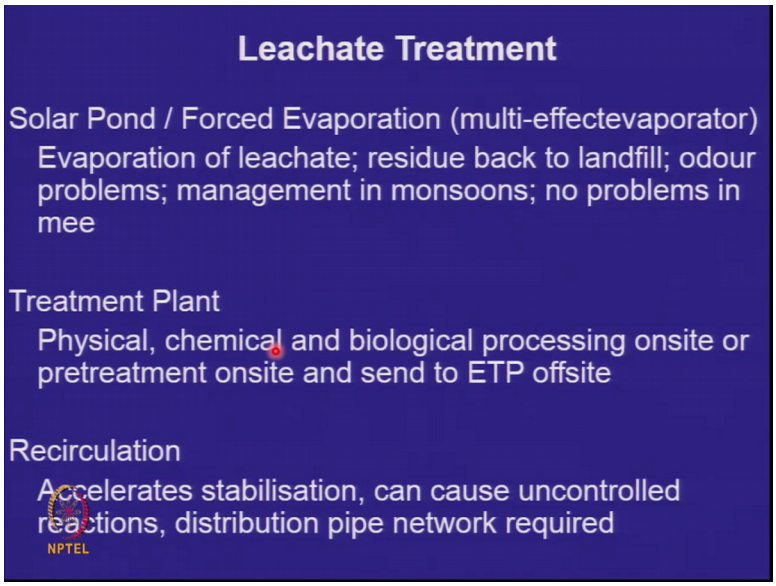

And take out your leachate and you can have an outer annular space from which you can collect the gas and when we do gas collection system I will try to visit this again.

Finally, you got the leachate. It is come out from the pipe and from the pump what are you going to do with it that is the most expensive issue. In some areas the evaporation is more than the precipitation. So, a choice appears to be solar ponds. Solar ponds means you allow the you collect the leachate in a big pond allow it to evaporate and you become powder in the end only problem is lot of odor lot of odor because leachate is exposed right. Or you can use in vessel containerized evaporation systems which are called multiple effect evaporators.

So, multi affect evaporators. In fact, there should be a gap here between effect and evaporator. These are forced evaporation systems you take your leachate in the form of slurry you inject it and that slurry at high temperatures the liquid will evaporate the solids the salts will come out. So, basically the technologies evaporate leachate and if you have an in vessel MEE or multi effect evaporator you have to have all the gas control emission control measurements, you do not want the wrong gases going out by volatilizing.

So, evaporation of leachate residue the solids will go back, to the landfill odor problems in solar ponds management in monsoons also a problem, but no problems in MEE. So, multi effect evaporators are expensive, but they work and they are working at a couple of

sites otherwise your only option is to have an onsite ETP and an offsite ETP and on site ETP will be expensive.

So, if you have a large landfill no problem you can absorb the cost of an on onsite effluent treatment plant, but if you are a small landfill then there must be a sewage treatment plant in your vicinity you will have to pretreat your leachate and send it to the effluent treatment plant off site, then it can be sent in trucks in tankers huge tankers to the offsite plant. So, you have to see what works. Recirculation is also strategy; that means; you collect the leachate and pump it back into the landfill. So, this works well with the concept of.

Bioreactor landfills you can stabilize the ways faster, but the leachate keeps on becoming more and more intense it is quality keeps on becoming worst some contaminants do get you know held by the recirculation earlier they are there later they are not there, but by and large the total leachate becomes more and more higher concentration and even when you want to re circulate the leachate, please remember it is not taking a pipe and putting it at the top of the landfill.

How will you recirculated leachate you want the leachate to be equally spread out on your landfill right how will you if you sprinkle it then you are creating the same odor problems, you will have evaporation, but you are creating the same odor problems if you want to inject it if you have 5 points of injection, the leachate will go vertically down. So, how do you re circulate leachate.

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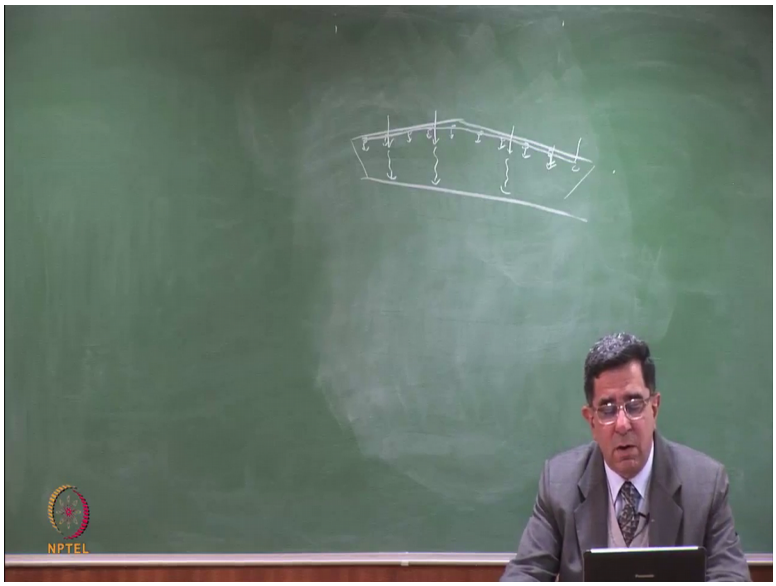

If I have a phase; if I inject leachate at 6 locations, just put in a pipe and chal. This will form a preferential c page path. It is not going to spread all around you uniformly right when you are going to irrigate your lawn you spray the material. So, then you need a drip irrigation or a distribution system. So, the better thing is to have a network underground below the cover distribution network.

So, you can have injection at multiple points. So, what it says at the end you need a distribution pipe network under the cover for distributing this has to be different from the leachate from the gas collection layer which is also under the cover. So, that you can uniformly make the waste wet and make this leachate. Otherwise it will go down in a preferential path.

So, these are the strategies for leachate treatment. I have seen solar ponds multi effect evaporators I have seen offsite leachate being sent to offsite ETPs. We have not yet seen an onsite many people say the enemy mee is like an onsite ETP which is correct, but people are talking of reverse osmosis is also an effluent treatment and otherwise you have to have 3 levels of treatment physical treatment chemical treatment and biological treatment especially for the MSW leachate.

So, with this we will stop here just given you an overview about how to estimate the amount of leachate very simple precipitation multiplied by the active area that is a good thumb rule plus 5 percent of the precipitation multiplied by the closed phases. So, simple

and that is the amount of leachate that you are going to get to be treated peak precipitation peak leachate rate precipitation rate.

So, these are the 2 values that you need for hydraulic design; however, you can do many simulations and come up with the appropriate values help is good software to do this. Any questions or anything which means bothering you any clarifications you would like to have eventually the quantity of leachate goes down and the concentration of the leachate also goes down.

Thank you.