Course Name: Industrial Wastewater Treatment

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Week – 06

Lecture 30: Treatment and disposal of sludge

So, welcome you all. Today I am going to deliver lecture 5 of module 6, which is on the treatment and disposal of sludge. So, if we recall our previous lectures, we have started with the sludge characteristics, various equations to be used to determine the quantity and volume of the sludge and then we have seen the design of gravity thickener, then sludge digestion process and now we are going to learn about the sludge drying bed, its design and various types of sludge drying bed like unplanted and planted sludge drying beds and then we have also covered here the design criteria which are used for design of sludge drying bed along with the various steps to be followed in design of sludge drying bed and then finally we have taken few numerical steps which will illustrate the design procedure and the various design parameters to work out for assessing the performance of sludge drying bed.

So here if we see what is basically this sludge drying bed, so this is one of the simplest and oldest techniques which are used for dewatering of the sludge and if we see that is composed of impermeable beds overlying with the different layers of filter media made of gravel and sand above which the sludge is applied and below this the under drainage systems are provided, perforated pipes are provided which will collect the entire filtered water from the sludge and will take out of the sludge drying bed and will be recycled back to the primary settling tank for its complete treatment process. Whereas the sludge which remains on the top of the bed gets dried in due course of time through the evaporation and open sun drying and then finally it is collected as a sludge cakes by excavating the topmost layer of the sludge drying bed. So, if we see during rainy season the operation of this sludge drying bed becomes difficult because of very slow rate of evaporation. So, if we see out of 12 months, we can operate this sludge drying bed normally for 10 months only considering 2 months rainy season period for which this sludge drying beds are discontinued from its operation.

So, this is a kind of facility which are mostly used for dewatering of the sludge. Before we go in more details let's see have a picture where if we see these are the number of rectangular beds they are provided on both side here and there. So these sludge drying beds they are mostly rectangular shape. So if we can see here these are the number of rectangular plots and this if we see that is the longitudinal pipe which consists of number of transverse pipes. So these are the sludge inlet through which the sludge enters into these different beds enters into first this longitudinal sludge inlet pipe from here these are the outlets through for different sludge drying beds. So, like this the entire sludge is applied on to the different beds and then it is allowed to filter the water and then let the top bed of the sludge which gets deposited on the top layer of sand gets dried and then finally it is excavated and taken out of the sludge drying bed so as a fresh layer of the sludge can further be applied. And in this there are the under-drainage systems which are provided which will collect the filtered water and will take out of the sludge drying bed and will be recycled back again to the for complete treatment system to the sedimentation tank wherein this will be further treated in the treatment plant.

So this basically says the plant and this is the cross sectional view of the sludge drying bed if we can see this is the longitudinal pipe which are made here and these are the transverse pipes through which the sludge enters and get spread over these rectangular plots here and there. So both side we can see number of beds of particular size they are made of and here if we see the cross section so we can see this is like the sludge inlet pipes these are the transverse pipes and this is basically the sludge layer below this there is the layer of sand basically that is provided around 20-30 cm below which there is a gravel layer provided to support this layer of sand and the sludge layer and at the bottom there is a under drainage system which is provided to collect the whatever the filtered water through the entire cross sectional area that will be collected at the bottom here and through this pipe it will go out of the sludge drying bed. So, this is basically the complete diagram to understand the structure of the sludge drying bed.

And if we see they are basically the types of sludge drying beds. So basically, they are two types like one is unplanted and another one is planted. So unplanted type of sludge drying bed does not have any plantation over the sludge drying bed whereas in planted type of this sludge drying bed that are designed like a reed bed system where this unplanted one that is designed as the sand filters.

So, let's see one by one the layout and the design of both types of sludge drying bed. So this is basically the cross section of the unplanted type of sludge drying bed. So here if we can see this top layer that 15-13 cm that is the layer of the sludge we apply below this if we see that is 20 cm depth layer of sand and below this everywhere here there are the gravel media that is provided and this is basically the 100-150 cm diameter and pipes they are basically open jointed earthen pipes which will collect the entire filtered water from this sludge bed and that will be collected through this open jointed pipe and will be taken out of the sludge drying bed for dewatering. So, this is basically conventional type of sludge drying bed which are mostly used for disposal and dewatering of the sludge. So here if we see the design of this type of sludge drying bed that is basically designed as like the gravity filters we design like slow sand filter, rapid sand filter for the water treatment process and this type of basically the drying bed that requires frequent de-sludging after one cycle is completed. So, this de-sludging has to be done and again the bed has to be prepared for the next layer to be applied on the sludge drying bed for dewatering. So, these are the basically the limitations of this unplanted type of sludge drying bed.

But if we see in planted type of sludge drying bed so here we do not require any kind of de-sludging after every cycle and this design concept that is based on the design of reed beds or one constructed wetland system and here basically the kind of porosity which is required for filtration of water that is maintained in this system through the root system of the plants which are grown on the top of the bed. So here the design if we see that is the basically the topmost layer that is the layer of the sludge we apply below this, this is like the sand bed and below this is like the gravel media and here all the water which is filtered over this through entire cross-sectional area that will be collected and here this is the basically outlet through which the entire water will be taken out and will be recycled back to the treatment plant for further treatment process and one more difference here before the sludge is applied there is a screen is made here so this entire sludge that has to be passed through the screen so whatever the debris, sludge debris and some bigger size of impurities which are present in the sludge that is basically removed here and then it facilitate like proper filtering of the water and at the top if we see there are the number of aquatic plants we grow so that every time we need not to de-sludge the dried sludge and then again we can apply the next sludge layer without any de-sludging operations. And these are basically the two ventilation pipes they are provided so as if anything like further whatever the gases which are produced during the further decomposition process they are taken out through these pipes and discharged into the atmosphere through these ventilation pipes. So these are the different types of sludge drying beds we use but normally in almost conventional system we follow this unplanted system because of lot of trouble in growth of these aquatic plants onto the top of the sludge drying bed and the difficulty in every time preparing the bed and again applying the next layer of sludge so because of this the use of this type of sludge drying beds are mostly limited.

So then let's talk about the various design criteria which are used for design of sludge drying beds so mostly this having two criteria that is basically the size of the bed and the requirement of the surface area for proper filtration of the water from the sludge separation of water from the sludge. So here if we see that is the important criteria which is the dry solids loading rate or we also say sludge loading rate to sludge loading rate basically that that is defined as the amount of dry solids that can be applied per unit area per unit area per time. So that is the sludge drying bed and usually this is expressed in terms of kg dry solids per unit area per annum. So this is the unit and this is basically applied to determine the surface area required for sludge drying bed and then overall as a thumb rule we have to check per capita the sludge bed requirement is 0.1-0.25 m^2. So this is another criteria for which we have to check our design parameters whether our design follows these two important criteria. So this for digested primary sludge and if we have a mixed sludge like primary and secondary sludge then the same criteria we follow like 0.15-0.28, which is slightly different from this and then here instead of 80-120 here we take $60-120\ kg\ dry\ solids/\ m^2\ yr$ and then for the size of the bed if we see that the length we can take from 6-30 m, whereas range of width we take that is around 3-8 m in normally the size what we prefer that is 30 m × 8 m, so this is the size of the one bed that normally we consider while designing the sludge drying bed as a conventional practice and this is again the important criteria that is the depth of the sludge bed because it directly affects the rate of evaporation. So we try to have minimum depth of the sludge so that the bed gets dried and the moisture gets evaporated if the bed thickness is more it will the rate of evaporation will be less so we try to maintain that sludge thickness which is applied on to the bed should not be more than 15 cm, normally the range is 15-30 cm but we try that the while designing it should have minimum prescribed range. And then if we see that is the sludge drying time, so how much time it takes for sludge to remove its moisture that is normally 2 to 4 weeks. That also depends upon the type of the sludge whether it is digested sludge, whether it is undigested primary sludge or its mixed sludge. So depending upon the type of the sludge that sludge drying time differs and usually we for all design purpose we take usually 2 to 4 weeks for its drying time and then this is a specific sludge loading rate which is another criteria that we can take like $50 - 210\ kg/m^2\ yr$. So these are the various design parameters which are used in design of the sludge drying bed

So then let's see what are the various design steps to be followed while designing a sludge drying bed so we know that the sludge drying bed is designed based on the total amount of dry solids that can be applied per unit area per unit time and time basically that the sludge loading rate that is given as per year, so we have to first complete the total amount of that dry solids which are produced per year and then we can assume the appropriate sludge loading rate for different types of sludge depending upon the type of the sludge and then using this criteria if we divide the total amount of the dry sludge produced with this sludge loading rate criteria. So we are able to compute the bed requirement the surface area requirement of the sludge drying bed and then this requirement has to be checked per capita basis like if it should not exceed to the prescribed range and then what we can do is like having the total surface area we can assume the size of the bed and for one bed we can calculate the area and then we can find out how many number of a particular size of bed is required as per the total surface area requirement of the bed so this is the next step and finally then we have to check that the thickness of the sludge should not exceed by 15 centimeters, so for that we have to assume the number of the cycles that can be performed in a year so assuming like two months rainy season the sludge drying bed operations are discontinued and one month time will take for one cycle to complete. So total out of 12 months we can have 10 number of cycles so depending upon the number of the cycles we can operate in a year we can calculate the depth of the sludge that is applied over the sludge drying bed and then it has to be checked that it should not exceed by 15 centimeter for better performance of sludge drying bed and then also we can finally check as per the actual size of the bed how much the surface area is provided and this must always be higher than the required surface area of the sludge drying bed which we calculate using the sludge loading rate criteria. So these are the different steps that we can follow to design the sludge drying bed.

So let's see take some example and then using this example we can illustrate how the design of the sludge drying bed can be carried out so if we read out this example so here we see that we have to design a sludge drying bed to dewater the digested sludge which is produced from a wastewater treatment plant which is based on the activated sludge process and here following data we need to assume for design of the sludge drying bed so here if we see that the population data is given like the treatment plant is serving for a population of 50,000 and then here the another criteria that is given as per capita dry sludge produced that is 70 gpcd and the solid concentration in the sludge that is also given as 7% and this is the specific gravity of the sludge solid that is 1.02. So here if see what we have been given is like the population and the per capita per day solid contribution so using these two data we can find out how much total dry solids will be produced in a day and then using the sludge loading rate criteria we can find out the surface area requirement and then we have to also consider that the solid concentration that is 7%. So how this design we will be doing.

So that is you see here, the solution is given here first of all we have computed the amount of the total solids they are produced per day and if we can calculate for per day then in a year also by multiplying 365, we can calculate per year total solids produced from the treatment plant for which we have to design the sludge drying bed so here for estimation of the total amount of dry solids produced that is as per the numerical the per capita sludge contribution that is given as 70 $g/capita/d$ and we have been given with the population also that is 50,000. So if we multiply this with the per capita contribution of the dry solids though we will get total amount of the dry solids which are produced per day, since the value is given in grams so it will come in total amount of the sludge in gram per day since the quantity will be very high so we have converted this into kg/day. So here 10^{-3}, we have to further multiply to convert this gram into kg. So if we estimate we will get this total amount of the dry solids which are produced that is 3500 kg/day and then once we have calculated amount of the total solids produced per day then we can find out the surface area, which is required for designing the sludge drying bed because this dry solid loading rate that is to be assumed here as this data is not given in this problem. So here we have assumed as per the type of the sludge if we see the sludge is basically from activated sludge process so that the criteria that we can assume that is 100 kg/m^2/year which is within the design range for activated sludge process, so accordingly if we find out the total surface area required for the sludge drying bed. So this will be equal to surface $area\ of\ bed\ needed = \frac{dry\ solids\ applied/year}{dry\ solid\ loading\ rate}$ the assumed criteria for solid loading rate or sludge loading rate so here if we see 3500 kg/day is generated and if we multiply with 365 so we will get total amount of the dry solids which are produced in a year and then divided by sludge loading rate or dry solid loading rate which is we have assumed 100 kg/m^2/year ($\frac{3500 \times 365\ (kg/year)}{100\ (kg/m^2/year)}$). We get this total amount of area which is required that is 12275 $m^2/year$. So once we get this total area so we can check for per capita requirement of this area so here this is the total area divided by total population for which it is designed. So that comes around 0.255 $m^2/capita$. Which is within the prescribed range as per the design criteria prescribed for sludge drying bed. So we can say our design of sludge drying bed as per the per capita requirement that is satisfied. So once this check is completed then we have to find out how many numbers of beds are required, so for this we have to presume the size of one bed so let's presume or assume the size of one bed to be 30 meter long and 8 meter wide. So the area for one bed that will be something 30×8 m^2 area, so for how many bed will be required for such a size of beds so we can find out by dividing the area of one bed to the total area required for the sludge drying bed ($number\ of\ beds\ needed = \frac{total\ area\ of\ the\ bed}{area\ of\ one\ bed}$). So this is $\frac{12775\ (m^2)}{30\ (m) \times 8\ (m)}$, so by putting the value here in the equation we can get the total number of bed that is required that is something 53.22. So this is not a complete integer so we have to take the next positive integer value that is 54 number of beds, while deciding this we cannot take it like 53 because if we make 53 so total area requirement will not be made so taken always higher side instead of taking the lower side. So now for this we have designed like that 54 number of beds are required of this size. So now another check that is like the thickness of the sludge that will be lying on to the top of the sludge drying bed so that has to be checked. So for that we have to presume like how many number of cycles a bed can be performed in a year so as I discussed there are like two months rainy seasons so if we subtract two months rainy season so we have 10 months for operation and to complete one cycle like including the application of the sludge dewatering of the sludge drying of the sludge and then again excavation of the sludge so this complete cycle completes takes about one month so in a year we presume that total 10 cycles can be performed for every bed.

So looking into this consideration now we can find out how much thickness of the sludge will be there on the top of the bed. So for that we have to first estimate the volume of the digested sludge for this much kg of the dry solids so this formula $Volume\ of\ digeste\ sludge\ =\ \frac{W_s}{\rho_w \times S_{sl} \times P_s}$. So we all know this data $\frac{3500\ (kg/d)}{1000\ (kg/m^3)\ \times 1.02\ \times 0.07}$. So, by putting this value we can find like per day this much amount of the sludge that will be generated. So equal to something around 49 m^3/d volume of the sludge that will be generated. So from this volume we can further find out the depth of the sludge bed required. So here if we calculate this sludge depth what will be there for the given size and the given volume of the digested sludge. So here if we can use this formula $sludge\ depth = \frac{total\ volume\ of\ sludge\ applied/year}{number\ of\ beds \times area\ of\ each\ bed \times number\ of\ cycles\ of\ each\ bed}$. So by putting this value we can find out how much will be the depth of the sludge being applied on to the sludge drying bed. So that we can check that it should not exceed by 15 cm. So let's put this value here $\frac{49.0\ (m^3/d)\ \times 365\ (d)}{54\ \times 240\ (m^2)\ \times 10}$ we get the thickness of the sludge that is that will be equal to 0.138 m which is less than this 15 cm approximately equal to 15 cm. So I think this also confirms the prescribed range of sludge thickness that is around should not exceed by 15 cm. So here finally we can recommend like total number of sludge bed to be designed that is 54 but always we have to take plus 2 number of sludge drying bed as a standby bed. So that if any of these beds gets some repair, so these bed standby beds they can be used and the operation of the sludge management is not hampered and each of these beds will have a size of 30 m × 8 m.

So this is the answer for this problem then we can check again the total number of beds that has been provided depending upon the actual volume of the sludge, so if we see $49 \times 365\ m^3/year$, so in a year this much of volume of the sludge will be generated and if we see the volume of the sludge that each bed will handle with 10 number of cycles of operation in a year. So how much volume a single bed can occupy so we can see $10\ \times 30\ m\ \times 8\ m\ \times 0.15$, so this much m^3 of sludge it can handle a single bed in a year. So $number\ of\ beds\ required =\ \frac{total\ volume\ of\ sludge\ per\ annum}{volume\ of\ sludge\ each\ bed\ can\ handle\ per\ annum}$, so here if we can see this value comes around 49.68. So this is 50 beds, so within 50 beds the total requirement is fulfilled and we are providing in fact 54 beds. So this is well within the acceptable range so this rest of the bed at the time of emergency can be used as a standby beds.

So if we again see the problem that is another numerical we have to design the sludge dying bed for the digested sludge which is obtained from a low-rate anaerobic digester. So here the sludge which is produced is already digested and treating basically a mixture of primary and activated sludge process so this is the mixed type of sludge digested sludge and this is produced from wastewater treatment plant having activated sludge process of capacity 50,000 m^3/d. So following data we need to consider while designing the sludge dying bed. So here directly the volume of the digested sludge per day is given instead of giving the per capita contribution of the solids or any other data so here directly the volume of the sludge is given and here again if we see dewatering drying and sludge removal cycle that is given that is 10 days means for one complete cycle it requires only 10 days instead of 30 days which is required in a conventional sludge dying bed process for different types of sludge because this is already digested sludge. So it will require very less time for dewatering drying, so this is normally 10 days and then you can see the another data which is given is that is 0.3 meter that is the thickness of the sludge layer that should be applied in the maximum thickness up to 0.3 meter.

So for this data how we can do the calculation so here if we see that is first of all again we have to depending upon the volume of the sludge that will be generated in a one cycle. So here if we see that is the amount of the sludge that is generated per day, so if we presume a complete cycle takes 10 days, so within 10 days how much total amount of the sludge that will be generated and if we divide with the thickness of the layer. So how much the bed area requirement would be there so this is like how we can calculate the total bed requirement that is required for sludge drying bed. And now instead of assuming the size of the bed we can assume the number of the bed also that is another way of solving the same thing the designing the sludge drying bed. So here the total plan area for each bed if we see that will be total area divided by the number of the bed and that comes around 254.43 and for this area that is coming so we have to check whether this area we have got that follows the per capita contribution area so here if we see per capita waste water flow if we assume that is 150 lpcd. So if we presume per capita waste water flow to be assumed as 150 lpcd. So, for the given amount of the waste water flow that is generated around $\frac{50000\ (m^3/d) \times 10^3 (l/m^3)}{150\ lpcd}$. So, we can find out how much population that is being served by this waste water treatment plant so here it comes 3,33,333 persons or capita so now if we divide this total area with this total population so we can find out that is the per capita area that comes around 0.023 m^2. So here we can see that the area for this digested type of sludge that is very-very less compared to the per capita area requirement for the sludge drying bed for different other types of undigested or mixed type of sludge. So, this is how we can do the design of the sludge drying bed.

So here you can follow these references like we have taken most of the material from these references

So, thank you.