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

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Lecture - 09
Planning of Landfills - Part 2

So, today we continue the discussion on planning of landfills last time we are started this topic and we had seen what are the options when you place waste on ground what are the option you have in terms of the plan and the layout of the landfill and what are the options that you have as far as the section of the landfill is concerned. So, 2-3 important things we did last time what is the design life for landfill.

Student: (Refer Time: 01:03).

Active very active period when the waste will be filled plus forced closure monitoring period, we would like the active period to be as large as possible typically it should be between 10 to 25 years, it should not be less than 10 years typically based on the amount of waste being produced by city or a group of cities the that landfill site area can be decided.

And I use the word group of cities because now the concept of regional landfills is also coming up in India why regional landfills. So, take a look at Delhi, Delhi is surrounded by different states and the city has expanded to its boundaries if you want to go more south you have Haryana if you want to go more east you have Uttar Pradesh if you want to go west you have Rajasthan.

So, all these kinds of we are like an island. So, if 2 or 3 states or 2 or 3 districts or 2 or 3 municipalities in a district are having difficulty in finding land to dispose then they can try and set up a regional facility; that means, within 50 kilometers if you if you have a spot where you can set up a facility you draw a circle with the 50 kilometer radius and all the cities which are touched by that they can actually send their waste to this regional facilities.

So, depending on the waste coming in you have an idea of the area that you need for the design life to be able to get an area of the design life you will have to fix the height. So,

that brings us to the section the sectional view of the landfill and we talked about below ground landfills above ground landfills and side slope landfills with an valley landfills. So, just think about what can be the typical height of such landfills and we will address this because you have a particular quantity of waste which will come in 20 years if you know; what is the limit of your height you can say how much area that you need.

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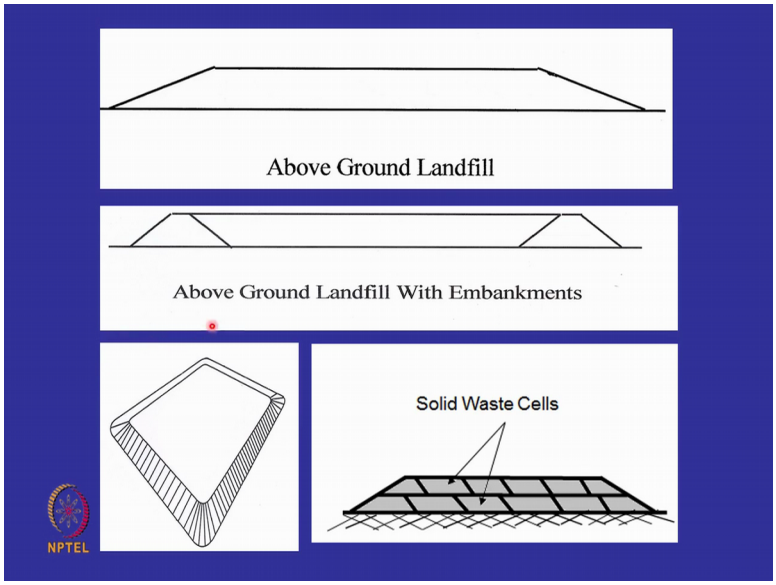

So, let us continue from where we left off last time we talked about an above ground landfill last time it could look like this or it could look like this the difference between the 2 is this is got a embankments. So, if you are having sludge coming in from which little bit of fluid might though it is dewatered sludge some fluid might come out you might want to have these embankments the other is that these embankments are made of compacted soil. So, these can have steeper slopes than this. So, these are 2 options and it will look like this in plan or in a 3D view.

Now, let me go inside this landfill and what do I find I find small small cells solid waste cells now let me go closer at the base of the landfill.

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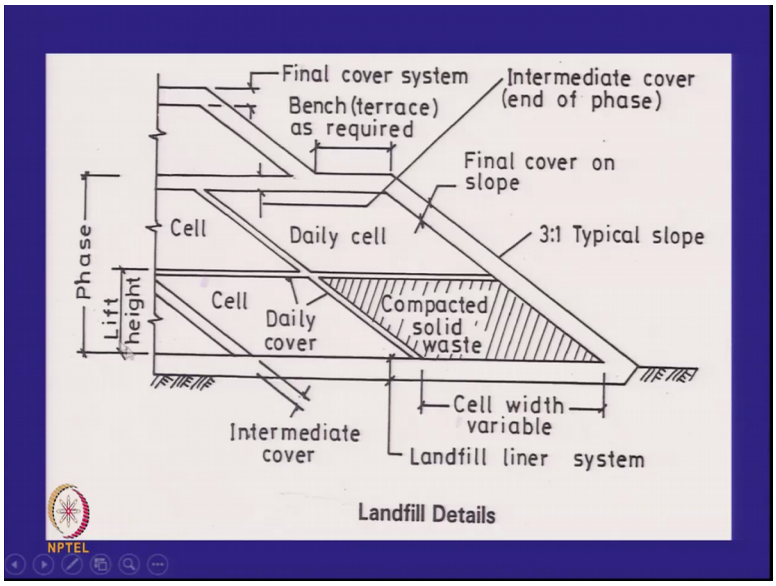

I have a liner, it is a multiple layered system and at the top I have a final cover base liner final cover on the slope and final cover on the top these are daily cells every day the waste will be placed in a cell. So, therefore, yesterday it was placed here yesterday it was placed here today its placed here and then you see thin layers here.

So, the concept of an engineered landfill is that there is a daily cover at the end of the day you do not leave your waste exposed this may be soil cover we tend to use and waste cover here as long as it is not very coarse because the idea is to have no pests and rodents which are accessing this. So, if you put soil cover they will not be able to assess it so easily and then something called an intermediate cover.

So, final cover intermediate cover and daily cover an intermediate cover comes at the end of a phase and I will talk about that little late, but inside the landfill it looks like this you have a lift or a height. That means, you have fix the height of the daily covers your landfill may be 20 meter high or 10 meters high, but your daily cover may be only your daily cell height may be one and half meters. So, that is the lift; that means, the daily cells increase the height by one to one and half meters every day and the phase is typically the total height achieved after one year this will look at little later.

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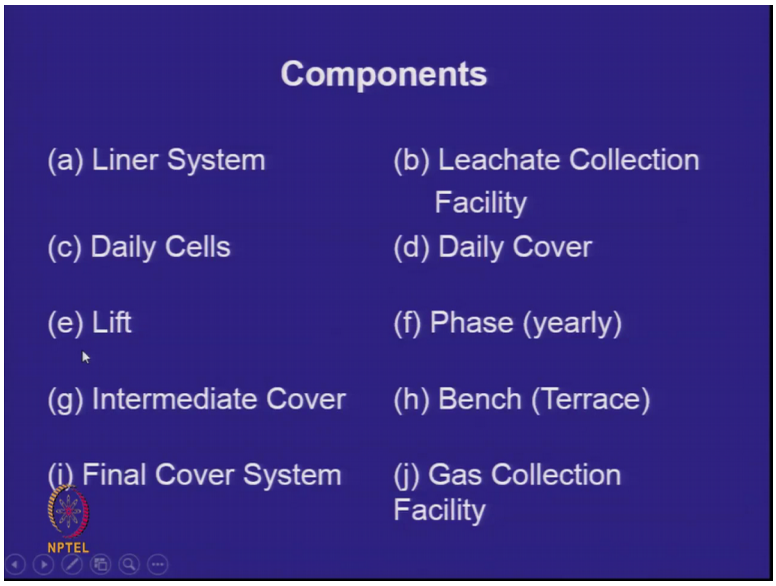

So, which are the components as geotechnical engineers that we are going to be dealing with we are going to be dealing with liner system the Leachate collection system daily cells daily covers lifts yearly phase the landfill must be closed every year. So, your phase which is done every year which must be closed with an intermediate cover or preferably with a final cover the concept of intermediate cover the concept of a bench you may have berm or a bench or a terrace as they call it final cover and then the gas collection system.

So, this is what we will be dealing with in our designs first let us look at the issue of landfill capacity how are we going to estimate the area that we need or if we have a fixed area how are we going to estimate the height to which we have to take the landfill.

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So, we have to estimate the quantity of waste we have to estimate the compacted density if I know the quantity of waste in terms of how many tons of waste is coming per day and if I know its density then I can know the volume over and above the volume of the waste will be the volume occupied by the liner and the cover because every day they are coming into position and some volume will reduce due to settlement; that means, as biodegradation goes on you will have more airspace created, so the density of municipal solid waste in.

Please remember that I am talking of the green waste and the food waste is between 0.6 to 1.2 tons per cubic meter in soil mechanics term this is the total unit weight this is the total unit weight if you have inorganic waste most of the waste coming out from industries is inorganic right then its more having densities like soil you what is the unit weight of soil typically compacted soil you will have 1.2 to 1.6 unit weight.

So, in hazardous waste landfills this if you are having inorganic waste then this may be the density, but for municipal solid waste this may be the density if you have inorganic compacted waste; waste not going to settle much you are not going to get more airspace specially if you have compacted it properly it might settle by a few percent. So, do not rely on this additional capacity the municipal solid waste does give you settlement, but does not give you in the first few years like that I mean the biodegradation process actually slows down, because you have put a cover. So, when you talk that we can get 20

percent of 15 percent settlement and municipal solid waste we are talking of its happening over 20, 30, 35, 40 years. So, you have to be very cautious if you are going to take that volume in your area computations.

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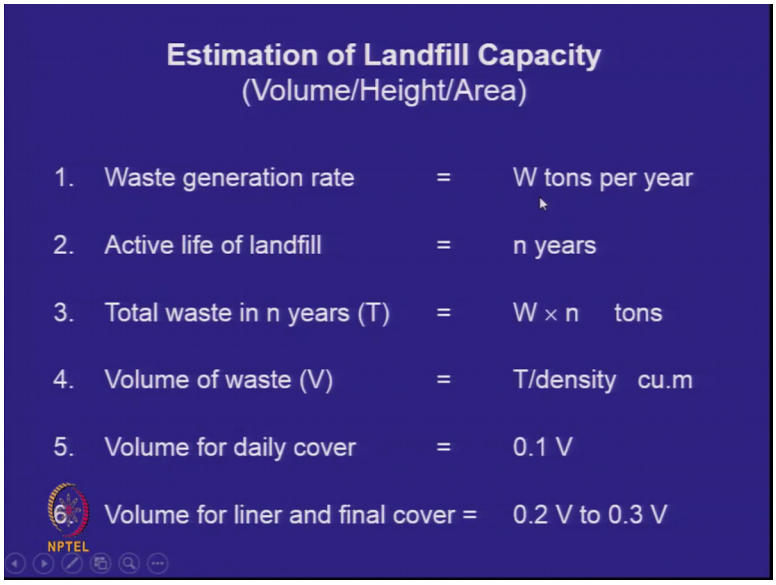

So, in a very simple sense I am going to do this very simply waste generation rate is w tons per year if you know the population of a city then you can estimate the waste either from the records available with them many a times they may not have a record then you have to presume what is the per capita waste which comes out. So, typically in India in a city like Delhi or in the mega cities you may have 0.35 kg per person in rural areas and villages it may be much smaller in America it may be.

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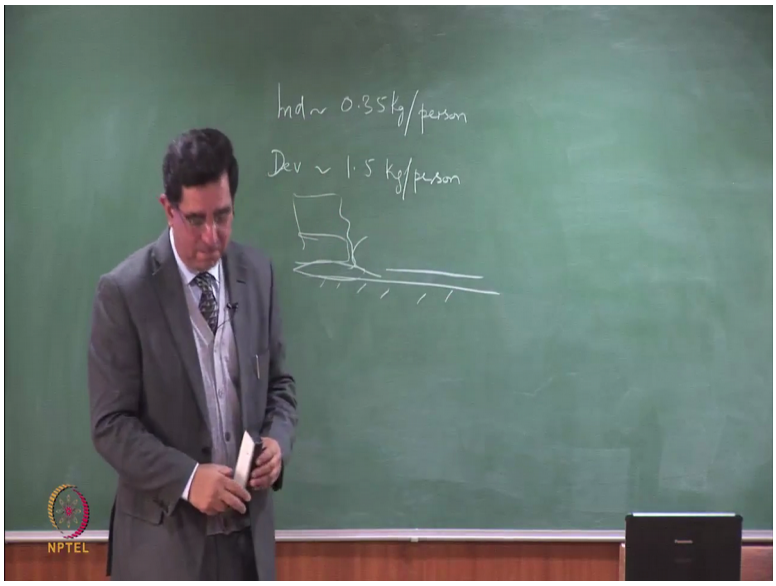

Student: (Refer Time: 10:17).

Much larger, how high anybody has an idea;

Student: (Refer Time: 10:22).

So, it could be in a developed world it could be why because the more developed you are the more consumptive you are. So, more consumptive simple in indication is the amount of electricity we consume the amount of petrol we consume developed world consumes more petrol than we do per person they will use more relax city than we do per person and they produce more waste than we do per person and really the rural of the in the village setting we produce much lower waste than the city.

So, if you know the population and if you have this; this is rough figure this is developed countries it can have a wide variation then you know that you are producing w tons per year and let us say the active life is n years then the total waste is w into n tons now your simple formula we have not taken into a count the rate of growth of population this is not very important to the developed world because the rate of growth of population not very high in some country it is negative, you are aware of that the trees are taking over what does negative growth rate means.

Student: (Refer Time: 11:52).

That this year I have one thousand people next year I have 950 people. So, there is a negative growth rate and in those cities in those developed countries houses are being taken over by the trees. So, you have only 2 options either to promote marriages and more children per marriage which may not happen because you are developed in everybody is independent and working and. So, a best marriage we have they may have one child per couple the other option is to open your borders to immigrants. So, if you are a negative growth rate society and there is a positive growth rate societies like India.

So, if you have a population growth rate then this has to be multiplied by that appropriate figure I mean it is like just simple interest or compound interest you have a population growth figures. So, it will be one plus something to the power of n and then you will get the total waste in your design period of n years you divide this total waste by the density and you will get the volume.

So, how much does a daily cover occupy of that volume daily covered I mean I told you about a lift a 1.5 meters and what is the thinnest layer of soil you can spread if I ask you to use a dozer to spread soil what is the thinnest layer you can spread on ground by mechanized equipment what is the thinnest layer of soil you can spread above a human being what is the thinnest layer of soil you can spread one millimeter 10 millimeter well a dozer or a grader or a mechanized print can spread 6 inches to eight inches of soil you cannot ask him to spread 10 millimeters of soil. So, if you are doing mechanized daily cover you are going to have a 6 inch soil layer where somewhere in the municipal solid waste management rules or the manual brought out by in India they have said 15 millimeters of soil I think they are off how many millimeters is 6 inches.

Student: (Refer Time: 14:34).

How many millimeters is 6 inches?

Student: 150 (Refer Time: 14:40).

150, thank you for that correct statement because one inch is 25 millimeters approximately. So, 150 mm is the soil thickness. So, if you have a 1.5 meter thick and you have 15 centimeters you are taking off that much of the volume. So, what is shown here is volume of the daily cover is 0.1 and the final cover and the liner are more than a meter more than 1.5 meters sometimes 2 meters thick. So, there is a volume taken by

them as well. So, if you have a volume of ways the entire way volume is not going to have that waste in it.

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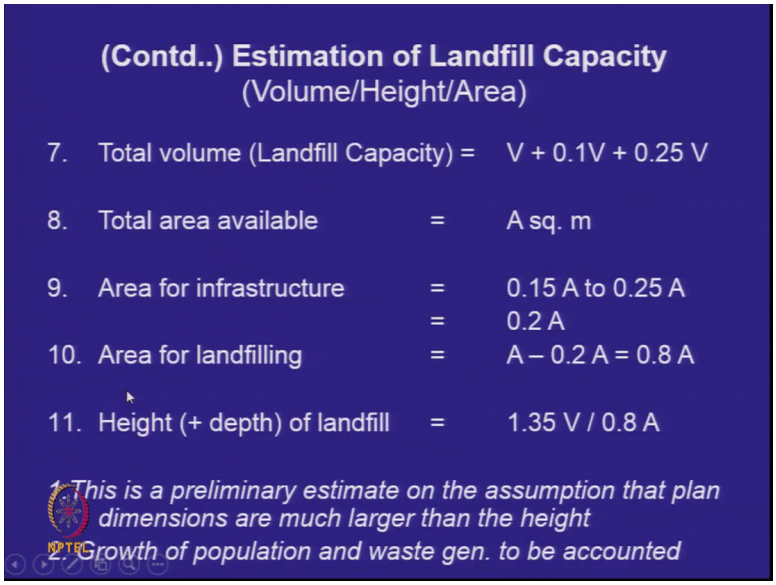

So, the total volume will be v plus point one v for daily cover plus 0.25 V; suppose the area available is a right then the area required for the infrastructure as I said 20 percent if all the area is going to be used for placing the waste. So, you can get the height of the landfill very simply as this becomes 1.35 V divided by 0.8 a and it will give you the height plus the depth of the landfill. That means, to accommodate the waste for the next n years if I am being given an area a then I need to have a height plus depth of 1.3 V by 0.8 A.

Now, is that height more than acceptable or less than acceptable is the next question, but the problem could be the other way around also if the municipality fixes the limit; what is the problem with having a very high height some stability issues of the waste slope stability, but there is a larger issue of visual aesthetics I mean suppose you have a you are a city and most of your houses are single storied or 2 storied or four storied then if everything is the skyline is 4 storied then if the skyline is four storied then the mount should not rise above the skyline. So, it is a statics issue, if you have high rise buildings no problems you can have a higher wisdom it should not be the dominant feature of the landscape.

So, you can fix the height and then you know how much area you need. So, if you are designing a landfill for the next 20 years you know the amount of waste that is going to come out you fix the height has 20 municipality says you cannot go beyond 15 meters we will not go give of this much area you should be able to find A. So, the area that we need is desirable for the full life.

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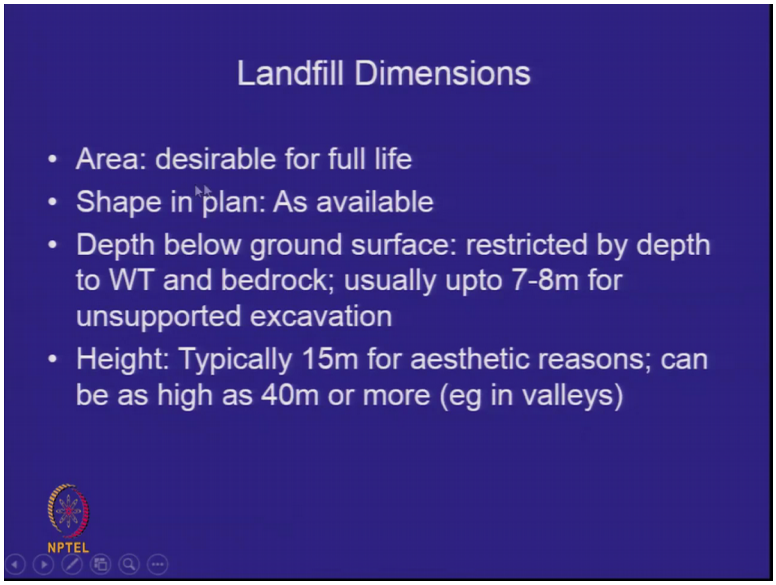

If I can get area for 25 years very nice nothing like it if I cannot whatever is available the shape in plan will be as available it neither be a square nor be a circle nor be a rectangle it will be as available how deep can you go when here we are trying to actually now say that the municipality says do not go beyond 15 meters well then can I go below sure how deep can I go well somewhere there will be a water table somewhere there will be a bedrock if neither of the 2 are available how deep will you go well we never typically go deeper than the unsupported excavation we can do in that area.

So, usually we go 7 to 8 meters for unsupported excavation that technically we can go to very deep areas as well. So, really if there is a 15 millimeter cap of the top and there is a seven to eight meters cap at the bottom you are going to have an h plus d of about 20 to 25 meters. So, typically as I said for aesthetic reasons 15 meters is acceptable; however, landfills are more it can be more than 40 meters high especially in valleys I mean if you have low you are in a mountainous region then have a landfill which is 40 meters high. It is like the little dam keeping reservoir water behind it here instead you are going to fill it

with waste any questions on this any issues. As I said this formula is approximate you have to set it right by the rate at which the population is going up that is important especially when you are doing 25 years cycle of life for designing the landfill the next most important aspect is phased operation.

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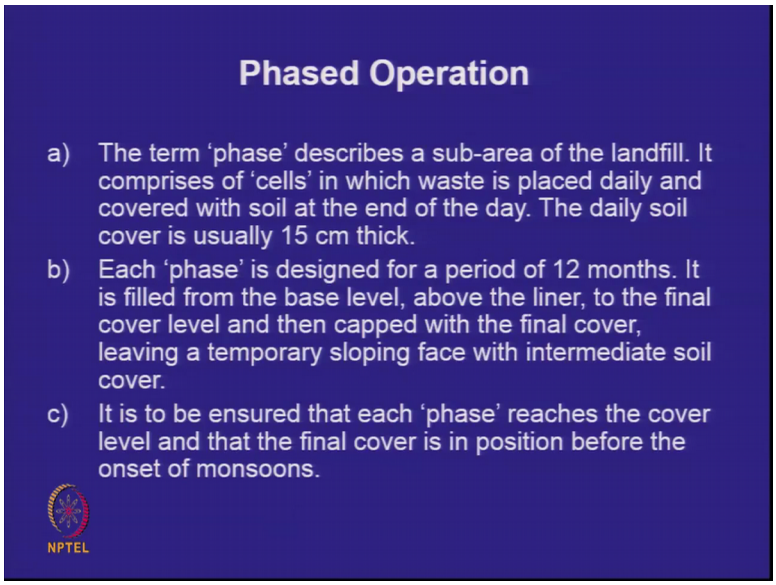

In the end of last times lecture somebody asked me when do you actually put the cover on the landfill and I said this is a the most critical question because many people do not understand this that you do not cap the landfill in the end you do not cover the landfill at the end you cover it before every monsoon.

So, in a country like India we want to cover a landfill before the main rains coming. So, it means every year we have to cover the landfill to be able to cover the landfill are we talking of an intermediate cover or are we talking of a final cover please understand that the intermediate cover is slightly thicker than a daily cover it is not an impervious cover a daily cover gets covered by another cover within a few days another cell within a few days.

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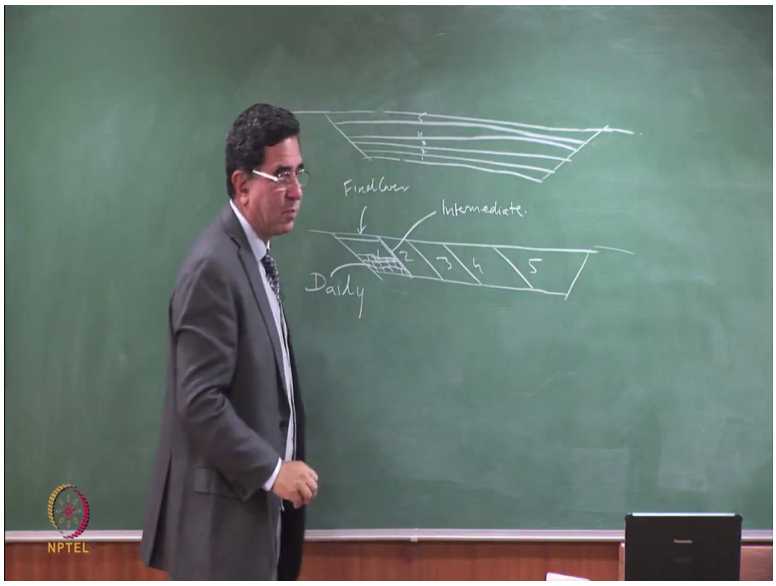

So, suppose I have a below ground landfill and this landfill in this direction is going to be filled in five years let us say or four years whatever then first I have got the form that I am only making a landfill which is below the ground why because my municipality says I want to make a football field over it I do not want you to elevate it creates problems. So, I am going to use it later. So, you have this volume you have the height or the depth. So, you can see how much waste you can put in it the next thing is to decide the phases and a phase is basically a sub area of the landfill and it will be a nearly phase.

So, I want to say 5 years let me try first year the ways to become like this oh maybe I will do 2 options that is one way of doing it first year second year third year fourth year and the other way of doing it is so many examples exists where people have not understood this concept, but really which one is better in terms of phases; you can do one 2 3 4 5 which concept is better for phasing, any thoughts.

Student: (Refer Time: 22:33).

Why?

Student: Because in the (Refer Time: 22:37) we have to go for a movement of in the whole area.

So, here the; in movement like this for example, maybe the same as movement like this.

Student: That line is cover system like daily cover system.

Right, so, what about the daily cover system?

Student: (Refer Time: 22:59).

Basically, larger horizontal areas exposed to rain and when it rains I cannot put a final cover here and I put a final cover here because if you are going to put a final cover after every phase it is going to be very expensive whereas, I can put a final cover here because I have reached the top you understand what I am saying. So, this allows me to reach the top at the end of the year and before the monsoon comes I can put a cover. So, this becomes my final cover and I have my daily cells here with their daily covers is this the final cover; the slope.

Student: (Refer Time: 24:02).

It will be more than the daily cover because it is going to remain exposed for one year till this felt self fills up. So, it is intermediate cover. So, this is final this is intermediate because its intermediate because it is not going to be the final cover. So, this is daily. So, this is better than this why at the end of first year when the monsoons come there is no waste here there is no Leachate the rainfall which can make Leachate is this rain multiplied by this area whereas, here it is the same rain multiplied by the full area so; obviously, this will create much more Leachate. So, this is not acceptable this is acceptable that is the concept of phases.

So, the term fails describes a sub area of the landfill it comprises of daily cells and is covered with daily cover the daily cover is usually 15 centimeters thick each phase is designed for a period of twelve months it is filled from the base level above the liner to the final cover level and then capped with the final cover leaving a temporary sloping phase with intermediate soil cover now instead of being 6 inches thick the intermediate soil cover may be four layers of 15 centimeters that may be 60 centimeters that is about 2 feet you are too conservative you want to make it one feet, but it really have much thicker than the daily cover it has to be ensured that each phase reaches the cover and that the final cover is in position before the onset of monsoons.

So, if the monsoon is come in Delhi in July august and the end of the summer and June I should have put the final cover at the top I should have reached the top and I should have put the final cover at the top that is how you will decide the size of the base of the phase and this is not understood by many.

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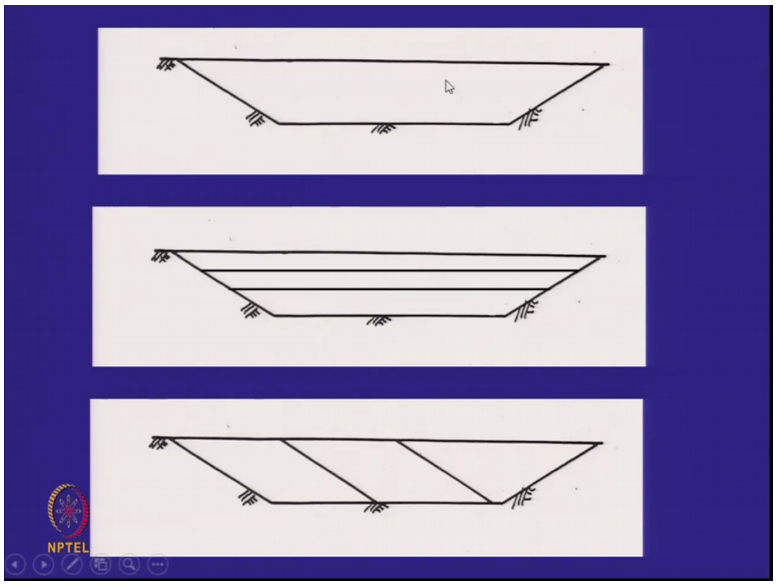

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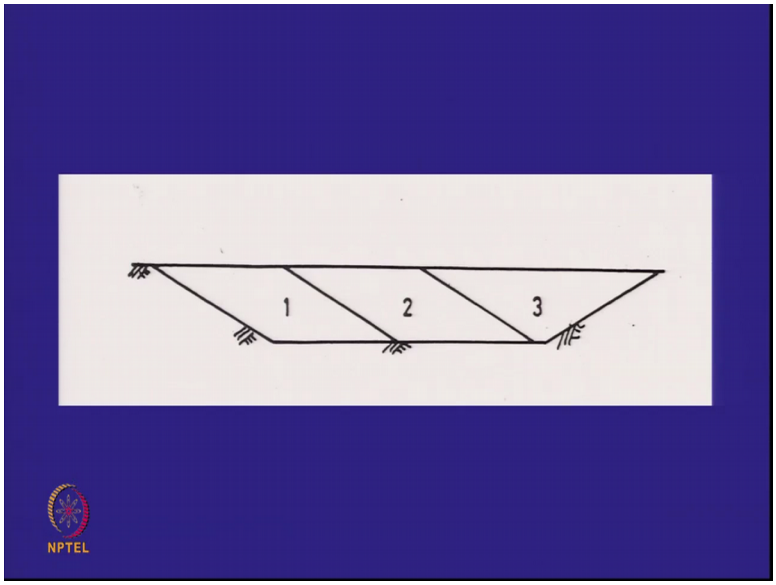

So, between this and this and this; this is better and you can phase it like this I am just showing you another example.

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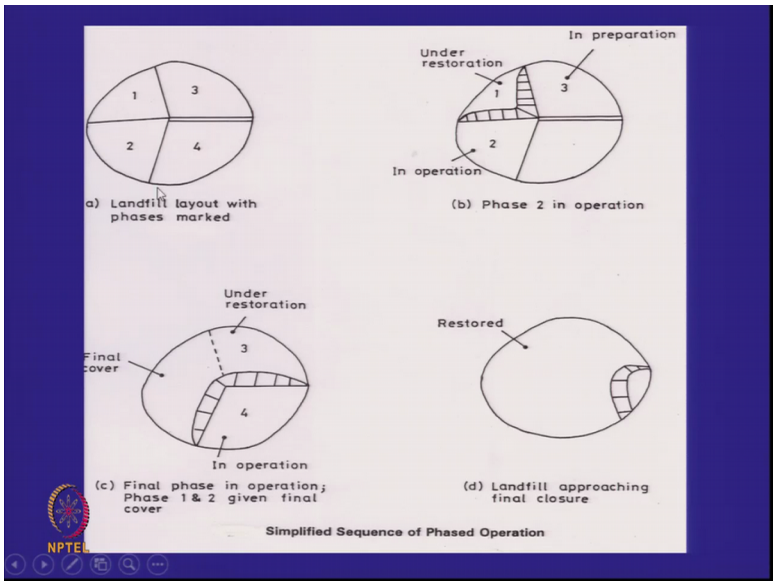

In plan a small land filled with four phases 1 2 3 4. So, if you look at it at the end of the first year this phase has been completed can you see this is a plan view and this shows the slope. So, it is rising above the ground. So, in the first year you fill this and then you cover it while you are filling this you are putting the liner for the next in preparation right and this is an opera. So, let me say one year is over the second year is on. So, in the first year you will place the waste here agreed at the end of the first year you will cover this in second year what will happen while you are placing the waste here you are putting your liner here.

So, in the second year this is under operation this has been filled it is covered this is under operation means waste is been put on it on a daily basis and this is under preparation you are putting the new liner for the next year and then after 3 years are over all this is covered with final cover this is an operation.

So, in this all the rain which falls here is not Leachate the rain which falls here is not Leachate the rain which falls here is not Leachate because it runs off the cover only the rain which falls in the operating area becomes Leachate. So, it is a much smaller amount of Leachate that is generated and that is the most critical option our issue.

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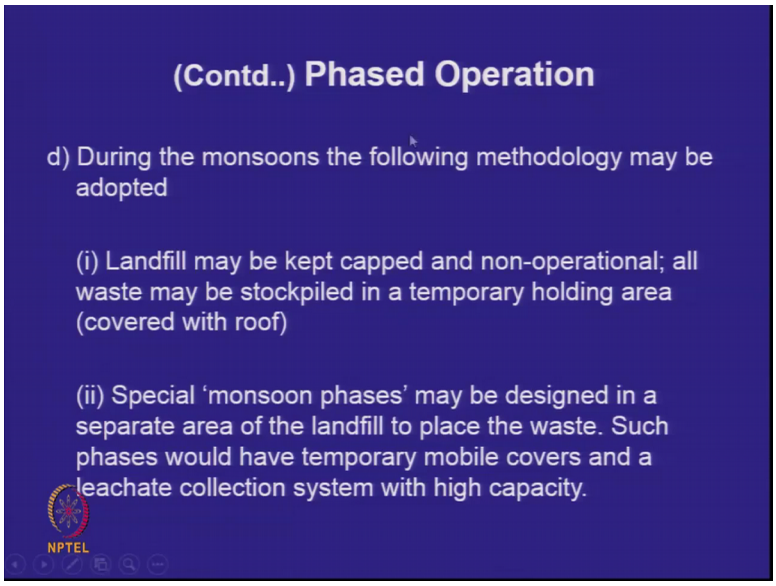

So, you understood incrementally fill the waste in small small area and what do you do during the monsoons during the monsoons you can do 2 things landfill may be kept capped you may cap the landfill final cover is on the top on the side slopes you can put a geomembrane or tarpaulin something which does not allow water to go in on the intermediate tower, and it may be kept normal operational for 2 months or what they are doing in enclosure is the waste comes in from the industry they have capped it they have got the temporary geomembrane also the waste is put in the temporary holding area it is a double handling.

Now the moment they have a window the today it is not raining for the next four hours they will remove the tarpaulin and put the waste there and cover it again because you otherwise you have to create a temporary holding area for 2 months that is pretty expensive because you have a large area is required to be covered. So, they are opening it in the windows where they can place it.

So, landfill may be capped and non operational all waste may be stockpiled in a temporary holding area covered with roof or you may occasionally remove the material from the roof temporary holding area to the landfill when there is a weather window sometimes you may make special monsoon phases in separate area of the landfill to place the waste.

So, what happens is during the monsoon the waste is smaller, but the rain is more intense. So, your Leachate collection systems have to be more larger capacities. So, you may make a monsoon phase that all right during the monsoon I will not place it in the main landfill I will send it to my monsoon phase I will place it there I will try and put it only in the weather window when it is permitted, but still you make that for handling larger Leachate.

So, such phases would have temporary mobile covers and a Leachate collection system with high capacity. So, monsoons have to be treated either this way or that way how do you manage emissions now you made the landfill you are collecting Leachate what do you do with the Leachate can you discharge the Leachate to the drain.

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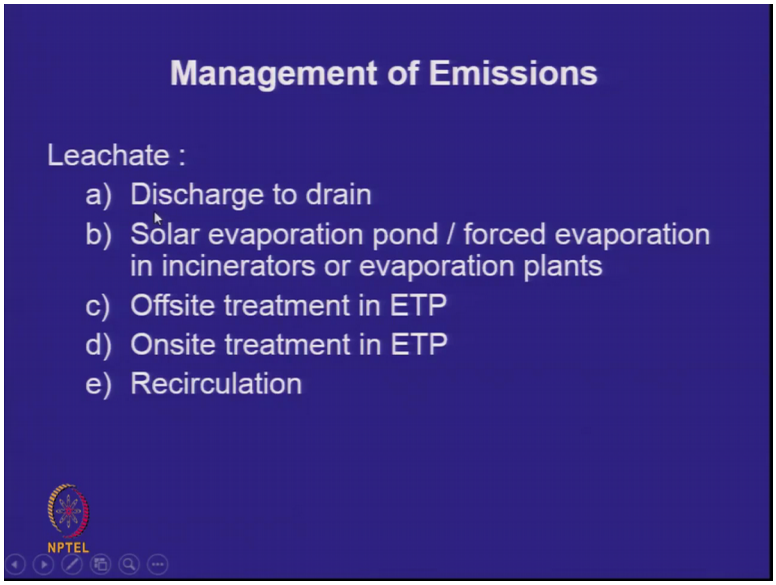

First question can you discharge Leachate to drain and depend on the type of landfill you have you have a construction and demolition waste landfill Leachate is coming out beneath it can you discharge it.

I do not know I have to test it if the Leachate meets the standards for discharge to drains specified by the central pollution control board then you can discharge it then you can discharge it. So, if it does not then you have to treat it. So, definitely hazardous waste Leachate and municipal solid waste Leachate cannot be discharged it has to be treated. So, how do we treat it one only options is to if you have a net more evaporation than precipitation then you can makes solar ponds. You know, you have the evaporation and

precipitation figures for your area if you find that end of the year all of this will evaporate then you can put it in a solar pond this is what people do, but solar evaporation ponds give you a lot of smell.

So, there is an older issue at your site it is not the best way to do this still if you do not have any facility you have not set up in a fluent treatment plant its expensive. You do not even know the kind of affluence which I going to contaminate they are going to come out you cannot design an affluent treatment plant till the kind of contaminants which are going to come out; especially in an industrial hazardous waste then you will say all right I will collect the Leachate for one year and then see what kind of ETP I have to design.

So, you can first put it in solar evaporation ponds or you can put it in forced evaporation multiple effect evaporators or incinerators where this Leachate is in the form of a jet and slurry it is place inside the boiler and these are design systems that it will evaporate and the powder will fall down. So, inside the incinerator or inside a multiple effect evaporator you are design that the Leachate will evaporate and the powder will be collected which will go back to the landfill in a solar pond. There will lot of folder the other 2 are closed container systems you may have an offsite treatment plant at enclosure what is happening the sludge from the affluent treatment plant is coming to the landfill; when the rain falls on the landfill the Leachate comes out the Leachate has the same contaminants as the affluent treatment plant which it is treating you send the Leachate back to the affluent treatment plant.

So, the better you handle it the less is the Leachate, but you can send it to an offsite treatment plant that is not on your site you do not want to invest in it there is an ETP of the industrial area anyways the contaminants are similar it goes back again the sludge comes again it comes back to you all you can make an onsite treatment plant you can have an onsite treatment plant. And finally, you can have recirculation; recirculation is not the end of all problems you do not know what to do the Leachate put it back in the landfill after some time concentrations will become. So, high some concentrations may change because the Leachate may react, but in the end you have to do a blow down a blow down is Leachate has become. So, concentrated it has to get out of the system.

So, do not think that Leachate recirculation will reduce the contaminants or it can be infinitely adopted for small period of time say for a year you have not set up you are

studying the Leachate you can re-circulate it inside the system. That means, taken back put it into the covered area will should have a piping system for being able to irrigate the covered area beneath the cover. So, that is recirculation.

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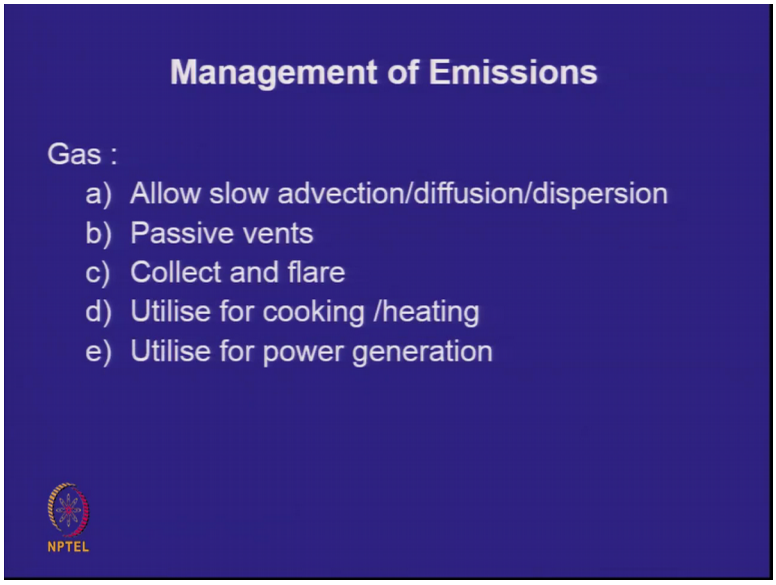

So, these are the strategies which one has to use for managing Leachate expensive strategies what do you do for gas well if you do not cover the landfill then the gas will slowly get produced and that is diffuse out and disperse with the width this would be fine, but greenhouse gases are coming out in a big way from these landfills. So, methane is a big big culprit. So, nowadays we do not allow or do not expect that engineered landfills be allowed will allow the gas to (Refer Time: 36:03).

So, you can have passive vents. So, this is over the entire surface if you put a impermeable cover you can have small pipes coming out of it if you do not have the initial money after some time you can connect the passive vents to pipes and collect and flare it you can burn the methane and in the end you can use the methane for cooking gas or heating of homes or power generation. So, this is utilization it requires an investment it requires deodorization it requires deodorization and this is an intermediate step you can collect and flare it, when you flare it methane turns to carbon dioxide and that is much one twentieth greenhouse gas effect in comparison to methane.

So, these are the ways in which we can manage the emissions any questions or any thoughts any suggestions we could do it better we have to do the geotechnical design of

many components and this is what we will cover in this course embankment design liner design Leachate wells and drains we will not be doing the hydraulic design.

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So, we are not going to do open channel design pipe flow design pump design estimation of floods estimation often what we will do is the geotechnical the wells which go the cover design the gas wells will do stability analysis environmental monitoring what is buried inside the ground and the bulk of the cost of a landfill is by all these operations waste placement embankments liners. So, we look at how to estimate the quantities and costs of landfills.

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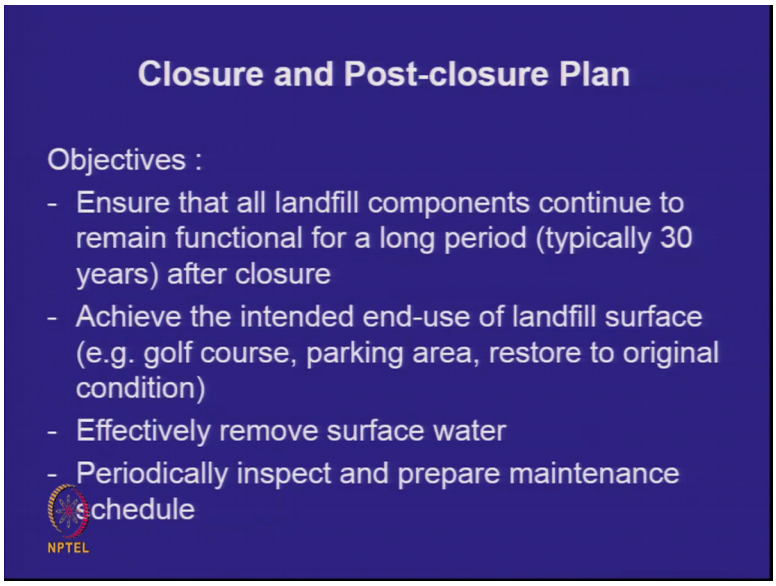

In the end we have to have a closure and post closure plan and the idea is that we should be able to after you walk off the landfill and if the waste is becoming stabilized we should be able to return the we should be able to restore this land to its original condition.

So, we have to ensure in the closure and post closure plan that we monitor it for thirty years and ensure that all the components continue to remain functional we want to achieve the ended use the end use of the landfill. That means, golf course or parking area we have to continue to remove the surface water and we have to continue to maintain it.

So, we look at this a little in detail in the next class, but the concept is that after you have finished filling the waste after you have finished filling the waste you have to ensure that for 30 years you monitor it. And best is during the monitoring you have some kind of an end use plan for yourself. And finally, if it is going to become stabilized waste then you have to ensure that it becomes part of the ecosystem and does that mean I have to dig it out or does I mean it I restore it to its original condition we will see in the start of the next class any questions any clarifications.

Student: Sir, how can be control the fire (Refer Time: 39:35).

I will do this when we are talking of a rehabilitation of old dumps the question that is being asked is how do we control fire which is coming out of old waste dumps many

waste dumps have got smoldering fire and smoke is coming out. So, we are going to separately address old waste dumps at the moment we are doing design of new facilities when we do old waste dumps.

We will see how we tackle old fires which can be deep seated because of methane burning inside the wisdom we will take it at that time all the best have a good day.