Course Name: Industrial Wastewater Treatment

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Week – 06

Lecture 27: Treatment and disposal of sludge

So, welcome you all. Today I am going to deliver lecture 2 of module 6, which is basically on the treatment and disposal of the sludge. So, if you recall our previous lectures where we have dealt with the various characteristics of the sludge, the quality parameters of the sludge and then we have seen their relationships and then we have also seen like what types of sludge, what are the different units which generates the different types of sludge. So, depending upon the sludge, we have to find out different alternatives for the sludge treatment and its disposal. So, here in this we are covering the various alternatives which are used for the treatment of the sludge. Then we will be also looking like sludge thickening which is a process which will deal with the concentrating the sludge so as to reduce the total volume of the sludge which require further treatment and handling and then we will also cover here the types of sludge thickening methods like gravity thickening methods, centrifuge thickening methods, rotation methods and then belt type of thickening, rotary drum type of thickening which are normally used for carrying out the process of thickening. Along with this we will be also discussing more about the gravity thickener process, its design concepts, design parameters and then we will be also including the some numerical which are based on the design and estimation of the parameters for the design of gravity thickener.

So, let us start with the various alternatives which are used for the sludge treatment process. So, if we see these are the primary sludge where wastewater is treated, where the lot of suspended solids they are removed and this sludge basically we can have two types of treatment like one is flotation based and then another is gravity based. So, this flotation means if the sludge particles are of a nature like flocculent natures so they have density < 1 even water so they easily get floated onto the surface. So, if again if we enhance the process by aerating, so this can remove lot of floating and flocculent sludge from the concentrate. So, this is the method that we will be discussing and then the type of sludge which have specific gravity more than 1, so they can be treated by gravity separation methods. So, this is after thickening the sludge is stored here in a sludge storage tank and from here the next process what we do is that is the digestion of the sludge. So, here this may be anaerobic digestion, this may be aerobic digestion. So, various types of digestion systems we will be looking into. Then there is a heat treatment method which also are used for thermal digestion of the sludge and then we will also look upon the wet oxidation method which are normally used for oxidizing the organic compounds which are present in the sludge. So, then after digestion of the sludge they are more stable form and they have better dewatering property. So, then after this we have to dewater the sludge. So, these are the basically if we see these are the different methods which are used for dewatering of the sludge starting

from centrifugation then vacuum filtration and we also use sludge drying beds for filtration of the stabilized sludge from the rest of the water and then there are filter press are also nowadays available which compress the entire concentrate and removes the water and sludge solids separately. So, these methods we will be going in details under dewatering of the sludge and then finally whatever this after dewatering of the sludge whatever the sludge solids they are basically stabilized in nature they do not have any offensive orders. So, they can be disposed by different methods there are number of methods if we see starting from incineration then land disposal methods. So, incineration what we do because they are having lot of calorific value. So, they can be incinerated and the heat can be generated and then similarly land disposal system we can just dispose on to the lower lying area which in turn the soil becomes enriched with various types of nutrients. So, then that is like ocean disposal method where we use to dispose these sludge solids, but normally in India that this kind of systems only preferred in the area where there is oceans or sea source of level and then that is like soil conditioning system. So, this sludge solids have lot of nutrients value. So, they can be used as a good soil conditioner when we apply for agricultural purpose for remediation of degraded land and then finally there are also method that is underground disposal methods. So, like we can make a open pit and then we can dispose this into the pit cover with the soil. So, this can be used for disposal of dewatered sludge. This slide says like different types of systems, different techniques which are adopted for the treatment dewatering and drying and then finally disposal of the sludge.

Then let us start with the sludge thickening when we say the sludge thickening that are itself indicates the sludge is thickened. So, sludge is thickened because if we see the sludge it contains hardly 2 to 4 percent of the solids and rest is the moisture. So, if we can further remove the moisture then it becomes more concentrated. So, the process of removal of this the free water which is present in the sludge mass that is basically called as the sludge thickenings and here what happens basically the particles do settle at the bottom of the tank when it is taken in a tank in a quiescent condition for certain period of time. So, the particles which are the sludge which are settleable in nature they will be settled down and there will be like a stratification of the clarified water and then the concentrated sludge. So, by way of their gravitational separation techniques we can use this for removal of moisture. So, this and a kind of gravity thickness we will be studying in more details and then you see there is another procedure which we take into account that is centrifugal thickening. In this process the sludge mass is rotated and because of this rotation there is a centrifugal force which are acting on the sludge solids which separates these solids from the water and we remove the rest of the water and that thickened sludge can be separated. And then we have a flotation technique and under this we used to aerate the sludge mass. So, what happens this air gets trapped within the sludge mass and that makes the sludge buoyant and there are like already presence of flocculent sludge. So, they will more easily get floated onto the surface and then there are the skimmers, various types of skimmers we designed which skims out this floated sludge from the rest of the water and then we also use that rotary drum type thickening process where basically a perforated drums are used as a screens wherein the sludge mass is taken into and then this is rotated so that all the water gets separated from the rest of the sludge solids.

So, here if we see these are like different types of thickeners we use gravity thickener, centrifugal thickening process, flotation technique and then belt type of thickeners, then rotary drum type of thickeners. So, different types of thickeners are there we will be going one by one in more details of these types of thickeners.

So, here if we see the first thickener which is mostly used in the treatment of the sludge that is gravity thickener which works based on the gravity separation techniques. So, here the sludge solids are separated by the action of gravity so that is referred as the gravity thickening process and which basically separates the bio solids which are condensed to produce a concentrated layer of solids at the bottom whereas the relatively less solid concentration water that will be taken as a supernatant and that will be floating onto the surface so from there it will be removed out. So, this basically if we see the design is like based on the gravity separation. So this is designed like conventional sedimentation tank design process. So, we use the same process for design of gravity thickeners which are mostly designed based on the hydraulic loading rate. So, this process basically is mostly effective for primary sludge which have more of inorganic nature of sludge.

Then let us see how this gravity thickener looks like so this if we see the two diagram here one top view of the gravity thickener. So, here if we see the water basically is coming out through this influent pipe and this is basically the central well where the sludge is fed into and from here this will come out and there this central well inside this there is a rotational system which is rotational arms which are attached which rotates in clockwise direction. So as to the entire mass of the sludge coming into this tank that will be rotated at a certain speed so as to separate out the water from the sludge and then here if we see these are the weirs provided and then there are the effluent landers and then this is the effluent pipe from where this the entire sludge can be removed out. If we see the cross-section at A-A, so here this cross-section if we see so this if we see that is the handrails where a person which can enter into the this central well area where there is at the top if we see that is the motor and driving unit that are affixed and this is mostly the central well where the sludge will be taken through this influent pipe and from here it will this basically the feed well and from here the sludge will come out through this different directions and these are the rotational mechanism which will basically this rotate in a clockwise direction so whatever the incoming sludge that is rotated at a very small rpm like 2 to 3 rpm and then because of this rotation the sludge solids they are separated out of the water and then they there are the weirs provided at the top you see water that will enter through this weir into this effluent launder and from this the water is taken out whereas all the sludge particles which are settled at the bottom here and there that will be taken out into these sludge hoppers which are provided at the bottom of the tank in aligned with the central well and then if we see that is the sludge outlet pipe from where the concentrated stream of the sludge that will be taken out from the water for further treatment process.

So here if we see the design criteria which are used for gravity thickeners. So here if we see that is designed based on the safety separation process. So this the principle used in design of primary sedimentation tank which is like based on the hydraulic overflow rate so this criteria always taken into this account and then there is another criteria which is called as the solid loading rate. So solid loading rate basically that is the amount of the solid that can be loaded per unit square area of the tank per unit time. So this solid loading rate basically depends upon different types of the

sludge the nature of the sludge whether the sludge is stabilized sludge digested sludge whether this is raw sludge the sludge which generated from the activated sludge process like from sedimentation tank primary sedimentation process chemical sludge so depending upon the type of the sludge there are different types of solid loading rate that has been already arrived for better settling of this process so for the different types of sludge and their percentage of the solid depending upon the how much percentage of the solids are present into that sludge so depending upon that there is a particular solid loading rate that we have to select from a table which is derived from a number of experiments carried out on different types of sludge. So that table we will be showing in the next slide and then that is like maximum hydraulic loading rate so hydraulic loading rate as you know that is the surface overflow rate, so as we know that if there is a very less hydraulic loading rate retention time of the sludge in the tank will increase and that in turn may cause putrification of the sludge. So there is a limit for like the hydraulic loading rate should not be less than 4 to 15 $m^3/m^2.d$ then similarly if we also have very high organic loading rate that is also not good so that is basically affecting the thickening process because high hydraulic loading rate that leads to the improper settling of the sludge solids because of the high surface overflow rate but that there is a design range that has already been provided for design of the sludge thickeners. So like for if there is a primary sludge if there is a activated sludge and if there is a combined primary and activated sludge so there is different criteria if we see for primary that is 15.5 to 31 $m^3/m^2.d$, whereas in case of waste activated sludge this value comes to a very less that is 4 to 8 $m^3/m^2.d$ because here the sludge solids they are stabilized in nature and then there are mixed sludge so value in between these two that is 6 to 12 $m^3/m^2.d$ that has to be taken for design of the gravity thickeners depending upon the type of the sludge.

So then that's what that is the solid loading rate what we were discussing if we see this column tells different types of sludge like the primary sludge, trickling filter sludge, RBC, rotating biological contractor sludge then activated sludge then this is again the high-purity oxygenated sludge then extended aeration process sludge then anaerobically digested sludge so for different types of sludge if we see that is the initial percentage of the solids which are present normally like if we see and after thickening they are increased like 2-6 if it is there in the primary sludge it can be increased up to 10% of the solids after the thickening process. Similarly for trickling filter sludge if we see initial concentration of the solid that is in the range 1- 4% but after thickening we can increase the sludge concentration up to 6%. So this is like depending upon the percentage of the solids it is present in the sludge there is a different solid loading rate criteria that is the amount of the sludge per unit square area of the thickener per unit time. So that is in terms of $kg/m^2.d$ whereas this is like FPS system where this $lb/ft^2.d$ it is used so these are the value given for the two unit system so for primary sludge if we see that is 100 to 150, whereas for the trickling filter sludge which is comparatively more stabilized form so the values for this that is basically taken less as compared to the primary sludge. So like that for different types of sludge you can see the value ranges from 20 to 40, 20 to 40 this is for anaerobically digested sludge 120 so like that so different types of sludge and here if we see that is mixed sludge which is like primary sludge plus trickling filter sludge then the sludge generated from primary treatment process and RBC process and then primary and activated sludge process like these are the percentage solids and then these are the solid loading rate criteria that we have to take during design of this gravity thickener then again we have like chemical sludge so which may contain high percentage of lime maybe low

percentage of lime and then like the coagulation process which uses iron salts as a coagulant so there lot of iron content you will have so for different percentage of solids we have different criteria for solid loading rate. So this is like a very important criteria based on that the dimensions of the gravity thickness the size of the gravity thickness that are being determined.

So here let's see the procedure for design of gravity thickener so here if we see that is the determination of percentage of the solids first we have to determine because we have to select a proper solid loading rate. So first of all we should know like what is the initial percentage of the dry solids they are present in the sludge and then depending upon this percentage of solids present and the type of the sludge we can assume a particular sludge loading rate and for that sludge loading rate if we divide with the total amount of the sludge, so what we are going to get that is the surface area which is required for the thickener and then using this surface area we can further design the dimensions mostly circular in diameter so accordingly we can find out the diameter of the tank which is needed as a gravity thickener to be designed as a group gravity thickener and then whatever this area we have got that has to be also checked for this the second criteria that is hydraulic loading rate. So based on this again you have to get another area that is A_1 and A_2 so here you will get the area based on hydraulic loading rate which is basically the volume or the discharge of sludge per unit surface area $HLR\ or\ OFR = \frac{Total\ flow/day}{surface\ area}$ of the tank. So, here again we know the total flow of the sludge which is coming out to the treatment plant if we divide with this hydraulic loading rate or so we can find out the area. So we can we can do otherwise or we can get the area and check for the hydraulic loading rate. Any of the process we can use for complying our design for both of the criteria. So here if we see this hydraulic loading rate we have to check that should come out in between this range 15.5 to 31 $m^3/m^2.d$ for primary sludge or there are depending upon the sludge this criteria can be replaced with so then once we get the surface area.

So, we can determine the diameter because this is circular section $\frac{\pi}{4}D^2$ that will be the area and from this formula if we find out diameter. so that will be $D = \sqrt{\frac{4A}{\pi}}$, where A that is the surface area of the tank and then after designing the system, we have to also look that whenever we design a gravity thickener, we have to also design a standby unit so as if one goes under operation so another can be used for continuity of the treatment process.

Then you see there are another type of thickening process that is centrifugal thickening process basically this is the process which uses ten centrifugal forces under the influence for separation of water from the rest of the sludge. In this process if we see the sludge are taken into the cylinders and they are rotated at a speed ranging from thousand to four thousand rpm and sometimes we may aid also some kind of polymers which are required for improving the technique process so normally if this process have very good efficiency and they may not require this polymers for further improving the efficiency. So centrifugal thickening process mostly that is mostly suitable for the waste activated sludge process, where there are lot of flocculent sludge, stabilized sludge present in the sludge mask.

So how this process basically takes place if we see that is kind of rotating bowl so this is the driving unit through which the this entire cylinders that is rotated at a speed of thousand to four thousand rpm so this generates suction here and the sludge enters into this and this is finally rotated into this in a centrifugal forces acts upon this which separates out water so whatever water that is separated that goes to the dewatering which and whatever this sludge cakes that are formed from the top that will come out as a sludge cake from top and bottom there wherever from this side whatever the sludge we will get that will be in the form of concentrated sludge so this again is collected and then further put for further treatment process.

So this is like another type of thickening that is flotation technique which is again based on a density separation techniques because flotation like if the sludge mask contains lot of flocculent mass which can float onto the surface which has less than one which are mostly generated from suspended growth the process, like activated that process suspended growth nitrification process so this type of sludge they are mostly efficient and this techniques basically what happens we used to diffuse lot of air into the sludge mass so as this air they entrap within the sludge marks further makes the sludge more floated onto the surface and from the surface is skimming mechanism are used with separate salts the sludge concentrate from rest of the water. So this is like the dissolved air flotation process which are mostly applied for the sludge solids which are neutrally wired this techniques can also remove other floating impurities like oil and grease along with the sludge particles.

So how this flotation techniques are used basically this like a kind of settling tank. So here if we see that is basically the sludge which enters through this insulin pipe here if we see this sludge is pressurized with the air so along with air the sludge will be diffused out from this central well so this comes to this central well into this this will be diffused in all the direction. And then this is the rotating arms which will rotate all the sludge mass in the tank and that will basically separates out because the sludge mass they are propellant in nature so because of their less specific gravity they will be floating onto the surface and this if we see this is the skimmer mechanism which are used and whatever the sludge solids they will come on the top because of this air flotation process they will be removed using this skimmer technique, the skimmer system which are designed to remove out this sludge into this float through so all the sludge that will be collected here the water will be going here so then whatever the floated sludge that is the outlet from here it will be taken out where whatever the rest of the water that basically will come out here and through this effluent wear that will be taken out of the tank so this is the entire process which basically based on the air flotation process.

Then if we see this is a belt type of a thickening this is again a gravity separation process which are performed through belt type of mechanism where a gravity belt thickeners are provided. So this has been used mostly for thickening the activated and industrial sludge which are generated from different industries. basically it consists of a gravity belt that moves over the roller, here if we see how it works basically whatever your sludge that is taking into a flocculation tanks so here if we see we can add some polymers also.

So here it will be mixed into this flocculation tank and from here this will be rotatory belt so this will rotate through on these pulleys so these are the pulleys provided this is a perforated belt. So

whatever the sludge that will come that will roll through this belts and what will happen whatever your water that will be separated out during its rolling over the belt and this will be collected again here into a sump provided at the bottom and whatever your concentrated sludge when it moves to the outer pulley so it will be because of the centrifugal momentum of the sludge particles that will come out through here and it will be collected here. So concentrated sludge will be collected here and the water which will be drained out through this rotatory belts so that will be collected in a sump and then again it will be sent for the further treatment process. A belt type of thickeners are designed for thickening of the sludge mask.

And then this is rotatory drum type thickener so this is again basically is used for a small to medium size of plants and mostly suitable for activated sludge thickening process and basically it consists of a conditioning system and then rotating cylinders which are used as a screen to remove out the water from the sludge mask similar to the belt type of thickener here also polymers may be mixed with the diluted sludge mixed into the tank in a conditioning drum. So this condition sludge is then passed to a rotating screens which separates out the flocculated solids from rest of the water and then what happens in this the system is designed in a such a way that thickened sludge rolls out at the end of the rotatory drum and get separated from rest of the water.

So you can see here this is the diagram so this is like the drum where the sludge solids enter so this is rotated so when it is rotated all the water that gets filtrated from here and that is collected into this sump. So all the water will be separated during this rotation process whereas during rotation all the sludge particles that will form this kind of heap and finally this accumulated sludge from the bottom that will be removed out like the thickened sludge. So this water what is collected in the sump that will be sent for the treatment whereas this thickened sludge that will be taken for further digestion or further dewatering and then disposal process.

So here we have taken one example which contains two types of sludge like primary sludge then waste activated sludge having different characteristics different specific gravity, different percentage of the solids and having different flow rate for which we have to design a system the peak and design conditions data that we have to use for design that is also given that is for primary sludge and this is for activated sludge. So here the specific gravity and this has to be same but for this peak condition the percentage solids that may be increased so that is 3.4% and this we have to take as 0.23% solid flow are same like 400 to 420 and this flow we have to take from 2250 to 2500 for the peak conditions. So this is the problem for which we have to design a gravity thickeners.

So what we have to see first what type of sludge. so this is I can see that there is a primary sludge there is a waste activated sludge and we have to design for mixed sludge so when these two sludge are mixed what will be its percentage of solids that we have to get and then according to that percentage of the solids and taking the mixed sludge as a type of sludge we have to see the table for the empirical value of solid loading rate and then accordingly we can design the gravity thickeners. So how this procedure has to be taken so that is illustrated here so here if we see first of all we have to compute the dry solids for the peak design conditions how much dry solids are produced from the different types of sludge. So if we see for primary sludge, so the flow rates are

given like 420 m^3/d and the specific gravity is given as like 1.03 into thousand so multiply with the specific gravity $kg/dry\ solids = 420\ (m^3/d) \times 1.03 \times 1000\ (kg/m^3) \times 0.034\ (kg/kg)$and this the specific weight of water. So it becomes the density of the sludge and if we multiply with this volume or flow rate. So we will get how much kg of solids they are generated and then in this how much only solids are there. So solid percentage that is given as 3.4%. So here 3.4% is the decimal fraction of 3.4%. If we put the right multiply so we will get how much dry solids they are present in the primary sludge if we multiply it will come 14,708 kg/d. Similarly for waste activated sludge this is the flow rate this is the density of the sludge and then here 0.23% of the sludge so this gives us the value that is 5779 kg/d. If we do the total so this will give us the total amount of the sludge solids they are generated so that is mixed sludge total amount of dry solids will be 20,487 kg/day. So and if we see the total flow so total flow will be 2500 + 420, if we add we will get 2920 m^3/d.

So this is like the sludge characteristics when they are mixed how much weight of the sludge how much flow rate will be of the sludge and from this data we can determine how much percentage of the solids will be there in the mixed sludge. So here if we see how much primary solids so only solids we have to multiply with the density and the flow rate. So this is the amount of the primary solids they are present in the primary sludge and then this is again flow multiplied the density of the sludge, like this is specific gravity multiplied density of the water this will give us the density of the sludge, so multiplied by this will give us the amount of the solids which are present in the activated sludge. So now if we do the total so we will get the total amount of the solids that is this much and from here if we see how much percentage of the solids so this is basically the total amount of the solids and this is the total weight of the solids so this is if we find out the percentage this value comes 0.69%. So now we have got like for 0.69% how much value of solid loading rate that has to be taken. So if we see again this table and if we have this percentage solids in between this primary and waste activated sludge process here the solid loading rate criteria that is given 25 to 70 kg/m^2.d. So this is the range and here using this table here we have assumed the particular solid loading rate so we have assumed here for this percentage of the solids let's have this solid loading rate equal to 50 kg/m^2.d.

So solid loading rate is divided with the total mass of the solids so we will get this much surface area is required so again this is the surface area requirement $Area = \frac{20487\ kg/d}{50\ (kg/m^2.d)}$. we have to check for the hydraulic loading rate because the system must be also complying for hydraulic loading rate. So here if we see that is again the total flow divided by the surface area, so total flow we know that is $Hydraulic\ loading = \frac{2920\ m^3/d}{407.7\ m^2}$ we have hydraulic loading rate equal to 7.13. So here if we see using this surface area because our surface area, it is less than the less than the prescribed range of like 15 to 31.5 m^3/m^2d. So because this is less so to reduce this hydraulic loading rate we have to further reduce the area so for area reduction we have to again think of this solid loading rate. So solid loading rate again if we see we have assumed 50. So if we further reduce the value it will go to a higher surface area and then it can come to this prescribed range of 15 to 31.5. So this revision exercise has to be checked and repeated till both the design criteria are fulfilled and then finally you see for illustration how to find out this diameter. So this

$Diameter = \sqrt{\frac{4 \times 409.7\ m^2}{2 \times \pi}}$. So here we get this is 16.15 m diameter of the gravity thickener for this case.

So these are the references that you can refer for the complete details of the process. So here we have deal with the design of gravity thickeners and then in the next lecture we will be further going for the digestion process. We will be looking both aerobic and anaerobic digestion process factors affecting the digestion process and many more further unit operations for the treatment and design of sludge.

Thank you.