Water Quality Management Practices

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Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Dhar bhowmick. I am from the Department of Agricultural and Food Engineering of Indian Institute of Technology Kharagpur as continuation to our discussion about the Activated Sludge Processes. So, today we will be discussing about the equalization estimation of values of other operating parameters in Activated Sludge Process and this will be our main concept that we will be covering. We already have a basic understanding about all these parameters. Let us in this particular lecture video, I will be focusing on more in depth about each and individual component.

So, this information will literally engraved into your brain so that it will be easier for us to you know do the calculations or the numerical in later stage, do the actual design in the later stage. So, first one is the Hydrogen Retention Time or HRT, then is Mean Cell Residence Time or MCRT, food to microorganism ratio, estimating the quantity of excess sludge to be wasted, sludge recycling, sludge quality and the estimating the oxygen requirement. To start with the hydraulic retention time it is majorly it is very easy, we already had a couple of time we had a discussions about it, but let us talk about it again in to understand more in depth. Hydraulic retention time how we going to calculate? You have a volume you have say 100 litre of volume of tank.

You have a 100 litre volume of tank and suppose you are pouring it that tank with 50 litre per hour rate. So, how much time it will take to fill that tank? 2 hour because your capacity is 50 litre per hour and the total volume is 100. So, it is 100 by 50 ok. So, 100 by 50 means volume by flow rate. So, volume by flow rate will give us the hydraulic retention time ok.

In the hydraulic retention times typically we also call it detention time also sometimes hydraulic detention time also. So, it normally in case of activated sludge process it can be 3, 4, 2, 3, 4, 6, 5 hours in general. The volume of the aeration tank it determine the considering the return sludge ranging from 25 to 75 percent of the waste water volume, but it can go as high as 100 percentage even more than that as well ok, this return sludge. And based on this return sludge value and all you remember in the last class also we discussed about we theoretically predict the estimate the exact the value of the volume of tank aeration tank that it requires we can easily use that equation to calculate those the

aeration tank volume. And another important thing is the F by M ratio to maintain a desired F by M ratio you may have to little bit play with the volume in the very beginning.

So, considering the desired F by M ratio ok. Then there comes the mean cell residence time. Mean cell residence time in general it represents the mean duration in days that sludge is retained in the system. That is why it is also known as the solid retention time or SRT. Please remember that MCRT and SRT are the same ok.

MCRT normally is calculated by dividing the total mass of mixed liquor volatile suspended solid in the reactor by the mass of microorganisms wasted from the system each day. You understand? Mean cell residence time that the sludge the time for which your sludge is staying in the system. How you going to calculate it? You can easily calculate it based on the total amount of say like biomass or the biomass present in your aeration tank divided by the amount of waste amount of sludge you are wasting each day. So, if you divided so, what will happen? If you are having total 100 kg of sludge present in your say biomass is like almost 100 kg inside your reactor. And you are each day you are getting rid of 10 gram of say from 100 gram you are getting rid of 10 gram each day.

So, once you know that you are losing 10 gram of VSS each day and you know the total VSS is like you know 100 gram you know that your sludge retention time will be 10 days 100 divided by 10. So, this 10 how you going to waste the sludge in 2 ways. First through the actual sludge waste the waste QW, QW is waste volume, waste flow rate multiplied by the return sludge concentration which is very thick from the secondary sedimentation tank and another part very tiny teeny that is the effluent through effluent also some amount of VSS is getting wasted ok. That how can you calculate is Q0 minus QW multiplied by X0, X0 is the return the effluent sludge concentration effluent biomass concentration. So, from there you can easily calculate the VSS wasted per day and total mass is already known to us volume into multiplied by the mixed liquor volatile suspended solids concentration of your reactor.

So, Vx divided by QR into XR plus in bracket Q0 minus QW multiplied by XE. So, from this equation you can easily calculate the mean cell residence time of your reactor of your adhesion tank. As the value XE sometimes is negligible this equation becomes much more easier Vx divided by QW into XR because theoretically speaking the in case of effluent there should not be any cell biomass ok. So, it should be if your secondary sedimentation tank is working perfectly your effluent should not be having any biomass in it perfect. So, then there comes the mean cell residence time there what are the factors at which actually mean cell residence time is actually affected on affected by.

Say first is the recycling like you know SRT in general higher than HRT due to the recycling a fraction of sludge from the secondary sedimentation tank back to the aeration tank it is happening like every day. So, because of that HRT is quite high specially in some cases it can be like very high. So, hydrodotation time say like 2 hour, 3 hour, 5 hour HRT will be say like 10 days, 15 days, 100 days, 30 days like that ok. So, it cannot be 100 days it I mean like it is quite high I mean like if it is 100 days like in it is normally in case of anaerobic digestion systems it goes that high aerobic treatment system it does not go that high. Impact on BOD removal by maintaining a higher mean cell residence time the significant organic matter removal can be achieved in about 3 to 5 hours of waste water retention time in the aeration tank ok.

Manipulating the BOD removal efficiency you can manipulate the MCRT which allows the adjusting of the biological oxygen removal efficiency of your activated sludge process. What does that mean? Because if you manipulate the MCRT say instead of sludge retention time of 10 day you extend it for say 15 days that means, you are letting the microorganism stay in your system for more amount of time. So, the more amount of time it will stay the more amount of BOD it will remove from the system. Or even if it is like you know if you reduce the MCRT drastically that means, that you are letting the sludge get out of your system very fast ok. That may also have an impact on the value of BOD removed from your system.

So, value of BOD removed from your system means organic matter isn't it. So, organic matter is simply represented by the BOD value. The typical values of this conventional activated sludge processes have this MCRT ranging from 5 to 15 days. While in case of extended aeration activated sludge processes typically it has 20 to 30 days of value as I was mentioning, but not more than that that is like kind of a upper age. Food to microorganism ratio, in food to microorganism ratio we ask we it is a very crucial parameter in the design of an operation of activated sludge process.

In general maintaining a balance between the substrate consumption and biomass generation and the sludge waste is essential for achieving the system equilibrium and to make it perform the optimal way. And F by M ratio is also playing a crucial role in the oxidation of organic matter present in the wastewater. And the classification based on the F by M ratio like you know extended aeration 0.05 to 0.15 kg of BOD per kg of VSS per day conventional activated sludge process 0.

02 to 0.4 kg of BOD 5 per kg of VSS per day. In case of completely mixed it is 0.2 to 0.6 kg of BOD 5 plus per kg of VSS per day. In case of high rate activated sludge process it is 0.

4 to 1.5 BOD 5 per kg of VSS per day. So, this classifications we already discussed also in the earlier lecture material where we have you know remember that we have this

particular type of table. In this table we have different type of activated sludge processes and those different type of activated sludge processes demonstrate its characteristic you know phenomena like with not only in terms of F by M ratio, but also we discussed for different type of volume different type of HRT different type of the BOD the BOD removal efficiency that it may actually represents. So, anyway so, in general there are based on the different value of F by M ratio that it requires there are different type of activated sludge process and it named from extended aeration conventional activated sludge process completely mixed and the high rate activated sludge process. In case of how we can calculate the F by M ratio so, it is very easier for us to calculate the F by M ratio to start with the F means the food.

The food as you remember we discussed about it the food means like the influent flow rate. So, once we know the influent flow rate multiplied by the BOD of the wastewater so, we can easily calculate the food because BOD is nothing, but the substrate is the food that we are talking about. So, once we know the food so, that food can be easily calculated. So, this food means is the substrate total substrate. So, BOD in milligram per liter or say like gram per meter cube multiplied by the meter cube per day of effluent flow rate you will get the total amount of food available to your system for your system.

Then you divide it with the microorganisms when you divide it with the microorganisms that means, the reactor volume in meter cube and multiplied by the reactor biomass like the MLVSS or the VSS of your system that will give you an idea about the total amount of microorganisms present in your system. So, the moment you have an idea about the microorganisms present in your system and the amount of food you are delivering over time. So, this ratio is called the food to microorganism ratio. It is very important for us to you know maintain a proper F by M ratio for efficient substrate utilization and the waste management in activated sludge process. So, majorly if you see this equation S0 into Q0 divided by V into X that is what we normally follow.

So, where this Q0 is represented by this influent flow rate when meter cube per hour and X is represented by this influent biomass concentration in kg per meter cube. V is the volume of aeration tank of your activated sludge process and S0 is the influent soluble BOD concentration in kg per meter cube and the theta is the hydraulic retention time in hour ok. So, with this equation you see this because Q0 by V, V by Q0 is nothing but theta. So, that also can be replaced in the F by M ratio equation ok. Understanding the quality like quantity of excess sludge to be removed or to be wasted is very important because if it cannot estimate that particular value you cannot be assured about that what is the total amount of sludge that needs to be wasted on a particular day ok.

So, this excess sludge which remain remaining in their secondary clarifier after recycling a necessary fraction must be wasted every day to maintain a stable MLBSS concentration in the aeration tank. It this what are the factors that it depends on first of

all the increase in the higher increasing with the higher F by M ratio. The more the F by M ratio the more the sludge will generate why? More F by M ratio means what? More food is available if more food is available obviously, it will be converted into the cellular biomass. So, the more the cellular biomass that means, more amount of sludge you know. So, this excess sludge you have to eliminate from the system in order to have an optimal working condition in your in your treatment unit.

So, that is why this the more higher the F by M ratio the higher the excess sludge presence in the system and it also changes with the temperature whether it be higher or you lessen the temperature lower the temperature what will happen? It will decrease the amount of sludge why because the microorganism will start it reacting awkwardly like they will feel some resistance because of the temperature they would not grow much in higher temperature or say like lower temperature and because of that they will start they will succumb to death and because of that less amount of active sludge you will start getting in the system over time. So, temperature and the F by M ratio is very important for you know this the volume of sludge waste you for a particular and at any particular point of time in your activated sludge process. How we can estimate this quantity of the sludge that is generated per day Px is equal to y OBS into Q0 into S0 minus S multiplied by 10 to the power 3 y where this y OBS is equal to y divided by 1 plus Kd into theta c. So, whereas, this Px is the net mass of activated sludge in kg per day y OBS is the actual observed sludge yield your S0 Q0 is the influent flow it is a meter cube per day S0 is the influent substrate concentration in kg per meter cube S is the effluent substrate concentration in kg per meter cube y is equal to the sludge yield coefficient in gram of VSS produced per gram of BOD removed and Kd is the endogenous decay coefficient in day inverse. So, if you talk about the waste from the sludge recycling line versus the aeration basin conventional preference for the waste from the sludge normally return line like sludge return line due to the lower volume and also the wasting from the aeration basin it enhances the plant control and aids in subsequent sludge thickening in general in case of in case of sludge recycle line and all.

The net mass production of VSS or the Ps in terms of Px can be also estimated by the difference between the gross production of volatile suspended solid and the biological destruction of the cell due to the endogenous respiration in the system and it can be represented by Px is equal to gross production of x new minus destruction of xB. So, what is this x new gross production of x new is nothing, but the gross yield. So, y into Q0 into S0 minus S, destruction of xB is what? It can be represented by Kd into xy into V. So, where this y is what? Y is the sludge yield coefficient in gram of VSS produced per gram of BOD removed normally varies from 0.

4 to 0.7, Q0 is the influent flow, S is the influent substrate concentration in S0 and S is the effluent substrate concentration, Kd is the endogenous decay coefficient in day inverse and it normally has a range of value between the 0.06 to 0.1 and the xy here the

concentration of the microorganism in kg or the biomass concentration in kg per meter cube or gram per liter multiplied by the V. So, where this V is the volume of the reactor. What is the main purpose of sludge recycling in general? It is essential for achieving the desired degree of treatment by maintaining a high population of active aerobic microorganism in the addition tank.

That is one of the best one of the most prominent reason for providing the sludge recycling thingy. Return activated sludge fraction of the settled activated sludge is returned to the aeration tank for maintaining the MLVSS concentration and it ensures the sufficient concentration of microorganisms are there which are capable of degrading the organic matter coming present in the incoming wastewater. So, you have to maintain that amount of active sludge or activated sludge or activated microorganism inside your aeration tank so that they can they will keep on consuming the same amount of or at least a little bit better than the than that optimal value of organic matter present in the wastewater. So, that there is a less chances of having any reduction in the efficiency over time ok. Secondary clarifier role the condition of the secondary clarifier along with the return activated sludge flow rate determination determine the concentration of the volatile suspended solid in the RAS.

What is the RAS flow rate? In depends on the concentration of subtle sludge in the secondary clarifier and what are the factors which influence the RAS flow rate? First the sludge characteristics because it in including the sludge settleability by the sludge volume index you know that how we calculate that thickening of the secondary clarifier and also the then the good settleability results in better suspended solid concentration in the settle sludge and all. So, that is why it is better to do the sludge recycle for good settleability of the sludge. In general the if you see the return sludge ratio can be determined from the mass balance of solid in the aeration tank the accumulation is equal to inflow minus outflow plus production minus consumption and the it is a it is a steady state condition. So, mass accumulation is obviously, should be 0. So, it can be balanced like with the inflow plus production is equal to outflow plus consumption ok.

So, since the assumption since based on the assumption the microcosm concentration in the influent is negligible. So, it becomes the equation becomes q R into x R equal to q into x R into x. So, from there q R by q equal to x by x R minus x or this is called the R or the return sludge ratio x divided by x R minus x please remember this it is very easy. So, if you know the value of x if you know the value of biomass concentration inside the reactor inside the aeration tank divided by the amount of biomass that the like you know the amount of the VSS which is there in the return activated sludge and if you know the actual biomass inside the aeration tank you can easily calculate the return sludge ratio which can be represented by q R by q. Sludge quality sludge quality parameters majorly obviously, it impact the sludge the activated sludge process.

So, first of all the MCRT if it is a low MCRT it indicates a dispersion tendency of bacteria rather than the flocculant growth. If it is a high MCRT that means, it implies the floc predominantly consisting predominantly consisting of highly mineralized residue with limited flocculation capacity that means, flocculation capacity is less. So, that is why it needs the higher MCRT ok. So, in case of low MCRT it is somehow good because you know you have less time you it takes for you to do the operation plus your the system yours like you know your you do not have any filamentous bacteria present which will restrict the flocculation process or the sedimentation process to occur. ASP type influence the type of activated sludge process affects the characteristics of the generated sludge if it is a extended aeration time the characteristic will be completely different completely different the activators in case of extended aeration type extended aeration activate sludge process.

So, there the sludge characteristics are much better than the conventional ones. Environmental conditions the dissolved oxygen level pH food to micronisome ratio sulphide concentration and nutrient deficiency it definitely influences the sludge quality. Also the impact on treatment process like sludge quality it serves as an indirect indicator of the treatment process and effectiveness. So, which type of process treatment process that you have taken it is a normal aerobic process with the MBBR process with the MBR process with the activate I mean like I mean sorry even in activated sludge process also you can have a different varieties of activated sludge process. So, based on the process criteria also this sludge quality will differ.

Role of oxygen in case of normally oxygen serves as serve as an electron acceptor in the energy metabolism of aerobic heterotropic microorganisms, but it require the oxidation of influent organic matter and to support the endogenous respiration of microorganisms. Even for their endogenous respiration for consuming their own protoplasm the bacteria need some amount of oxygen. DO concentration the aeration equipment should maintain a DO concentration of about 2 milligram per liter in the aeration tank and adequate mixing of solid and liquid phase is very crucial here. Oxygen consumption in the aerobic treatment systems the oxygen is consumed for oxidation of carbonaceous matter and the nitrification process and carbonaceous oxygen demand it involves oxidation of influent organic matter and the endogenous respiration of the microorganisms. Representation of ultimate BOD, ultimate BOD represents the BOD 5 multiplied by a conversion factor where this F value is the ratio of BOD 5 to BOD ultimate.

This BOD ultimate also is very important for you to understand and there are like you know we there are we can also try to understand the oxygen requirement in your activated sludge process. So, if you want to know the oxygen requirement in case of effect of low DO in the extended aeration if there is a low DO concentration low oxygen

concentration it does not limit the kinetic of the processes in the external aeration system this minimum duration is required to prevent the washout of nitrifying bacteria. Then there is oxygen requirement estimation you can easily estimate the oxygen requirement using the equation Q into S 0 minus S 10 into 10 to the power minus 3 divided by F minus 1.42 into Q w into X R. This the second part is to cater the endogenous decay part and the first part is actually the amount of oxygen that it requires for converting those substrate into its final product.

This is the total oxygen requirement in case of if you only consider the organic matter is converted into some byproducts and here we are not talking about the nitrogenous product here. The moment we will talk about the nitrogenous product we have to introduce another factor here we will discuss about it, but in general in this equation the Q 0 represents by it is it showcase the effluent flow rate in meter cube per day S 0 is the influent substrate concentration S is the effluent substrate concentration Q w is the flow rate of waste sludge and X R is the biomass concentration in the sludge wasted. Now if we consider the nitrification try to understand that in nitrification also in that case also oxygen it is a oxygen demanding process in because it is a oxygen demanding process which oxidizes the ammonia and for that it requires some amount of oxygen which it actually consumes from the system. When it consumes from some amount of oxygen from the system it will also with that also we need to take care of that much of oxygen also we need to supply in the system. So, the aeration system will have additional load you understand.

So, this additional load this total oxygen requirement when the nitrogenation process is also considered is can be represented by this equation where additionally plus 4.57 into Q 0 into in bracket N 0 minus N multiplied 10 to the power minus 3 this equation is also this formula is also I mean like this part element is also added in the system. So, in general with this I will be concluding the today's lecture majorly the conclusion part if you say in general what we discussed today discuss in this particular lecture video are different type of nomenclature of very important parameters and the functionalities involved in the wastewater treatment system and the activated sludge process. And we it is very important for us to add those information add this have this information in your brain literally engraved in your brain. So, that it will be useful for us when we are going to design different type of activated sludge process in coming lecture and all ok.

So, these are the references that you can follow. Thank you so much see you on the next video.