Water Supply Engineering
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Lecture-41
Practice Problems

Hi friends and welcome to this last class for this week 7. So, we have been discussing about disinfection sludge management and advanced water treatment systems. So, we will take some practice problems, just few practice problems, we are on chlorination sludge calculation or one problem on RO operation. That is what we are going to see through the worked examples.

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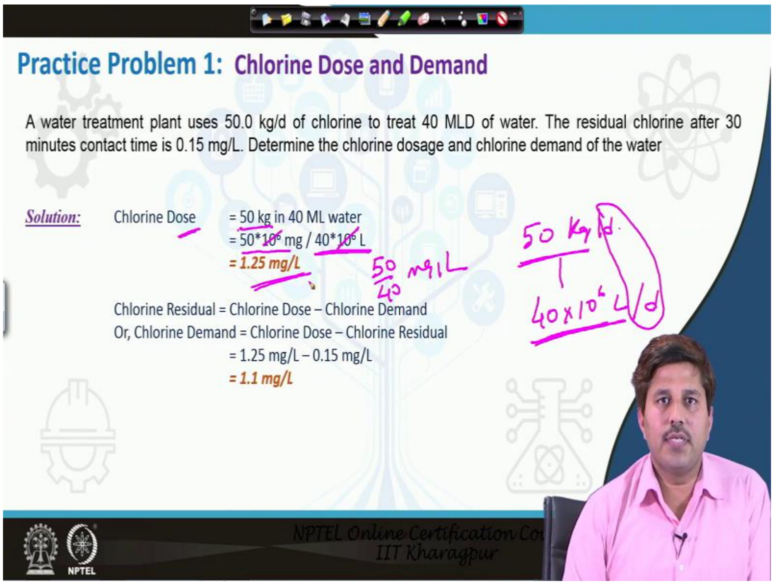

So the problems are very simple. The first problem that we have is a water treatment plant uses 50 kg per day of chlorine to treat 40 mld of water. The residual chlorine after 30 minutes contact time is 0.15 milligram per liter. We need to determine the chlorine doses and chlorine demand of the water. So, dose will be basically how much we are adding okay so we are adding 50 kg per day for a plant of what 40 mld.

So that means 40 x 10 to the power 6 liters per day is the flow. So, in one day if you see it on a daily scale, so in 1 day for 40 x 10 to the power 6 liters of water, we are adding 50 kg of chlorine. So, how much we are adding? That will be the dose that we are actually dosing so we are dosing 50 kg that means 50 x 10 to the power 6 milligram into 40 x 10 to the power 6 liters. So, this gets cancelled and we all we have is 50 divided by 40 milligram per liter which is equal to 1.25 milligram per liter.

Then that is the chlorine dose and we need to determine the chlorine demand also so chlorine demand like we know the relation between chlorine dose chlorine demand and chlorine residual. So, chlorine residual is typically chlorine dose minus chlorine demand.

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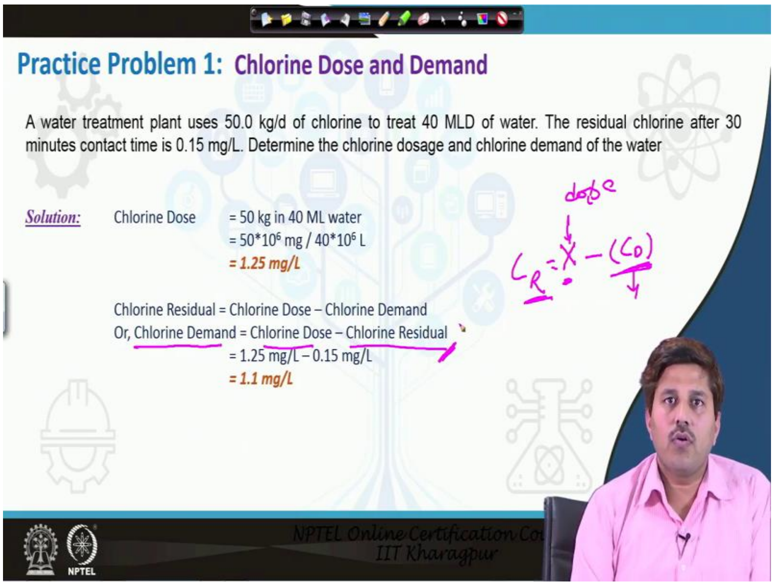

So, whatever chlorine we are adding okay let us say if we are adding X amount of chlorine okay so whatever chlorine we are adding out of that sum is getting consumed in the reactions with the reduced compounds so that is your chlorine demand okay. So, chlorine demand is getting consumed and whatever is left will be appeared as chlorine residual okay. So, if X is the dose if X is the dose and CD is the chlorine demand.

So chlorine dose - chlorine demand gives us the chlorine residual or we can change this equation as chlorine demand is going to be chlorine dose minus chlorine residual. So, whatever we have added of that whatever is available in the water that means rest has been consumed. So that would be the demand of the chlorine so in this case, we are having residual chlorine left as 1.15 milligram per liter.

We have added 1.25 milligram per liter of which 0.15 milligram per liter is still available in the water so that means the difference 1.1 milligram per liter is the chlorine dose. So, that way we can estimate the chlorine dose and chlorine demand of the water, alright.

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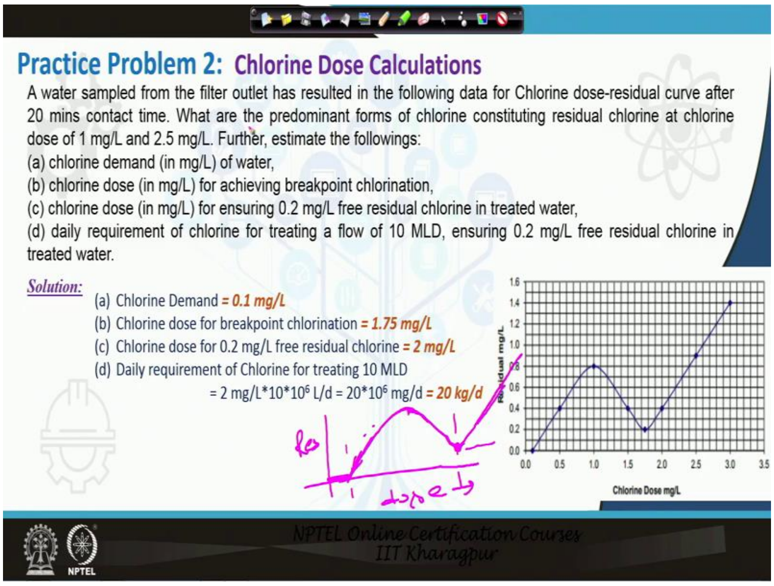

Let us move to the next question. So, next question is we have a water sample from filter outlet that has resulted the following data for chlorine dose residual curve after 20 minutes contact time. So, we have been given chlorine dose versus residual chlorine curve okay. What are the predominant forms of the chlorine constituents residual at chlorine dose of 1 milligram per liter and 2.5 milligram per liter.

And further we need to estimate the following we need to estimate the chlorine demand of water, we need to estimate the chlorine dose for achieving breakpoint chlorination, then, chlorine dose for ensuring 0.2 milligram per liter of free chlorine residual present in the treated water and daily requirement of chlorine for treating a flow of 10 mld ensuring 0.2 milligram per liter free residual chlorine in the treated water.

So our answers are going to be like dependent on the curve that we have the result, we have. If you recall the breakpoint chlorination curve so what happens when we add chlorine so if say this is our dose and this is the demand sorry this is the this is the dose and on here we have the residual chlorine okay now, when we add chlorine initially there is no free and no residual chlorine appears because whatever chlorine we are adding gets consumed into the reaction with the reduce reducing compounds okay.

That could be like anything reduced iron or manganese, reduced state organic compounds then if we have H2S okay. So, it will react with those and no chlorine will appear then it starts reacting to ammonia if there is and it forms the mono chloramine which is a form of combined chlorine residual. And then after this reaction completes then mono chloramine starts breaking to the dye chloramine and tri chloramine so residual chlorine dips.

And from one point onwards when all this reaction is essentially goes to completion, we get break point and beyond this point onwards, whatever we add appears as free chlorine residual. So this is the nature of curve that we discussed during the lecture also. So, the first question is, what are the predominant forms of the chlorine constituents residual, chlorine at chlorine doses one milligram per liter and 2.5 milligram per liter?

So, we have one milligram per liter this one and 2.5 milligram per liter this one. So, what are the residual what are the predominant form of chlorine here? And what is the predominant form of chlorine residual here this is what we need to determine or just tell actually. So, if you recall this curve again so, this is the point in which all these reducing agents are getting consumed and then this the mono chloramine buildup starts.

And at this place, we have mostly mono chloramines present as the present as the kind of chlorine residual okay. So, at chlorine dose one milligram per liter, what the dominant those we have is the mono chloramines all right. Now, this is the break point so up from break point onward this is the combined chlorine that we have combined chlorine residual and remaining appears as a free chlorine residual.

So, if you see at this point we have almost this much of combined chlorine and remaining we have as a free chlorine residual okay so, this is becoming free chlorine residual what will be predominant form here, for free chlorine residuals? So, at those like at those this is at those one milligram per liter, and when we are talking about the next which means add those two 0.5 milligram per liter what we have is it is going to be the combined chlorine free chlorine residual that are going to be preeminent predominant?

So that means we will having HOCL and OCL and means hypochlorous acid and hypochlorite ions will be the predominant form here okay. So, that becomes the answer for the first part that at one milligram per liter mono chloramines will be the predominant forms and at 2.5 milligram per liter those it is the HOCL and OCL depending on the PH. We have not been given the PH here.

If let us say we say that PH is if we say pH is 8, that means HOCL is going to be predominate. Then if we see pH is less that means or it is acidic medium that means OCL will be dominating in that case.

Or actually lesser pH, HOCL will dominate and at higher pH, OCLwill dominate so that like we can see that way. Now let us get back to the let's get back to the the questions asked in Part A to D okay. So, in Part A it says the chlorine demand in milligram per liter of water okay. Again if you recall the chlorine curve, so the first part till which there is no free chlorine appears, that is the chlorine demand.

So in this case this part is the chlorine demand and those here is 0.1 milligram per liter so that means it is 0.1 milligram per liter which is the chlorine demand. The next part is chlorine those in milligram per liter for achieving break point chlorination, now break point chlorination is here okay so break point chlorination corresponding dose is basically since it is in the mid of these, a break point chlorination corresponding dose is 1.75 milligram per liter.

So that becomes our break point chlorination dose then chlorine dose for 0.2 milligram per liter free chlorine residual okay. Now, this is the chlorine residual scale but up till this point we are what we are having is combined chlorine residual. Free chlorine residual is starting appearing from this point. So, here also these like the values below this. This is 0.2 actually So 0.2 is already there in the form of combined chlorine residual. And if we want to ensure 0.2 milligram free chlorine residual, so that means we have to move 0.2 further from this point.

So, at 0.4 here what is the dose that is B that is going to be our like what is the dose that is going to be our requirement for having 0.2 milligram per liter free chlorine residual and that is going to be 2 milligram per liter. The last part daily requirement of chlorine for treating a flow of 10 mld ensuring 0.2 milligram per liter free chlorine residual in treated water. So, daily requirement of chlorine for treating 10 mld will be like we need to put 2 milligram per liter chlorine.

So 2 milligram per liter and that is to be given in 10 x 10 to the power 6 liters per day water. So, we multiply it with the volume of water so liter gets cancelled we have 20 x10 to the power 6 milligram per day or 20 kg per day is going to be the requirement okay so this will be the requirement.

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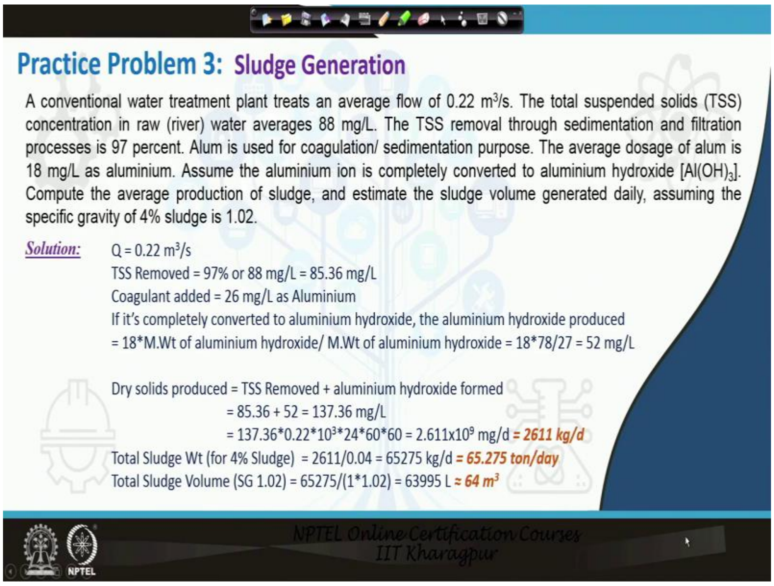

Now, let us move to the next problem which is we have a conventional water treatment plant that treats an average flow of 1 to 2 meter cube per second. The TSS concentration in the raw water is 88 milligram per liter and TSS removal through sedimentation and filtration process is 97 percent. So, 97 percent TSS is removed. Alum is used for coagulation sedimentation purpose the average dose of alum is 18 milligram per liter as aluminium.

Now we have to assume the aluminum ion is completely converted to aluminum hydroxide and compute the average production of the sludge and estimate the sludge volume generated daily assuming a specific gravity of 4% sludge is 1.02. So, discharge is given to us flow flow is given to us as 0.22 meter cube per second okay and TSS removed. So, in flow TSS is 88 milligram per liter and 97% is removal. So, 97% of 88 milligram that means 85.36 milligram per liter TSS is removed.

The covalent that we are adding is 18 milligram per liter okay and so, 18 milligram per liter aluminium is basically being added as aluminium now, this is completely converting to aluminium hydroxide so correspondingly if it is completely converting to aluminium hydroxide, the aluminium hydroxide that will be produced will be corresponding to the 18 milligram per liter which is being added.

So, 18 times molecular weight of aluminium hydroxide divided by molecular weight of aluminium in fact, okay. So, we will have 18 into molecular weight of aluminium is 27 and molecular weight of aluminium hydroxide will be 27 + 16 + 1 - 17 into 3 okay. So, 17 into 3 becomes 51 and 27 that becomes 78 so 18 into 78 divided by 27 this gives us 52 milligram per liter game.

Now dry solids produced is going to be the TSS that is removed and the aluminium hydroxide that is being formed okay because we have not been given any other information. So, let us assume these two are the constituents of dry solids which are being produced. So, in 1 liter 52 milligram aluminium hydroxide is formed and from one liter 85.36 milligram of the TSS is removed. So, totally in 1 liter 137.36 milligrams of solids are actually will be produced okay as a sludge.

So we are getting 137.36 milligram per liter weight of solids which is actually reduced, removed, okay from one liter water. Now this is treating 0.22 meter cube so the amount, total amount will be produced in a day. So, this is in milligram per liter and then this is the meter cube per second. We multiply it with the discharge meter cube per second we convert it with multiplied with the 10 to the power 3.

So we get liter per second and then multiply it with 24 into 16 to 60 in order to get per day. The amount that is coming is 2.611 x 10 to the power 9 milligram per day or 2.2611 kg per day. So, that is the amount of die dry solids which is going to be produced. Now our total weight of like sludge if you see, if you consider its 4 percents sludge, okay so that means if total weight is X so the solids are 4 percent that means 0.04x is going to be equal to the amount which is given to you 2611 okay so X is going to be equal to 2611 divided by 0.04.

So, the total sludge weight will be 2 6 1 1 divided by 0.04 this is coming 65,275 kg per day or 65.275 tons per day so this is the amount. This is the weight of total such that is going to be produced and this has a specific gravity of 1.02 that means density 1 into 1.02 in kg per liter liter per kg. So, we actually like divide this volume in order to get the volume in liter all right. So, this is in kg per day and this is say kg per liter, so what we get is in 3 63995 liters or that is equal to approximately 64 meter cube.

So, the total volume that will be generating approximately is going to be 64 meter cube of course per day okay. So, this is the daily volume okay. This is the daily sludge volume 64 meter cube per day all right.

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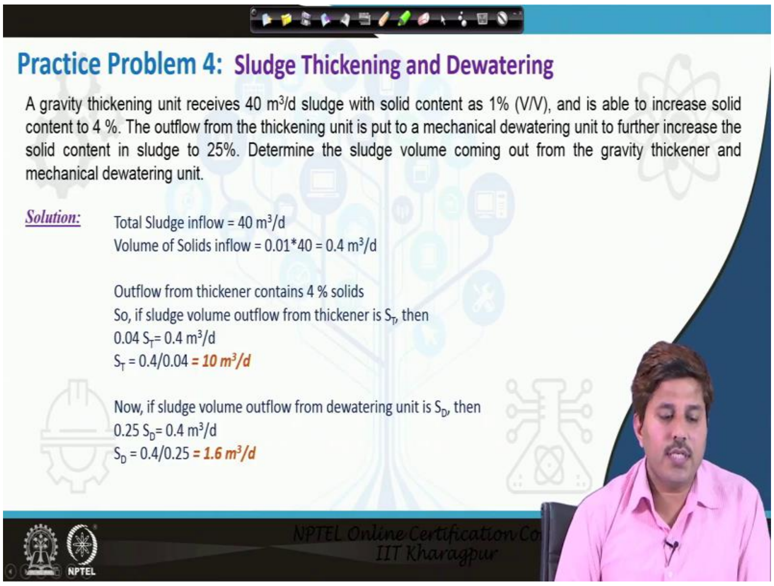

Now, let us move to the next question which is on this sludge thickening and dewatering. So, we have a gravity thickening unit that receives 40 meter cube per day sludge with solid content as one percent and is able to increase solid content to 4 percent, the thickening unit the outflow from thickening units put to a mechanical dewatering unit to further increase the solid content in sludge to 25 percent we need to determine the sludge volume coming out from the gravity thickener and mechanical dewatering.

So, this is practically like if you see the total sludge inflow is 40 meter cube per day okay and volume of solids that will be coming into the inflow is because it is one percent volume by volume so 0.01 into 40 that's 0.4 meter cube per day is the volume of solids inflow okay. So, the volume of solids that is being coming in with this sludge so, this volume of sludge will remain same, because what thickening and dewatering units does, they remove the water.

So we are having sludge mixed with water let us say this is the volume what thickening and dewatering units will do? They will basically the solid content will still remain the same but water will be expelled out so that the total volume is reduced alright so odd flow from thickener contains four percent solids if say sludge volume outflow from thickness ST that means four percent of S T or 0.04 ST is still going to be equal to the volume that we have got, volume of the solids that we have got.

So it is still 0.4 meter cube per day okay so 0.04 ST. So, the sludge volume coming out of the thickened is ST so 0.4 divided by 0.04. That means ten meter cube per day so the volume that will actually be coming out of this large thickness is going to be ten meter cube per day.

Remember we started with 40 meter cube per day volume, as an inflow and from thickness what we have got is 10 meter cube per day. The solid content was increased from 1 percent to 4 percent. So, simply also like you can see that since it is getting increased 1 percent to 4 percent means for time increase, so total volume will be reduced by 4 times of what they will be becoming 10.

Again if the sludge volume outflow from dewatering unit is SD so now the new sludge like solid content in the sludge after the dewatering unit is 25 percent. So, 0.25 SD is again going to be equal to the because solid volume is still there. That point 4 percent at that point 4 meter cube per day is still there so 0.25 SD is 0.4 meter cube per day. And that means the sludge volume coming off the dewatering in unit is 1.6 meter cube per day. So, that is the basically volume output from the dewatering unit.

So this 10 meter cube per day will further reduce to 1.6 meter cube per day okay so you can see that it is basically from 4 it is going to 25. So, corresponding volume decrease from 10 it is coming to 1.6 meter cube per day.

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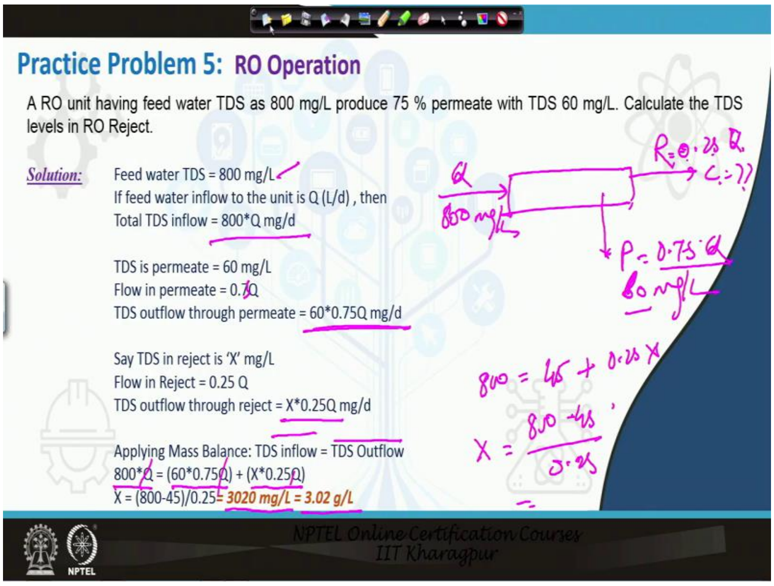

Now this is the last problem that we have in this particular class RO unit having feed water TDS as 800 milligram per liter produces 75% permit with TDS 60 milligram per liter calculate the TDS level in the RO reject water okay. So, we have feed water TDS 800 milligram per liter. Let us say like as discussed we have a RO unit so, this is say discharge coming in this is the permit which is coming out of the RO okay which is given to us as 0.75 percent means 0.75 times of Q because 75 percent is coming in a permit.

And say this is our reject which is actually 0.25 times of Q all right. The concentration here is 800 milligram per liter the concentration here is 60 milligram per liter so through a simple mass balance we can estimate the concentration here. What is going to be the concentration here? If you do a mass balance so this is like, this is Q and this is 800 so total inflow is 800 times Q this is 60 and this is 0.75 Q okay.

So total outflow through this way is 16 to 0.75 Q okay and say the concentration here is C or X whatever you assume if you assume C and this is 0.25 Q. So, this is going to be X into 0.25 qrc into 0.25 Q so if you do a mass balance, the TDS inflow is going to be equal to the TDS outflow. So, TDS inflow is 800 into Q TDS outflow through permit line is 16 to 0.75 Q and through reject line is X into 0.25 Q. So, from here we can get X because Q will get all Q will get cancelled.

So what we have is 800 is equal to 60 into 0.75 which is equal to 45 so 45 plus 0.25 X. So, from here we get X is equal to 800 minus 45 divided by 0.25 and that will becoming equal to 3020 milligram per liter or 3.20 gram per liter. So, this is this will be the concentration of TDS in the reject. So, these were some of the examples okay of course there could be like similar approaches can be adopted for solving more problems.

So anyway thank you for joining. We will conclude this lecture here and that way we will conclude the discussion in this week 7 here. In week 8 will start discussing about the distribution system. So, thank you for your company thank you for joining I hope you are enjoying the discussions and content of the course. See you next week.