Water and Waste Water Treatment
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Lecture-20
Oxygen Transfer: Types and Basic Principals

Hello everyone welcome to the latest lecture session. We have been discussing aspects relevant to calculating not calculating if I may say so maybe deriving the relevant variables. For example we would derive the concentration of the microbes X the concentration of substrate or the food waste or waste in the relevant effluent**.** We calculated or we derived how to calculate the solid retention time and so forth.

let us try to bring this together and then look at designing a relevant activated sludge process while also looking at the variables that we need to maintain let us get this started.

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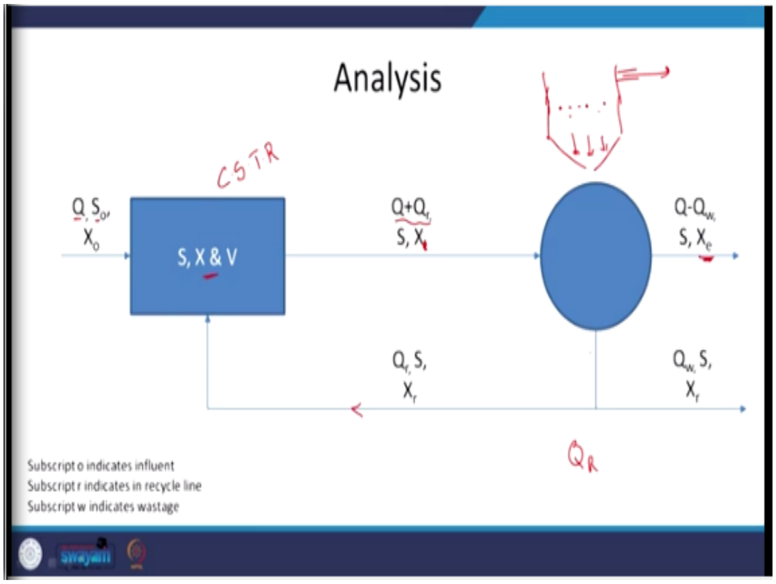

Analysis

Subscript o indicates influent
Subscript r indicates in recycle line
Subscript w indicates wastage

typical aspects quick recap waste coming in at a flow rate of Q this is the waste and then we have the recycle flow coming in here that is why here we have Q + Qr . I should use X here instead of X I because whatever is in this tank because we are assuming that the tank is a CSTR is coming out here. And then we have this secondary clarifier or settling basin wherein the floc forming microbes they are going to form flocs and then settle down.

As they settle down we will have clear water at the top and that is going to be the effluent**.** And some of the sludge will have to be wasted and we looked at different mass balances as and when we looked at the mass balance around the entire system for calculating Q recycle We looked at the mass balance around this particular system as in the clarifier we are done with that.

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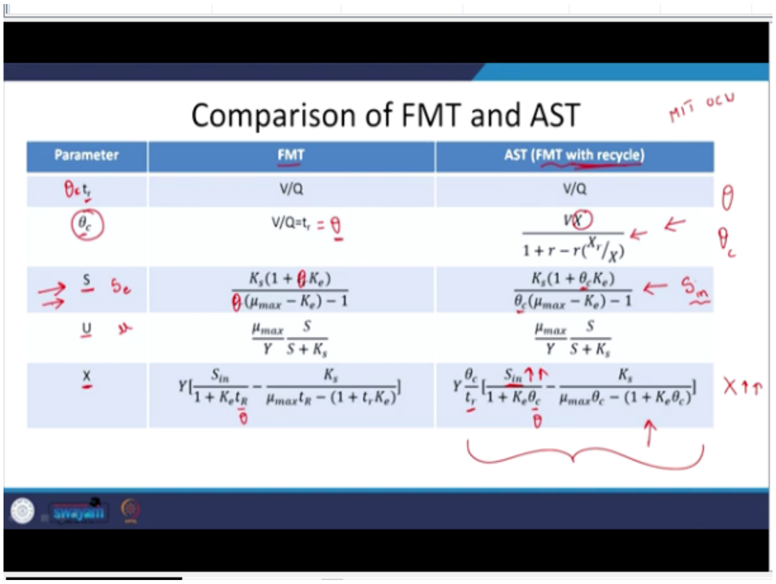

Comparison of FMT and AST

Parameter	FMT	AST (FMT with recycle)
$\theta_c t_r$	V/Q	V/Q
θ_c	V/Q=t_r = θ	$\frac{VX}{1+r-r(X_r/X)}$
S S_e	$\frac{K_s(1+\theta K_e)}{\theta(\mu_{max}-K_e)-1}$	$\frac{K_s(1+\theta_c K_e)}{\theta_c(\mu_{max}-K_e)-1}$
U	$\frac{\mu_{max}}{Y}\frac{S}{S+K_s}$	$\frac{\mu_{max}}{Y}\frac{S}{S+K_s}$
X	$Y[\frac{S_{in}}{1+K_e t_R}-\frac{K_s}{\mu_{max}t_R-(1+t_r K_e)}]$	$Y\frac{\theta_c}{t_r}[\frac{S_{in}}{1+K_e\theta_c}-\frac{K_s}{\mu_{max}\theta_c-(1+K_e\theta_c)}]$

Parameter	FMT	AST(FMT with recycle)
t_r	$\frac{V}{Q}$	$\frac{V}{Q}$
θ_c	$\frac{V}{Q}=t_r=\theta$	$\frac{VX}{1+r-r(X_r/X)}$
S	$\frac{K_s(1+\theta K_e)}{\theta(\mu_{max}-K_e)-1}$	$\frac{K_s(1+\theta_c K_e)}{\theta_c(\mu_{max}-K_e)-1}$
U	$\frac{\mu_{max}}{Y}\frac{S}{S+K_S}$	$\frac{\mu_{max}}{Y}\frac{S}{S+K_S}$
X	$Y[\frac{S_{in}}{1+K_e t_r}-\frac{K_s}{\mu_{max}t_r-(1+t_r K_e)}]$	$Y\frac{\theta_c}{t_r}[\frac{S_{in}}{1+K_e\theta_c}-\frac{K_s}{\mu_{max}\theta_c-(1+\theta_c K_e)}]$

And then we looked at this particular not schematic table where we compared a fully mixed tank without recycle and fully mixed tank with recycle. major aspect is that typically I use theta and sometimes people use retention time tr to represent hydraulic retention time but I look at theta. V by Q same for both theta c for the case where there is no recycle is going to be the same as theta.

The solids are going to spend the same time as the time spent by the water molecule that is what this indicates why there is no recycle. But with recycle we are what is it increasing the theta c meaning we are increasing the time that the microbes are present in your system. Meaning the microbes now have more time to degrade the organics thus the efficiency of the process is going to increase.

This is from the MIT open courseware so thus they would have used different slightly different variables but we do not need to go into that in detail now. We looked at this with respect to the variables that we use. For substrate here with respect to the one without recycle it is theta or in the case of the one with recycle we have theta c or the solid retention time and HRT a few hours typically theta c a few days typically.

S is going to be much lesser for the case where we have fully mixed tank with recycle. S is the one as in the effluent and then U are substrate utilization rate that depends on mu that is what we looked at we are not going into that now. X one aspect is you can play around with the variables and get this equation .

Here we have theta while here we have theta c or theta c by theta is one variable here and as you can see the concentration of the microbes in the relevant plant will also be higher in the case where we have the recycle and one other aspect we need to look at is when we were looking at the case of the substrate or our waste in the treated wastewater we saw that it is not dependent on S in or it is not depend on how much waste is coming into the system well.

That seems a bit counterintuitive is not it? I mean it is as if how much your waste I put in with the relevant design and with the relevant theta c it looks like my outlet or the concentration of the microbes not microbes pardon me concentration of the waste or the BOD in the effluent is always going to be the same how is that? It seems counterintuitive well the trick here is in understanding or looking at X or X this equation**.**

As S in the amount of waste coming into the waste water treatment plant increases what do you see? You see that X which is the concentration of microbes also increases and if X increases if you see it out here if X increases theta c will also increase**.** it is going to or the system is going to self adjust as in if the substrate or there is more food for the microbes coming in the concentration of the microbes will increase**.**

in that effect or in that scenario you are going to have self adjustment of the system and you are going to more or less end up with the same outlet concentration irrespective of the inlet concentration. that is something to keep in mind.

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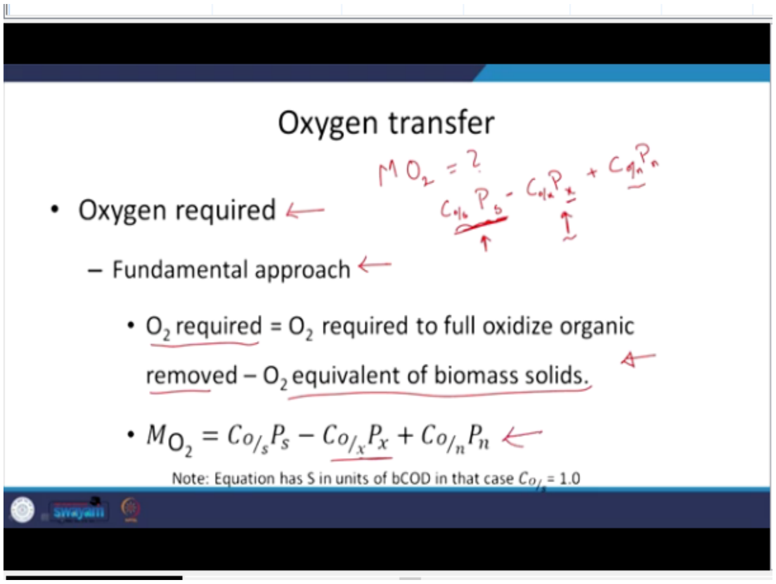

Oxygen transfer

$MO_2 = ?$

$C_{o/s} P_s - C_{o/x} P_x + C_{o/n} P_n$

- Oxygen required
  - Fundamental approach
    - O_2 required = O_2 required to full oxidize organic removed – O_2 equivalent of biomass solids.
    - $M_{O_2} = C_{o/s} P_s - C_{o/x} P_x + C_{o/n} P_n$

Note: Equation has S in units of bCOD in that case $C_{o/s}$ = 1.0

$$M_{o_2} = C_{o/s} P_s - C_{o/x} P_x + C_{o/n} P_n$$

And next aspect as we discussed briefly was oxygen transfer until now we looked at what is the concentration of microbes that we need to maintain how much time the microbes have to spend in the system which is the solid retention time and the design variable which is the concentration of our waste or the food to the microbes or the substrate leaving the system**.** We looked at these aspects in different context.

One other aspect that is required from what we say the engineer here is the oxygen that needs to be supplied to the microbes. you need to be able to calculate the oxygen that needs to be given to the system well one other reason why we need to be aware of this particular variable is that the major cause of operation of an accurate sludge process or an aerobic process typically are due to the costs of pumping the oxygen in or the air in.

we need to look at the amount of oxygen required. 2 approaches we will look at the fundamental approach only if I am not wrong today. The oxygen required well this is a particular way to look at it but I will try to estimate in a better way. Oxygen required is equal to the oxygen required to fully oxidize the organic removed minus the oxygen equivalent of biomass solids.

this is the general version that people look at but let us try to understand it in better terms. I need to provide oxygen and I need to know how much. where does it go? Some of it goes into degrading the substrate. I need to know the amount of substrate that is being what we say degraded in the system and for that there will be a certain conversion factor which I am representing by C os.

But if you remember in I think one of these sessions probably a couple of sessions ago we looked at the case where I think for a particular compound from the dairy waste I think casein if I am not wrong we saw that not all the waste or not all the substrate goes into the final end products of carbon dioxide why is that? Because I think we looked at the where you or ratio being 5 8 and 3 8 .

And if I am not wrong 5 8 of this particular casein went into synthesis of new cells. here we are not really providing oxygen for the complete what do we see oxidation of the organics because some of the organics are being used by the microbes to form new cells. that aspect we have to remove and that is what we have. we will have we know the concentration of the microbes that are being produced.

And we know that oxygen is not required for that particular reaction. we have the conversion factor for that. we have to remove it from this particular term or set of variables we have. This is the amount of oxygen we need to give if all the waste is to be oxidized but we know that part of the waste will not be oxidized it will go into cell synthesis. That is what we have and if I need to look at nitrification as in if I have ammonia NH 4 + or NH 3.

And I need to oxidize it we looked at ammonia oxidizing bacteria nitrite oxidizing bacteria in this context how do they oxidize with the assistance of oxygen . you need the oxygen. whenever you have requirement of also removing nitrogen so we have this particular term. that is what we have that is a better way of understanding the relevant concept here.

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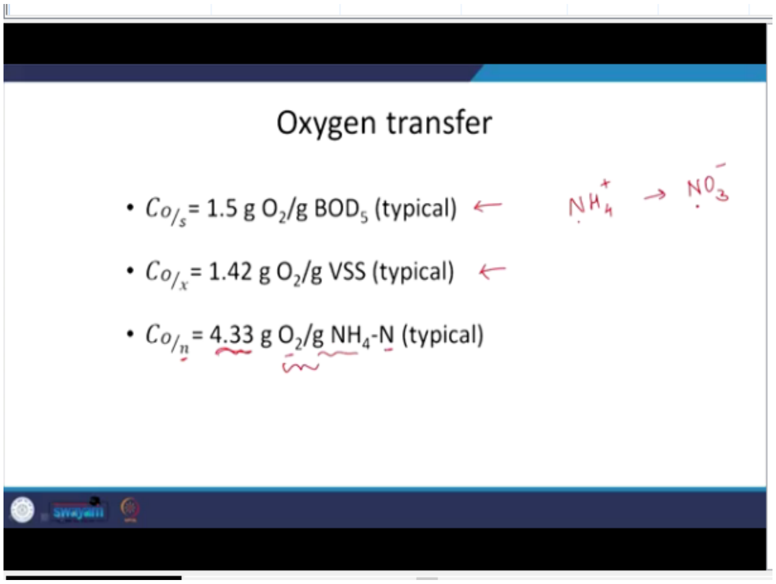

Oxygen transfer

- $Co_{/s}$ = 1.5 g O_2/g BOD_5 (typical) ←
- $Co_{/x}$ = 1.42 g O_2/g VSS (typical) ←
- $Co_{/n}$ = 4.33 g O_2/g NH_4-N (typical)

$NH_4^+ \rightarrow NO_3^-$

typical aspects or conversion factors and with respect to nitrogen you can see that it is 4.33 grams of oxygen is required per gram of NH 4 expressed in terms of n units. Well as you can see a lot of oxygen is required you can look at the stoichiometry you want to go from considerably reduced state to a considerably oxidized state. you need a lot of oxygen for each mole of nitrogen. here the units are in mass but you can see that though. that is one aspect to understand.

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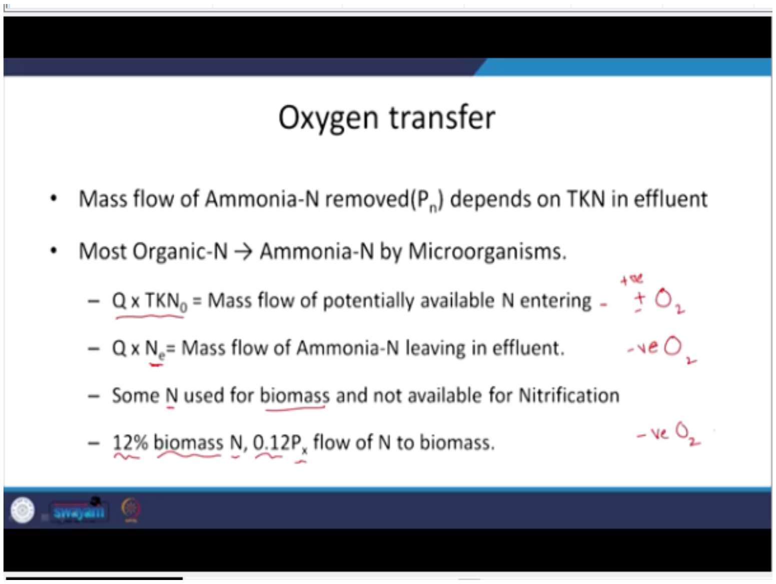

Oxygen transfer

- Mass flow of Ammonia-N removed(P_n) depends on TKN in effluent
- Most Organic-N → Ammonia-N by Microorganisms.
  - $Q \times TKN_0$ = Mass flow of potentially available N entering - +ve $+ O_2$
  - $Q \times N_e$= Mass flow of Ammonia-N leaving in effluent. -ve O_2
  - Some N used for biomass and not available for Nitrification
  - 12% biomass N, $0.12P_x$ flow of N to biomass. -ve O_2

And with respect to ammonia requirements we need to understand that in slightly greater detail. I want to remove ammonia in this particular system and I need to know the oxygen requirement fine. how do I understand the system? I know that it comes in the form of TKN. organic ammonia and also free ammonia if I may say and during degradation most of this organic ammonia will be converted to ammonia NH 4 + and then you are going to have oxidation**.**

here I can assume that all the NH 4 + is being degraded. that is one way of calculating how much oxygen is required from the stoichiometry**.** When I say degraded I am referring to oxidation of NH 4 + that I can presume but some of it will leave the system yes. that is one aspect I need to look at how much is leaving the system and second aspect is that microbes are going to require some nitrogen for cell synthesis.

some of the nitrogen will be taken up by the cells itself and there is no oxygen demand due to this nitrogen content**.** these aspects we need to take care of. Let us look at what we have. Q into TKN 0 is the mass of nitrogen that is entering the plant and for which we need to provide the oxygen and some of the nitrogen will not be degraded it will leave the plant. this we need to subtract.

This is going to add positive and this is going to this we need to subtract and as we mentioned some of the nitrogen will be used for biomass and is not going to be available for oxidation or nitrification. how much is it typically it seems 12% of biomass that is the N. 0.12 into P x is the flow of nitrogen to biomass. even this we have to deduct. now let us see what we have.

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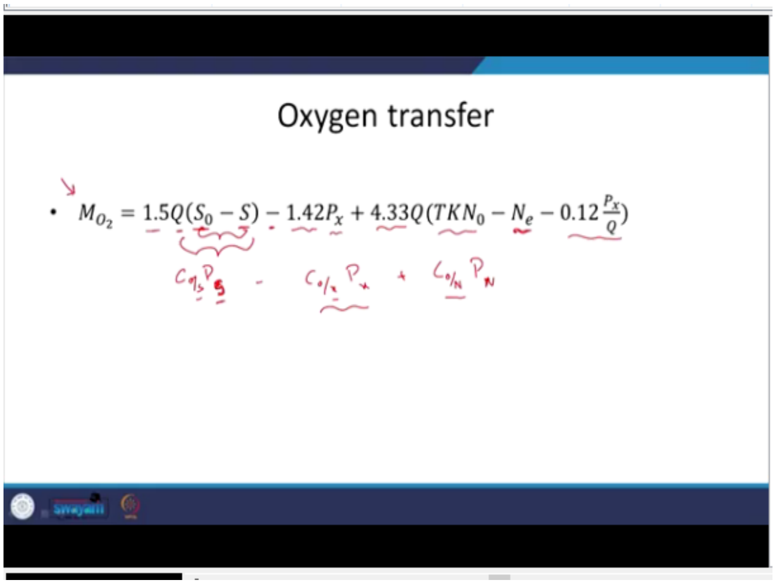

Oxygen transfer

- $M_{O_2} = 1.5Q(S_0 - S) - 1.42P_x + 4.33Q(TKN_0 - N_e - 0.12\frac{P_x}{Q})$

$C_{o/s}P_s - C_{o/x}P_x + C_{o/N}P_N$

$$Mo_2 = 1.5Q(S_o - S) - 1.42P_x + 4.33Q(TKN_O - N_e - 0.12\frac{P_x}{Q})$$

here we earlier we had C o by S C o by X are the conversion factors with respect to substrate microbes and nitrogen and then the mass of substrate mass of microbes and mass of nitrogen. here what is P s it is nothing but the amount of substrate that is being consumed for which we need to provide the oxygen. that is what we have here Q into s 0 - S initial concentration of the substrate minus final.

that multiplied by Q will give me the mass of what do we see the substrate that is available for or that has to be biodegraded and 1.5 is the conversion factor. Similarly negative here because some of the mass will go into cell synthesis and this is the conversion factor P x we already calculated it last session and here we have the conversion factor for nitrogen and TKN 0 is the one that is coming in initially.

And this is the nitrogen that is leaving the plant or via the effluent and this is the one that is being used for cell synthesis. that is what we have this is the mass of oxygen that is going to be required to be supplied. that is something to keep in mind.

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Oxygen Supply

- Diffused

different types of diffusers are available. diffused so you want to create these kinds of fine bubbles or sometimes coarse bubbles which I am not going into detail now.

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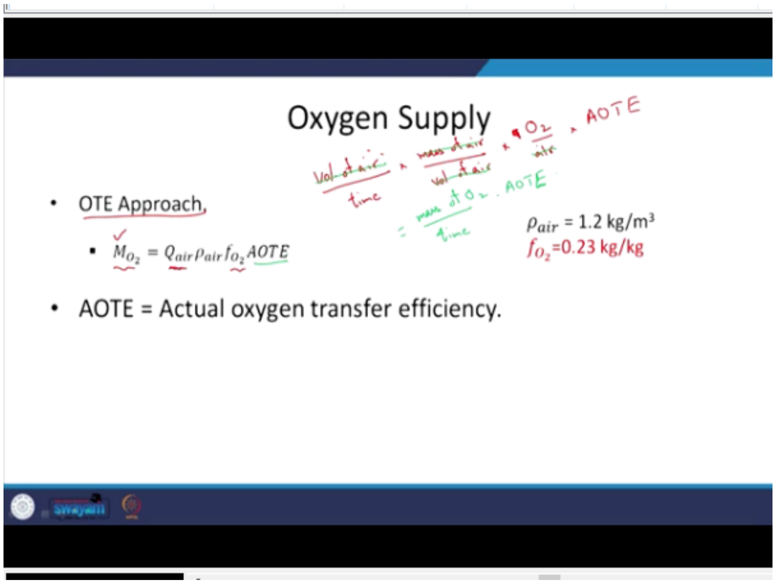

Oxygen Supply

- OTE Approach,
  - $M_{O_2} = Q_{air}\rho_{air}f_{O_2}AOTE$
- AOTE = Actual oxygen transfer efficiency.

$\frac{\cancel{\text{vol of air}}}{\text{time}} \times \frac{\cancel{\text{mass of air}}}{\cancel{\text{vol of air}}} \times \frac{O_2}{\cancel{\text{air}}} \times AOTE$

$= \frac{\text{mass of } O_2}{\text{time}} \cdot AOTE$

$\rho_{air} = 1.2$ kg/m^3

$f_{O_2} = 0.23$ kg/kg

$$Mo_2 = Q_{air}\rho_{air}f_{o_2}\text{AOTE}$$

with respect to the kind of bubbles the smaller the bubble size the greater the surface area the greater the oxygen transfer efficiency. Now if I may use that deals but the issues are that you will have clogging of your relevant diffusers that lead to fine bubbles . that is trade-off between maintenance and energy and oxygen transfer efficiency.

what is the mass of oxygen? How can I calculate that? I know the airflow that I is required this I calculated from my fundamental approach or I can calculate now and this is one aspect I need to mention is that earlier we looked at the fundamental approach. This is based on the oxygen transfer efficiency approach. This is the flow rate of air as in volume of air by time or with respect to time density of air as in mass of air per volume of air .

And the fraction of oxygen in air. the fraction of oxygen in air or gram mass of oxygen per mass of air into the efficiency actual oxygen transfer efficiency how efficient is it being it transfers. what do we get? volume of air let me use a different colored pen. volume of air volume of air cancel out mass of air mass of air cancel out.

the units that I end up with are mass of oxygen required per time and depending on the oxygen transfer efficiency we have to supply more. that is what we have. that is the mass of air that is required. this is the actual oxygen transfer efficiency which you need to calculate based on the relevant variables.

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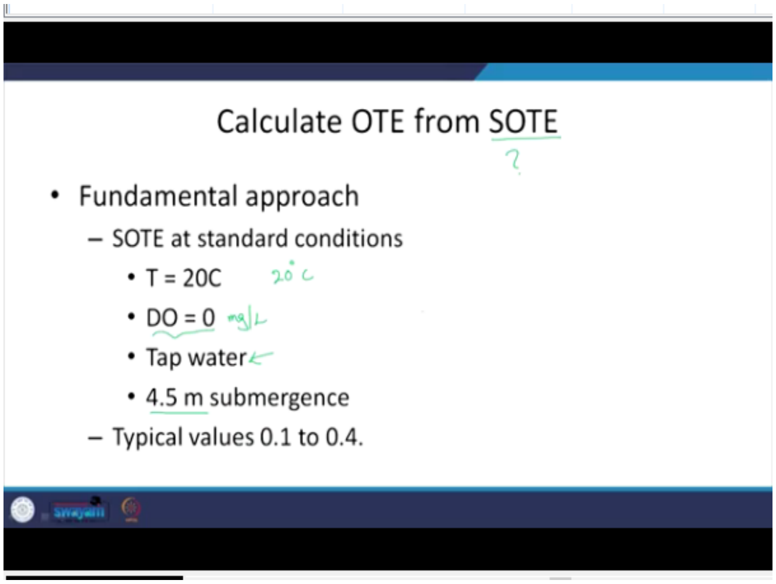

Calculate OTE from SOTE

?

- Fundamental approach
  - SOTE at standard conditions
    - T = 20C 20°C
    - DO = 0 mg/L
    - Tap water ←
    - 4.5 m submergence
  - Typical values 0.1 to 0.4.

Let us look at how we will do that? first we have to understand that there is a standard oxygen transfer efficiency and what are these standard conditions? These conditions are at 20 degrees centigrade for water that has dissolved oxygen of 0 milligram per liter calculated for tap water and we are assuming a 4.5 meter submergence or depth. for these conditions the standard oxygen transfer efficiency is calculated.

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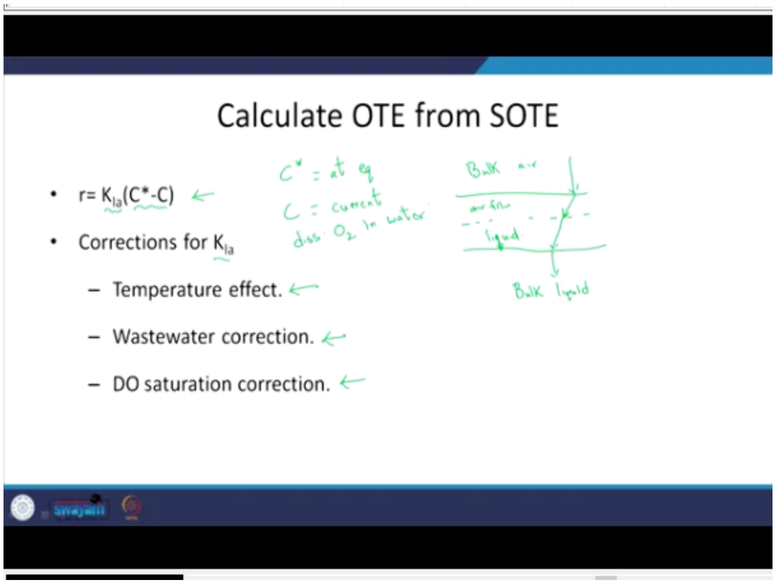

Calculate OTE from SOTE

- r= $K_{la}(C^*-C)$ ←
- Corrections for K_{la}
  - Temperature effect. ←
  - Wastewater correction. ←
  - DO saturation correction. ←

C^* = at eq

C = current diss. O_2 in water

$$r = K_{la}(C^* - C)$$

And how is it that oxygen goes from or is supposed to move from the gaseous phase into the aqueous phase. How does that occur? It is typically based on the 2 film theory if this is the bulk liquid and here is the bulk air if I may say so. it says that this is an air film or film of air and this is a liquid film. depending on the concentration in the liquid I am talking about oxygen concentration of oxygen in the liquid and concentration that is going to be present in the liquid at what we see equilibrium conditions.

Air in this particular or oxygen in the air will have to go through the film the liquid film and then into the bulk liquid and what is the driving force? It is the driving force is the concentration gradient and this is the relevant what we say constant that will look at the surface area and the relevant aspects out there and how is it or in which cases will you have greater transfer.

think of this if my water has no oxygen and there is a oxygen in the air that is in contact with this water the greater the difference between the concentration in the water and the concentration that can be in the water at equilibrium. then the driving force is greater yes. the lesser the difference the lesser the driving force. that is where this comes from and K la will depend upon temperature.

We have to correct it with for wastewater and for DO saturation also but we look at that. that is something to keep in mind as you can see this is C star is the one at equilibrium and C is the concentration in the solution current concentration current oxygen dissolved oxygen dissolved oxygen in water. that is how you can understand it.

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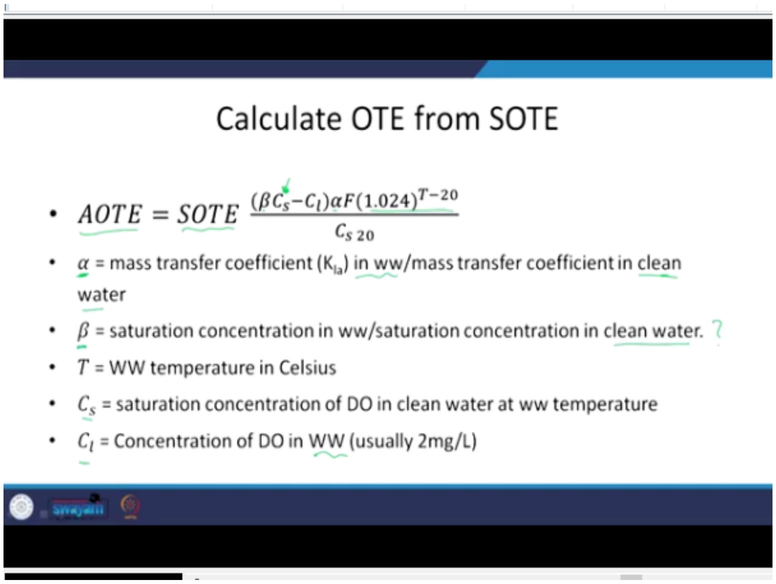

Calculate OTE from SOTE

- $AOTE = SOTE \frac{(\beta C_s - C_l)\alpha F(1.024)^{T-20}}{C_{s\,20}}$
- α = mass transfer coefficient (K_{la}) in ww/mass transfer coefficient in clean water
- β = saturation concentration in ww/saturation concentration in clean water. ?
- T = WW temperature in Celsius
- C_s = saturation concentration of DO in clean water at ww temperature
- C_l = Concentration of DO in WW (usually 2mg/L)

$$\text{AOTE} = \text{SOTE}\,\frac{(\beta\, C_s - C_l)\alpha F (1.024)^{T-20}}{C_{s\,20}}$$

And how do I calculate AOTE in terms of SOTE. here we have different correction factors one is alpha because typically the here is alpha the mass transfer coefficients are calculated for clean water. because I want to calculate it for waste water I am going to have to have a correction factor and beta is the saturation concentration in wastewater by saturation concentration in clean water why is there also a difference here?

Because here you are going to have ions and other compounds or impurities that can affect the maximum concentration of the oxygen in your water. that is why you will have another correction factor for it and this is the correction factor for the temperature and C s is the saturation concentration of dissolved oxygen in clean water and C l is the concentration of DO in wastewater which is the actual concentration in your wastewater.

From that you can calculate your actual oxygen transfer efficiency and how do I or is this always constant or what does it depend upon. P v equal to NRT . it depends upon the pressure pressure depends upon the elevation**.** looks like I have to discuss another aspect here too.

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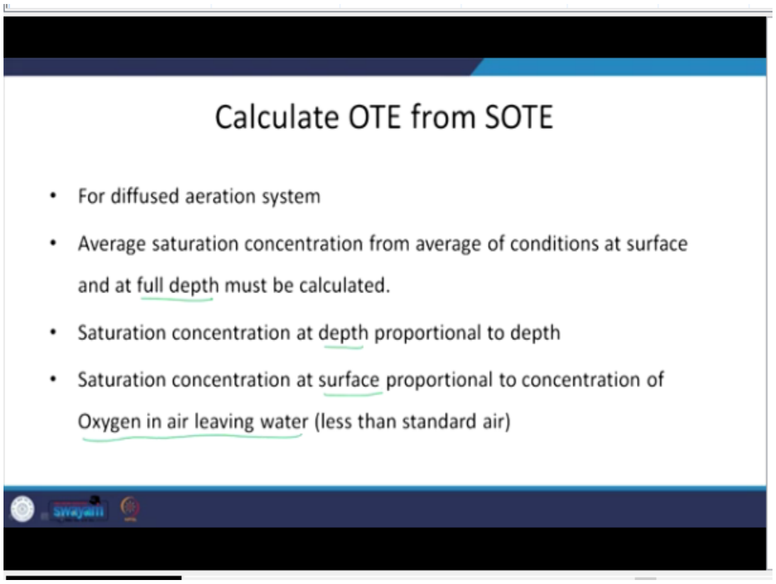

Calculate OTE from SOTE

- For diffused aeration system
- Average saturation concentration from average of conditions at surface and at full depth must be calculated.
- Saturation concentration at depth proportional to depth
- Saturation concentration at surface proportional to concentration of Oxygen in air leaving water (less than standard air)

for diffused aeration system what do we have? Average saturation concentration from average conditions at surface and full depth must be calculated. as we were on the track. this will vary.

that has to be calculated and what do we need to look at? We need to look at the full depth and saturation concentration at depth proportional to the depth and at this surface. these are aspects we have to look at and it is proportional to the concentration of oxygen in air leaving the water.

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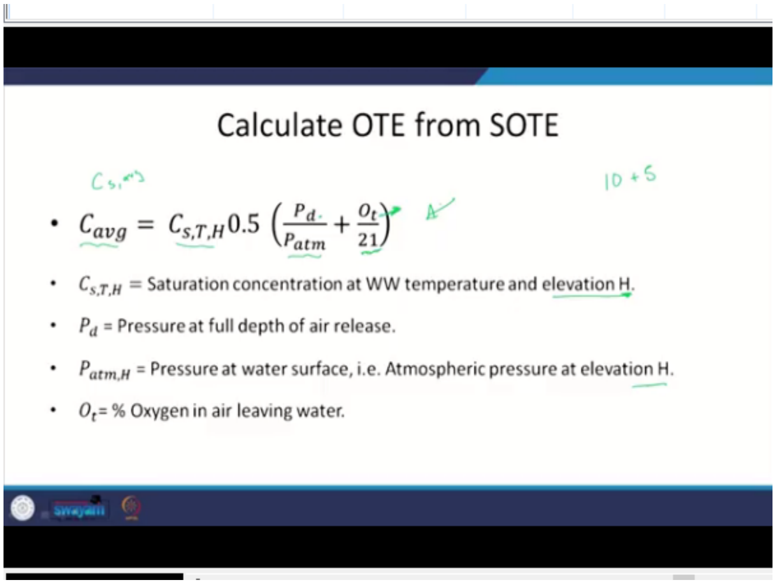

Calculate OTE from SOTE

$C_{s,}$

10 + 5

- $C_{avg} = C_{s,T,H} 0.5 \left(\frac{P_d}{P_{atm}} + \frac{O_t}{21}\right)$
- $C_{s,T,H}$ = Saturation concentration at WW temperature and elevation H.
- P_d = Pressure at full depth of air release.
- $P_{atm,H}$ = Pressure at water surface, i.e. Atmospheric pressure at elevation H.
- O_t= % Oxygen in air leaving water.

$$C_{avg} = C_{s,T,H} 0.5\left(\frac{P_d}{P_{atm}} + \frac{O_t}{21}\right)$$

all these formulas will be given so you do not need to worry about it. how will I calculate the C s average it is we have this saturation concentration at the wastewater temperature and elevation H elevation of that particular location and pressure at full depth. For example if the elevation is 10 and the depth of water is 5. P d will be 10 + 5 and pressure at water surface and that is what we already have out here.

And here what is this oxygen in air leaving the water typical this is 21% oxygen 21% in the relevant air and this is the oxygen in air leaving the water typically 19% 18% it is going to be less than 21% one aspect gentlemen. what are we doing here we know that there is a standard oxygen transfer efficiency how efficiently will the oxygen be transferred from the gaseous phase into the aqueous phase or the water?

to look at that actual oxygen transfer efficiency we need to look at some correction factors with respect to what is it now wastewater with respect to the maximum saturation and with respect to what else temperature and also with respect to the saturation concentration we know that it depends upon the elevation or the height at which the plant is located and also the aspects related to the pressure or the submergence.

these aspects we take into account and all these what is it equations will be given in the exam you do not need to worry about that and equally importantly you need to understand how or what are the variables at play here that is one aspect that you need to look at.

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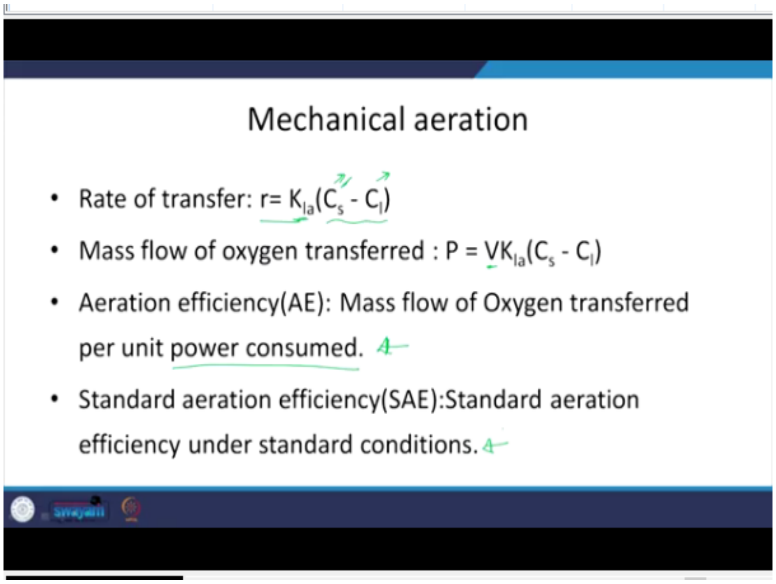

Mechanical aeration

- Rate of transfer: $r = \underline{K_{la}}(\overset{\nearrow\nearrow}{C_s} - \overset{\nearrow}{C_l})$
- Mass flow of oxygen transferred : $P = \underline{V}K_{la}(C_s - C_l)$
- Aeration efficiency(AE): Mass flow of Oxygen transferred per unit power consumed. A ←
- Standard aeration efficiency(SAE):Standard aeration efficiency under standard conditions. A ←

$$\text{Rate of transfer : } r = K_{la}(C^* - C)$$

$$\text{Mass flow of oxygen transfer : } P = VK_{la}(C^* - C)$$

let us move on mechanical aerations as I mentioned the rate of transfer depends upon the coefficient and the difference between the one at equilibrium this is typically the constant and the one in the concentration in the liquid. mass flow I will have to multiply that by volume and here we have other terms aeration efficiency mass flow of oxygen transfer per unit power consumed.

this takes into account the local conditions with respect to the pumps . Standard aeration efficiency standard aeration at I mean efficiency at standard conditions.

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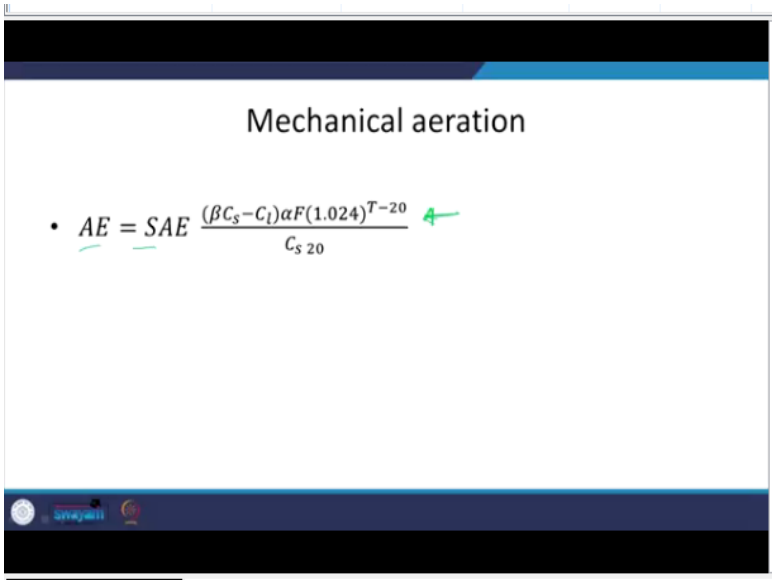

Mechanical aeration

- $AE = SAE \frac{(\beta C_s - C_l)\alpha F(1.024)^{T-20}}{C_{s\,20}}$

$$AE = SAE \frac{(\beta\, C_s - \; C_l)\alpha F(1.024)^{T-20}}{C_{s\,20}}$$

This takes into account your pumps and energy efficiency too. that is what you have similar profile. we will not go into that in detail here. all these are simple formulas and once we give the relevant values you just need to plug them in while keeping in mind how the units play role X and people would always prefer that I solve homework questions or sample questions.

But if I keep solving a lot of questions or sample problems or numericals we will not be able to cover the relevant aspects or the principles in detail. at least in this course we are going to talk about the principles more and maybe less examples but the TAS should be able to provide you the relevant assistance when required or they can provide you the relevant solved example if you want. that is something that you need to keep in mind.

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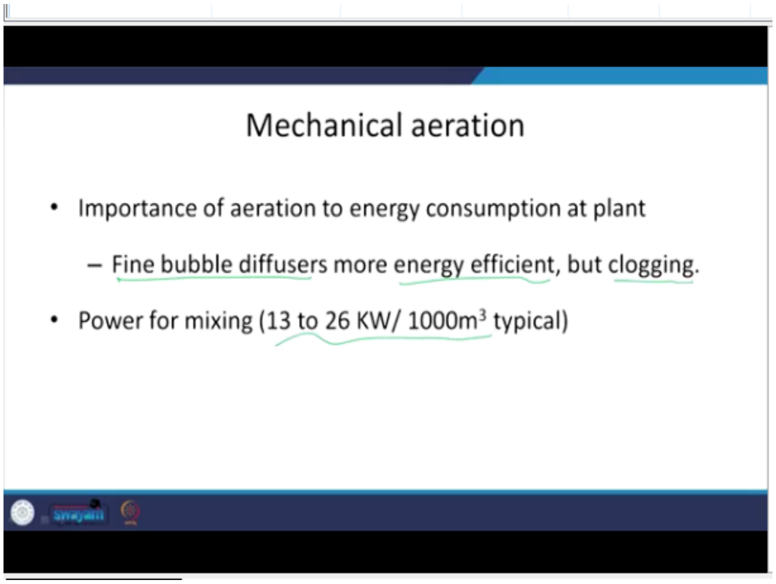

Mechanical aeration

- Importance of aeration to energy consumption at plant
  - Fine bubble diffusers more energy efficient, but clogging.
- Power for mixing (13 to 26 KW/ 1000m^3 typical)

mechanical aeration as I mentioned fine bubble diffusers are more energy efficient typically greater what is that oxygen transfer efficiency but maintenance is an issue due to clogging. Power for mixing typical power you can understand the relevant energy requirements.

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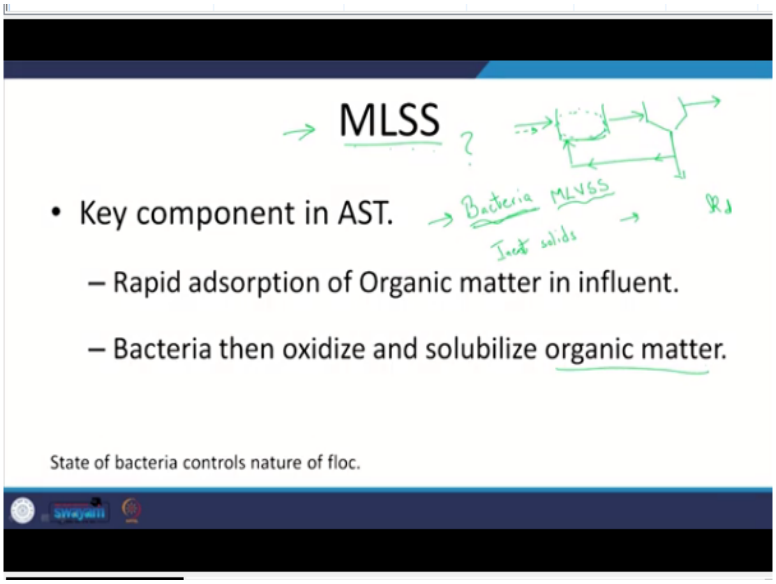

MLSS

- Key component in AST.
  - Rapid adsorption of Organic matter in influent.
  - Bacteria then oxidize and solubilize organic matter.

State of bacteria controls nature of floc.

now we will come across a term I think I might have used that earlier mixed liquor suspended solids. what is this about? that waste is coming in and here we have our aeration tank and then our secondary clarifier and considerable fraction of these of the sludge is going to be returned and some of it is wasted and then we have the treated effluent water.

And what do we have here we know now that the concentration of microbes here is going to be pretty high. the contents of this aeration tank are called mixed liquor suspended solids the contents. what does that contain? it will contain bacteria a lot of it depending on how you are maintaining it what else will it contain it will or the MLSS will also include some inert solids or fixed solids inert solids.

how do you distinguish between them these we call or try to measure anyway by MLVSS mixer liquor volatile suspended solids. you have relevant furnace and then increase the temperature and then look at what is remaining and that you say is fixed and what is not remaining we call that as volatile. that is one aspect to keep in mind and in this MLSS or such what else is it only bacteria no you have looks like you will have some protozoa of 5% and they also feed on the bacteria.

that is why you have the decay coefficient K d. that is one aspect and protozoa seem to be playing a important role in leading to good sludge that can settle. that is one aspect and you will have dead cells free swimming cells or the motile cells if I can call them. you will have different such or you have a complex ecosystem in this MLSS. what happens to the waste that coming in?

The waste that is coming in will be immediately absorbed or absorbed by this MLSS after that the bacteria will oxidize or solubilize and then oxidize the organic matter. that is how it is going to work. we are going to call the contents of this tank MLSS. let us move on.

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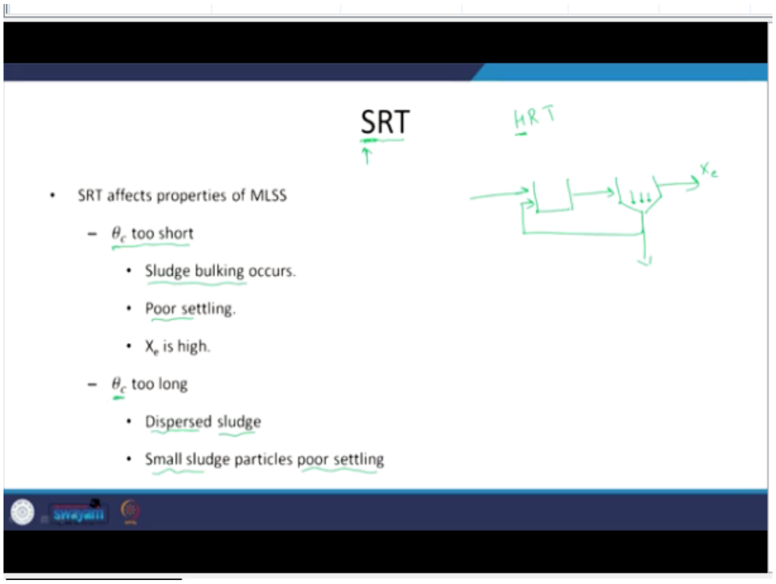

SRT

- SRT affects properties of MLSS
  - θ_c too short
    - Sludge bulking occurs.
    - Poor settling.
    - X_e is high.
  - θ_c too long
    - Dispersed sludge
    - Small sludge particles poor settling

solid retention time some aspects that we need to be aware of first this is not HRT this is about hydraulic or water. This is about solids which when we say solids we are referring to the microbes. if SRT affects the properties of MLSS why is that I have this tank and this is the recycle. recycle and the concentration that will affect the time that my microbes are spending in my system.

What happens if my residence time of the solids or the microbes is too less. that can lead to sludge bulking. here you want the sludge to settle down but if the cell residence time is too less it can lead to sludge bulking we will look at that later and it would not settle. I have that out here poor settling and if settling is poor then what happens X c the concentration of microbes that are leaving the system are going to be high.

Typically you want that to be almost 0 or negligible but if they do not settle well enough as in the sludge does not settle well enough what are you going to experience you are going to sit with that some of it will settle down it has in the microbes and some will leave the system and what happens if the theta is too high or too long. You can have dispersed sludge and st small sludge particles that will lead to poor setting.

we will look at what this is or such because not what why typically it is because of the kind of microbes motile cells or such which have a lot of time to be able to find the relevant food . so the balance has to be between keeping theta c too short and too long. that is one aspect.

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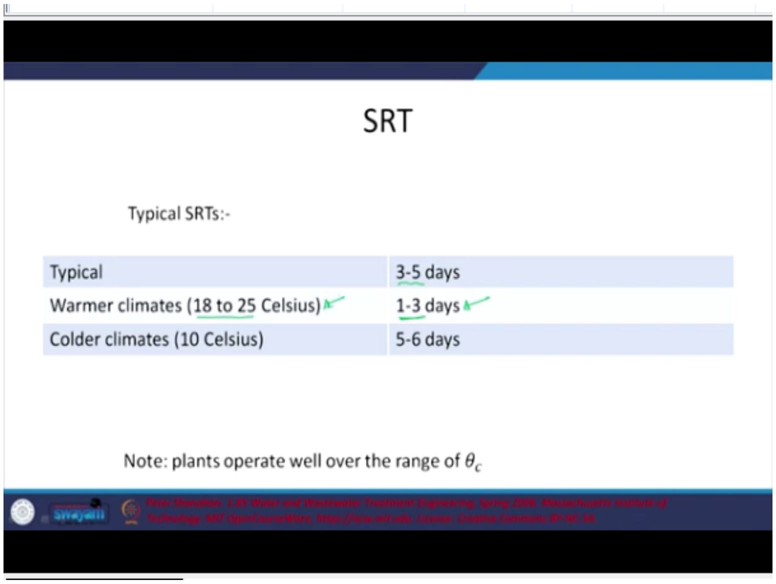

SRT

Typical SRTs:-

Typical	3-5 days
Warmer climates (18 to 25 Celsius)	1-3 days
Colder climates (10 Celsius)	5-6 days

Note: plants operate well over the range of θ_c

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Typical SRTs as I mentioned soil retention time will be pretty high as you can see it is in days in warmer climates because the temperature is higher the kinetics or the rate of degradation will be higher thus we can make do with lesser SRT. that is why in India even though the performance or the maintenance of the plants is poor because of the warmer climates looks like we are able to get it done. That is because the kinetics are pretty fast in general.

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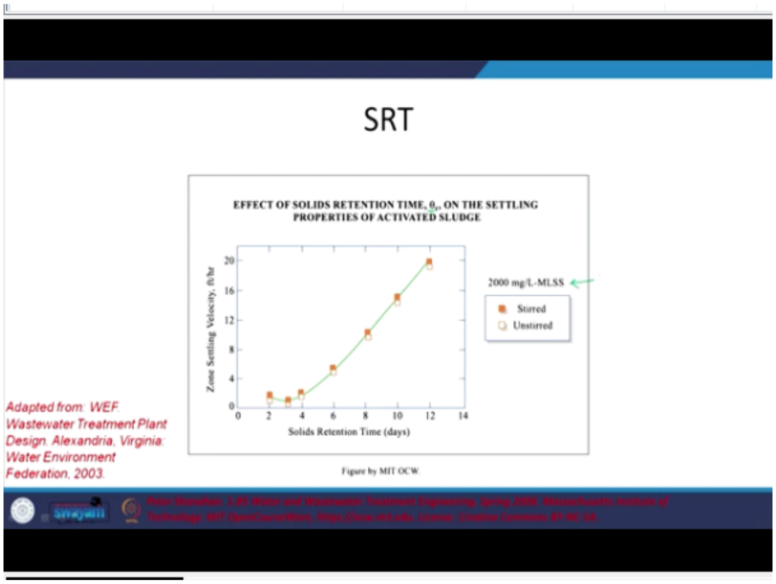

SRT

EFFECT OF SOLIDS RETENTION TIME, θ_c, ON THE SETTLING PROPERTIES OF ACTIVATED SLUDGE

Figure by MIT OCW.

Adapted from: WEF. Wastewater Treatment Plant Design. Alexandria, Virginia: Water Environment Federation, 2003.

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Let us move on and one aspect as we see for a particular range this is not for the entire range effect of solid residential time or retention time on the settling properties of activated sludge. typical range yes zone settling velocity you want it to be pretty good and   you see that with increasing

SRT you see what is it now? Better settling characteristics but there is going to be an upper limit. This is the case for a 2000 milligram per liter of MLSS or mixed liquor suspended solids.

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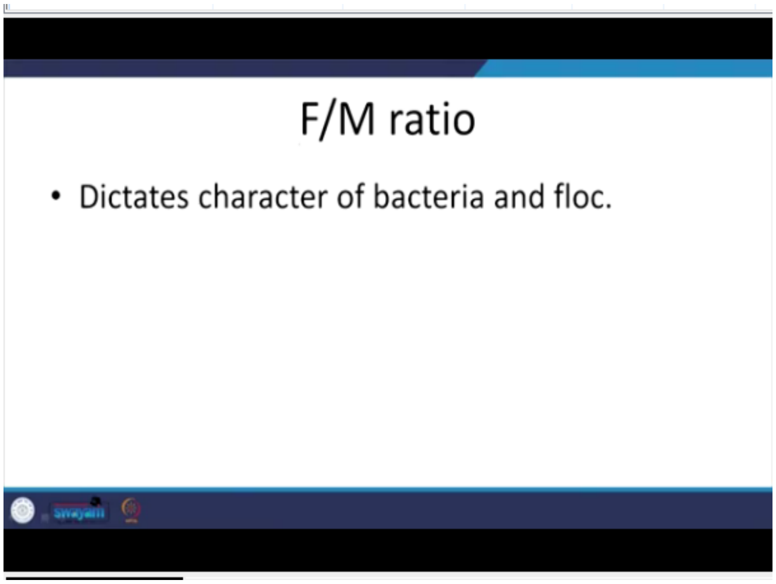

F/M ratio

- Dictates character of bacteria and floc.

Let us move on. F by M ratio. this is one other critical aspect. food by microorganism ratio. when we say food it is our wish that we are talking about microorganisms. we need to look at this ratio because we need to understand the optimum conditions that will lead to optimal settling of the sludge and also optimal removal of the waste from the relevant or optimal removal of our food or pardon me our waste from the relevant waste water.

how to achieve that there is a particular analysis we looked at the relevant aspects and derived the relevant variables but let us look at the extreme scenarios what happens when the F by M is too large F by M is too low but looks like I am out of time for this session. I will end the session for now and continue this in the next session thank you.