Water Quality Management Practices

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Week-04

Lecture-20

PST: Performance factors affecting efficiency and design recommendations

Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Gourav Dhar Bhowmick. I am a faculty in the Department of Agriculture and Food Engineering of Indian Institute of Technology Kharagpur. So, this is the last lecture of module 4, where we will be discussing about the primary sedimentation tank. As you have already might have understood the process flow for primary treatment units. So, earlier we discussed about the different type of screens, we discussed and designed about different types of grid chamber.

So, and the skimming time now we will be discussing about the primary sedimentation tank. In the primary these are the concepts that will be covering the purpose of primary sedimentation tank, the flocculent settling, the removal efficiency of primary sedimentation tank, design parameter for primary sedimentation tank and the design recommendation. To start with after we remember we discussed about the screen and then we discussed about the grid chamber, then the skimming tank and sometimes the combination of both, but after then what to do? As we already know that we after going through the screening and the grid chamber, we already get rid of majority of the suspended inorganic solids right. So, we consider that all the I mean like the all the this inorganic solids it is already removed ok.

So, now, our target is to remove the organic solids ok. So, organic solids which are in like you know in suspended form and all. So, get rid of them. It is very hard to get rid of them in which are in dissolved form. So, we will discuss about it how to get rid of this dissolved organic solid also in the secondary treatment unit, but majorly in primary treatment unit our target is to remove the suspended or like or the or the organic solid which are in suspended form ok.

So, this is our major target to remove the suspended organic solids from theour treatment line by using the primary sedimentation tank. So, in general we normally try to settle the lightweight organic matter in a primary sedimentation tank and which eventually helps us removing almost 30 to 40 percent of the total biochemical oxygen demand and also for 50 to 70 percentage of suspended solids from the raw sewage. So, you might have confused like how come BOD is getting removed. You understand like so, when we remove any organic matter definitely BOD is kind of a indication of the amount of organic matter present in your wastewater right we have we already know about that. So, if the organic matter can be removed definitely the BOD will also be removed theoretically and in a way if the BOD removes that means, your treatment efficiency is getting enhanced.

That means, you are getting you are treat you are treating your wastewater in a much holistic way ok. So, this primary sedimentation tank is used for removing 30 to 40 percent of the total biochemical oxygen demand and which stands for almost 70 percentage of suspended solid which can be removed from the raw sewage. In general these are some considerations that you need to remember the flow through velocity is normally kept as 1 centimeter per second at average flow with a detention period of around 90 to 150 minute. Try to understand here organic solids are removed by the help of the gravity right. So, when it gets sedimented over a certain period of time if we keep that water stable or you know keep it some I mean like in a large container or the tank the primary sedimentation tank what we call.

So, the what will happen all the solid particles are suspended solid particles organic solid will start settling down on the bottom. So, that is our major goal here ok. So, for that we need certain little bit higher amount of time higher amount of retention time or detention time in the system itself. So, it can be as high as 100 and 150 minutes to be kept in inside the primary sedimentation tank. Horizontal velocity which removes the organic solid suspended solid of above 0.1 millimeter and the wire loading less than 185 meter cube per meter of length per day is normally used for designing the effluent wire length ok. So, it can be as high as 500 meter cube per meter per day, but in general 185 meter cube per meter either length or width wherever we are placing the wire based on the length we this is the standard recommendations given by the like you know scientist. So, when we do when we design a primary simulation tank we need to start with certain considerations certain recommendations right. So, to start with whether we should go for circular or the rectangular type it depends on the average dry weather flow and also we can check with the peak flow conditions also we can check with the availability of the land and also we can check with you know the design efficiency that you are expecting. So, based on all these parameters you can either choose a rectangular or circular primary sedimentation tank.

The diameter if it is a circular tank it may be in the range of 6 3 to 60 meter up to 45 meter is typical length and is governed with the structural requirement of trusses and all if it is a rectangular tank it should be the length should not be more than 90 meter. Even it is 90 meter also it is not standard we in the standard practice we do not if the length is more than 40 meter we try to avoid you know having more than that length ok. So, in case if we our requirement is more than 40 meter we can have another tank. So, we can bifurcate our flow or when I can literally divide our sewage inflow into both the sedimentation tank like primary sedimentation tank or PST is in short when we call. So, remember that the length in standard we can go up to 90, but do not go more than 40 meter that is like it is unnecessary occupying the place I mean like the land footprint isn't it.

So, 40 meter is our standard practice. The depth of the mechanical clean tank should be as shallow as possible with the minimum of 2.15 meter because if it is more than that it will be very difficult to clean the bottom the sludge that is getting deposited over time. And also the average depth of the tank normally used in practice is 3.5 meter including 2.25 meter of sludge zone and 0.325 meter of freeboard on the top on the surface even above the top of the surface of the water body ok. So, all total around 3.5 meter of average depth of the tank is in standard practice. The floor of the tank is to be provided with a slope of 6 to 16 degree or 8 to 12 degree typical for circular tank and 2 to 88 degree for rectangular tanks.

So, why to have this slope? So, that the waste the sludge that is getting that is getting collected can be collected from a certain area. If it is a circular tank on the bottom you have the hooper line. So, from there you can have you can collect the sludge or if it is like rectangular one particular one angle from one side you can collect the all the sludges ok. So, that is the standard practice. The scrappers normally attached to the rotating arm in case of circular tank and because it is much easier the scrappers will actually scrap the sludges and in the scrappers it has a certain angle it makes it a certain angle.

So, the sludge will actually go to a certain edge or it will come towards the towards inside or outside based on our design. In general it goes the design in made such a way that it will come towards the center. So, once it comes towards the center from the in circular shape say like cylindrical shape the tank in a circular tank. So, what will happen? This the sludge can be easily collected from the center central hopper line. In case of rectangular tank we have a endless chain.

So, endless chain it is like you know it is like a like a rectangular in shape. So, it goes to the up till the bottom it goes like continuously it goes like you know like it is keep on moving on this on the from the bottom to the surface of this rectangular tank and it by this way it will actually move or push the sludge towards a certain edge certain side. So, from that side you can actually collect the sludge or the sedimented organic solid. So, when we design the primary sedimentation tank the sludge hoppers which collect the sludge either at the influent end normally at the influent end of the rectangular tank or if it is a circular it is in the in the center. The scrapper velocity should be around 0.6 to 1.2 meter per minute 0.9 meter per minute is typical in a rectangular tank and with the flat speed of around 0.0 to 2.05 revolution per minute 0.3 is typical in a used in case of circular tank.

Scum removal management is there to provide ahead of the effluent wire. So, in all the PSTs so, in case there are some scum that slowly float that on the surface of it. So, that froth can be that scum can be removed ok. Surface overflow rate in general we keep around 40 meter cube per meter square per day and for design for the average flow and in even in case of peak flow also it should not increase the value 120 meter cube per meter square per day. Please remember this value 120 meter cube per meter square per day because this is a very standard this is a typical value that we can have for SOR or surface overflow rates.

The wire loading rate less than 185 meter cube per meter per day is used for designing the effluent wire length in normally in the range of 125 to 500 meter cube per meter per day as I have already discussed and the loading rate can be 300 meter cube per meter days acceptable under peak flow condition, but in general you try to make it 185 meter cube per meter per day not more than that. Wire loading rate means wire loading rate means what after the wastewater is filled after the treatment is done then what happened that it the wastewater goes it crosses the wire and then it goes to a certain collection line and from there it goes to the effluent effluent line further for the further treatment. In that wire where normally wire is normally we use it for you know it is a we can for the quantity estimation and also there from there you can collect that water and you can collect it in the fall out treatment line. The detention time as I was mentioning it should be somewhere around 60 minutes to 150 minutes or 1 hour to 2.5 hour. See in the in the right hand side the picture the first picture actually showcases you like gives you an idea about the rectangular tank how it looks like see the in the in the influent line only there is a sludge hooper on the bottom because in the influent line when the water enters it hits the baffle one in the baffle and then maximum of the solid gets deposited there itself. But with time if there are time there is enough time if you maintain the flow in such way that it will stay there for couple of at least a hour or so. What will happen slowly see this scraper it is endless it is keep on rotating ok. This endless scrappers it is scrapping all the suspended I mean like all the sedimented organic solid on the bottom and push it towards the inlet side and in the inlet side you can see there is a here what is happening to this inlets here the all the sludge is getting collected from there the sludge can be easily take it out we can easily take out the sludge and from here this is the wire the water at the water is actually of the baffle it actually like you know jumps through this wire and comes to this comes to this effluent wire main line and through this effluent wires actually you can install couple of them based on the design requirement and you can then connect directly connected to the effluent line ok. So, this is how the circular sediment primary sedimentation tank look looks like if you see these baffles the waste water influent is here influence is provided from here you can see this is the scrapper this is this like it is like two wing it keeps on moving rotating towards the I mean like I mean like over the I mean like the how to say like the surface I mean like the bottom of this circular tanks and it is scrapping the all the sludges and it makes it has a certain angle certain angular blade which blades are actually moving all the sludges towards the inside.

So, in the inside there is a in the in the center where there is a circular you can see the sludge withdrawal line is there from there we collect the sludge also. So, from here we have the inlet line it will float from like it flows like a fountain on the other side then you have this how to say this scrappers through this scrappers you can collect the sludge from either of this side from the center side center only and then the effluent wire through effluent wire the fresh I mean like they are not fresh I mean like the waste water after removing after it is the solid organic solid is getting removed that goes through the safe line to the follow up treatment. What should be the follow up treatment here in general it should be the secondary treatment units, but sometimes if there is a fluctuation in flow we also install equalization basin. So, in general after primary sedimentation tank the standard practice is to go for secondary treatment unit, but sometimes in cases case to case basis we also install equalization basin to regularize the flow. So, this equation by CAM can be used for to calculate the critical velocity which is the horizontal velocity that will that will just produce the scar on the bottom.

So, that is the maximum velocity that we can actually approach. So, this is like

$$\sqrt{\left[\frac{8\beta}{f}g(S-1)D\right]}$$

So, here beta is the constant which is 0.04 for uni granular and 0.06 for nongranular sticky material, f is the Darcy Weisbach friction factor 0.02 to 0.03, g is the gravity acceleration due to gravity and the s is the specific gravity of the particle to be removed.

In general we target like targets material target out say particle in primary sedimentation tank is having a specific gravity of 1.2 to 1.6 generally 1.25 and the diameter of the particle is denoted by d. In general suppose if you all the other equation all the other factors the constants are given and the organic solid size of 0.1 meter millimeter and the specific gravity of 1.25 meter this the critical velocity will become 0.063 meter per second. So, that is the maximum 0.063 meter per second is the critical velocity for average particle size of 0.1 millimeter with a specific gravity of 1.25 in primary sedimentation tank. So, now let us do a couple of example couple of numerical.

So, once we do this numerical the concept will be much more clearer and you can actually design the primary sedimentation tank by yourself ok. So, please go through this material again and again I will first share the I will do the discussion first and I would request you to have your calculator and pen and notebook ready. So, that you can do it along with me. So, it will be easier for you to understand the flow. So, the it is asked to design a primary sedimentation tank to treat wastewater with average flow rate of 10 million liter per day and the peak flow of 22.5 million liter per day. If you remember 10 million liter per day is the average flow and peak flow is 22.25 million liter per day that means, the peak factor is 2.25. But anyway so, I am what the main important factor here is that the peak flow is the we discussed right that what at which conditions there is a chances of peak flow and how we can actually how our design can actually being affected because of the peak flow.

So, we will see. So, in general we have to assume a surface settling rate of 40 meter cube per meter square per day as it is mentioned in the last slide also. So, you have to first take the surface settling rate of 40 meter cube per meter square per day not more than that because this is the minimum time it is minimum like settling rate that it requires for your solid to settle on the bottom. So, if you consider this value 40 meter cube per meter square per day and so, you can easily find out the surface area you know the average flow 10 million liter per day if it is like 10 million liter per day. So, million liter means 10 to the power 6. So, 10 into 10 to the power 6 liter per day liter 2 you can easily convert into meter how you can convert into meter with the 10 to the power minus 3 because 1000 liter is 1 meter 1 meter cube.

So, from there you will become 10 into 10 to the power 3 meter cube per day. So, this 10 into 10 to the power 3 meter cube per day divided by say the surface area is given is 40 meter cube per meter square per day. So, 10 into 10 to the power 3 divided by 40 it will become 250 ok 250 meter square. So, this 250 meter square is the surface area of tank that you require. So, you know that the surface area should be 250 meter square.

Now, check for the peak flow condition in case of peak flow condition you check that this area is enough or not in case of peak flow condition what is the flow 22.5 million liter per day that means, 22.5 into 10 to the power 3 meter cube per day divided by 250 it will become 90 meter cube per meter square per day. You remember the recommendation value recommended value for the recommended value is 120 meter cube per meter square per day it should not be more than that. So, as the in case of peak flow also the value is 90 which is less than 120 that means, your design is ok.

So, that means, you can go ahead with 250 square meter of area that much of area surface area is sufficient. Now, assume a width of 6 meter you do not take more than 6 meter of width because it will be difficult for you to design the endless chain ok. So, in general one when we are talking about the design is here majorly the rectangular primary simulation tank as you can understand. So, if you have a length of 6 meter. So, what will be the theoretical width of 6 meter what will be the theoretical length 250 square meter is the surface area divided by length 6 you will become it will become 41.66 which is more than 40 meter. So, when it is more than 40 meter what I have told you that let us have two sedimentation tank. Do not I mean like do not we do not have to worry about like you know in that case it will reduce the footprint and also I mean like it will actually help us to control the process parameter in a very easy way. So, total length of the each tank now first we discussed it is like 41.6 is divided by 2 plus 2 meter plus 2 meter inlet and outlet you have to give some additional excess place in 2 meter plus 2 meter here and there.

So, it is coming around 40 24.83 say like 24.85 meter. So, each PSTs primary sedimentation tank for your design has having a length of 24.83 meter and the width is 6 meter. Now, we know that the flow rate into retention time flow rate into retention time it represents the volume because suppose the flow rate is 1 meter cube per hour and your retention time in your chamber is say 2 hour. That means, what is the volume of your reactor how much time it will take for the water to fill up 1 meter cube per hour and area total time is 2 hour.

So, 2 meter cube so that means, the volume is 2 meter cube. So, that is how we calculate. So, flow rate into detention time is equal to volume plus depth into surface area that is also volume ok. So, out of these 4 parameters which are the 2 you known to us flow rate we know, detention time as of now we do not know, depth we do not know, surface area we know surface area how much we took we take 250 square meter and the flow rate is also known to us. So, flow rate by surface area you will get the depth into detention time isn't it.

So, you just interchange it flow rate into detention time equal to depth into surface area surface area goes in the left side it will become depth by detention time and which is also the surface settling rate and surface rate is how much 40 meter cube per meter square per day. So, from there if you provide say take a detention time of around 1.5 hour you can easily calculate the depth how 1.5 multiplied by 40 isn't it. So, which is like 40 meter cube per meter square per day surface settling rate.

So, 1.5 into 40 so, 1.5 hour to convert it into day 1.5 divided by 24 into 40 meter cube per meter square per day. So, it will become 2.5 meter. Now, we know the depth so, depth is we find out the depth now. So, now, once the depth is known to us we can easily find out the flow through velocity what is the flow through velocity flow through velocity is like in the depth I mean like it is like a you cut that rectangular PST say like half.

So, what will be this area. So, it is a majorly the depth into width ok. So, depth into width and there are two two number of tanks are there. So, if you have a initial flow rate initial flow rate is how much 40 MLD sorry 10 MLD 10 MLD you do the calculation by yourself 10 MLD if you convert it into 10 MLD into say 10 into 10 to the power 3 meter cube per day isn't it. MLD to meter cube per day just multiplied with 10 to the power 10 to the power 3.

So, 10 MLD is now become 10 meter cube per day. So, 10 meter cube per day. So, 10 meter cube per day divided by how much. So, if you say 10 into sorry 10 MLD into 10 to the power 3 that is what I was I meant. So, 10 MLD means 10 into 10 to the power 3 meter cube per day. So, 10 into 10^3 meter cube per day if you convert it into second what will become.

So, you have to divide it with 86,400 isn't it because 86,400 seconds are there in a day. So, 10 into 10^3 divided by 86,400 if you do that calculation it will become 0.116 meter cube per second.

Please do it with your calculator to confirm it. So, 0.116 meter cube per second is now we know that this is the average flow. So, this average flow is the flow at which water is going and this is the say like surface area there the area cut sectional area cut sectional area and the surface flow if the surface flow divided by cut sectional area you will get the velocity isn't it. So, the flow rate divided by area you will get the velocity. So, the flow rate is 0.116 meter cube per second or cubic meter per second divided by surface area surface area is how much 2.5 meter is the depth 6 meter is the y width and 2 number of tanks are there 2 into 2.5 into 6. So, a flow through velocity becomes 0.0039 meter per second if you do the calculation it will become 0.0039 meter cube meter per second. So, which is less than 1 centimeter per second so that means, our design is ok. Our target is the flow through velocity should not be more than 1 centimeter per second. If it is more than 1 centimeter per second there is a chance that the suspended solid I mean a suspended organic that organic solid will not sediment properly. So, our target is to reduce have the flow through velocity less than 1 centimeter per second. In given in case of peak flow let us do the design for the peak flow even for the peak flow which is 22.5 milliliter per day. So, 22.5 into 10 to the power 3 that much meter cube per day divided by same 2 into 625 now it becomes 750 meter per day divided by 86,400. So, it will become in second. Since second if you see it is coming 0.0087 meter per second meter per second that means, that still it is much less than the 1 meter per 1 centimeter per second of I would say like the roof the deadline that we added value that we have ok. So, in it is always better to have the horizontal velocity should be checked for non-scoring velocity which is less than 0.06 meter per second and that is what the standard practice. So, that means, 1 centimeter per second is obviously, our target, but even in case of any emergency it should not be more than 6 centimeter per second ok. So, we can provide at so, what will the total depth of the reactor I mean if the tank 2.5 meter we already found out, but now we have to place around 0.5 meter say like for free board on the top and on the bottom we have to provide 0.25 meter of depth for sludge accumulation you know. So, all total will become so, it becomes total 3.25 meter the total height. Now, wire loading rate even in general if I if you only install the wire on the one side of the how to say the width wise. So, suppose in this design where if you remember in this design where is the wire here on the width wise ok.

If you width wise you provide only wire I mean like one wire what will happen. So, width means how much is the width in this calculation 6 meter. So, you have 2 tanks so, 6 plus 6 12 meter. So, you are considering that your flow rate flow is only your effluent is only going through from here it will go through this effluent wire and you are collecting it. So, but you have a limitation of 185 meter cube per meter per day that calculation also is there isn't it.

So, that also we need to be considered about. So, now, let us first find out what will happen if we only install in width wise. So, 10 into 10 to the power 3 meter cube per day divided by 12 meter 12 meter is the width that we have. So, now, the wire loading becomes 833. So, that is not a good design. So, we are not we will not it is not enough the wire that we have provide on the effluent wire that we have provide on the one side of the width of the tank is not enough.

So, we need to provide couple of more how what is the actual length of wire that we require if we provide this 185 meter cube per meter per day of wire loading rate. So, we can easily find out by total average flow divided by 185 meter cube per meter square per day per meter per day sorry. So, from there you can easily find out the length of wire that is required as 54.05 meter. So, what you can do you can have you already know you can have the 27.1 meter of wire length for each tank and this can be divided into you know 2. So, because we have 2 tank already.

So, one tank we can have 27.1 another tank also have we have 27.1 say. So, in 27.1 how we can divide it into your tank you place it on the 2 effluent channel across the width at the at the outlet end. So, outlet end if you are providing 2 outlet wire. So, each one will be having how much what is the length here what is the total width here 6. So, 6 into 6 there 12 12 into 12 if you like all total you will get 24 plus you have a side wire of 1.55 meter on each side ok. So, in general it is always better to have like you know. So, in that case you this way you can actually successfully actually install amount of wire that you require that you it is required and in your design is complete. So, the same way we can do this same problem also. So, this is almost the same procedure you can see here also the 1.12 million liter per day is the average flow and peak factor is peak factor is 2.

If the peak factor is 2 that means, what is the peak flow 24 MLT isn't it. So, from there you can see here also you can do the this problem by yourself. So, that you will get an idea because it is the same as earlier, but once you do it by yourself and you check with the solution it will be giving you a much easier interpretation ok. So, I am not going into details again I am not going to discuss it all. So, I am leaving it to you so, that you go through it and actually do the calculation by yourself.

So, to it will be it will give you a one kind of a exercise for actual design. So, in conclusion we got to know about the necessity of primary sedimentation tank and its crucial role that it plays in wastewater treatment by removing the organic matter and suspended organic matter from the solid. And this now this is normally placed after the grit removal tank grit I mean like the grit chamber and normally it has a we know certain calculations and certain understanding assumptions also we understood and what is the basis of it also we understand and we now will continue with further treatment unit design. So, these are the references and here only I will stop with the fourth module. So, and we will continue with the fifth module in a coming lecture. Thank you so much.