CTB3365x – Introduction to Water Treatment

W4b – Dimensioning of return sludge

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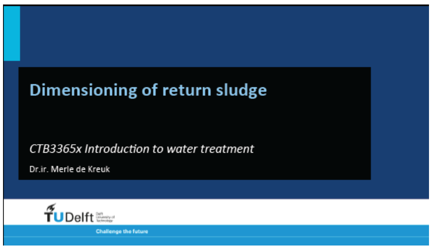
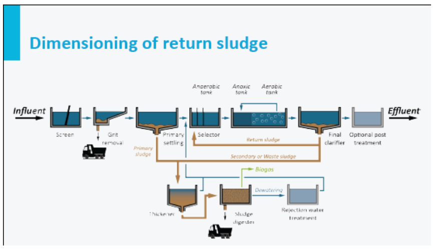
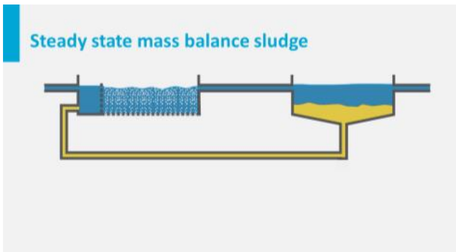


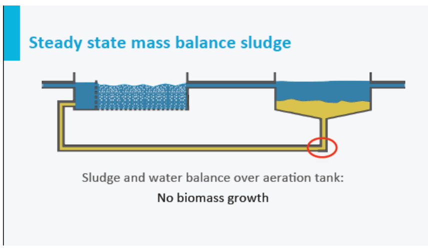
Today we continue designing the biological part of a sewage treatment plant.



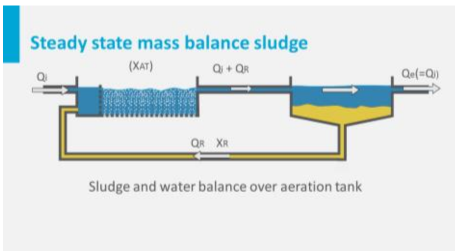
You previously learned dimensioning of an aeration tank



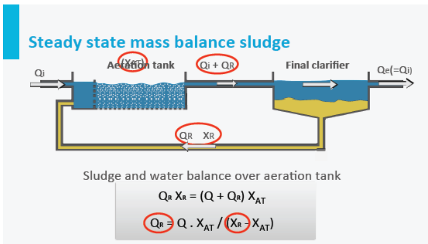
and we will now continue with estimating the recycle flow returned from the final clarifier into the biological process. We start with a steady state mass balance over the biological system and the final clarifier. Missing a flow in this picture?



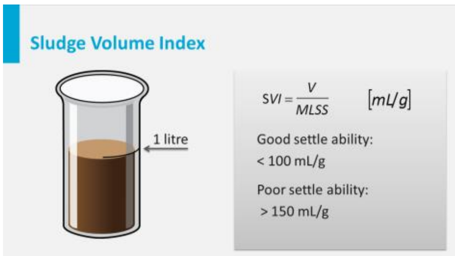
The waste activated sludge flow is ignored to simplify things a bit: for now we assume that there is no biomass growth, just for the sake of this design methodology. The waste activated sludge flow will be discussed at the end of this lecture, and will not negate what you learn now.



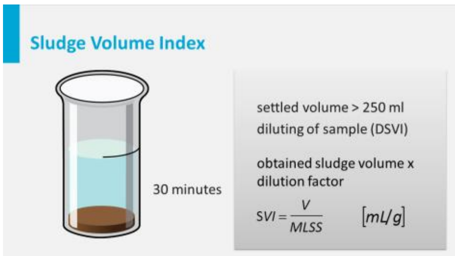
A steady state mass balance means that there is no accumulation, thus what goes into the system will also leave the system. For the total design we assume that there is no sludge entering the aeration tank with the influent flow and also the sludge leaving with the effluent flow is negligible. The overall mass balance over the aeration tank can therefore be described by assuming that the total sludge mass coming into the aeration tank equals the total sludge mass leaving the aeration tank.



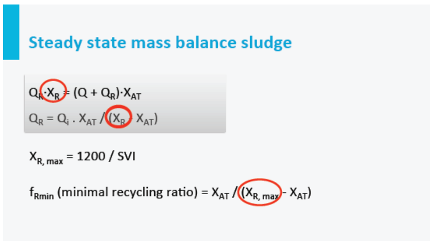
Sludge entering the aeration tank is calculated by multiplying the return sludge flow times the return sludge concentration. Sludge leaving this tank is calculated by the influent flow plus the recycle flow times the sludge concentration in the aeration tank. Since we are interested in determining the applicable return sludge flow, we can rewrite the equation. However, there are still two unknowns: the return sludge flow and the concentration of the return sludge. Because this is the concentration after settling; it will be higher than the concentration in the aeration tank.



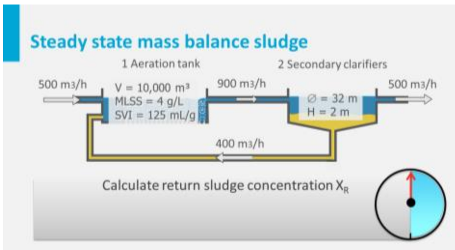
To determine the maximum sludge concentration that can be expected in the sludge recycle, you first need to be introduced to another parameter: the sludge volume index or SVI in short. This is a measure for the sludge settleability and is described as the volume of 1 gram settled activated sludge. Sludge that settles well has a low sludge volume index, while poorly settling sludge has a high SVI. The latter is known as bulking sludge. The SVI is determined as follows: one liter of mixed liquor is taken from the activated sludge tank and poured into a measuring cylinder or Imhoff Cone. After half an hour of settling, the volume of the sludge blanket in the cylinder is registered.



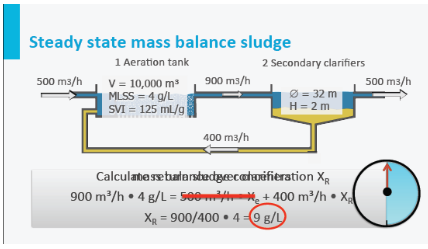
If this settled volume is larger than 250 mL, the sample needs to be diluted and the measurement needs to be repeated with the diluted sludge sample. Of course the obtained sludge volume needs to be multiplied with its dilution factor for the correct answer. By knowing the exact dry solids concentration in the original sample, a sludge volume index can be calculated. This is done by dividing the registered volume in mL by the dry solid concentration of the sample in g/L. If the sample was diluted, we speak about a diluted SVI or DSVI. Be careful: the units of SVI are milliliters per gram!



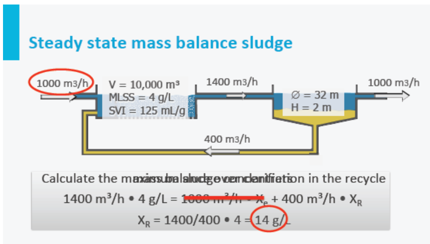
Now back to our mass balance of the aeration tank. For the design, we should know the recycle flow rate. The big unknown to solve this equation is the sludge concentration of the recycle flow, Xr. We cannot know the precise Xr unless we would measure it. Often return sludge concentrations from secondary clarifiers are between 4 and 12 g/L. We could estimate a maximum obtainable sludge concentration in g/L, by dividing 1200 by the SVI. 1200 is an empirical number: a combination of a maximum of 1000 mL sludge per liter and a safety factor of 20%. Be aware that this rule of thumb already corrects for the milliliters in the SVI unit! If a maximum sludge concentration of the sludge recycle is found, the mass balance and the minimum return sludge flow can be calculated. Also the minimum recycle ratio is set by this value.



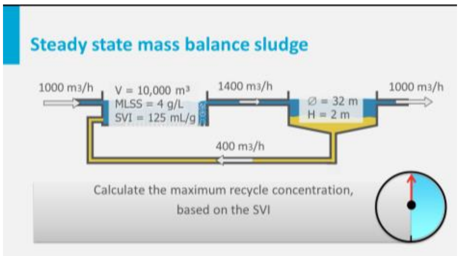
So let’s practice with this and also see the influence of heavy rain. Assume we have the sewage treatment plant that is pictured here. There is one biological tank and two settlers of the dimensions showed. Of course there is a sludge recycle and the dry weather influent flow is 500 m3/hr and the recycle flow is 400 m3/hr. Now please try to calculate the sludge concentration in the sludge recycle. I will give you a timer again on the bottom of the sheet. Pause the movie if you need more time, it would be nice if you can find the answer by yourself.



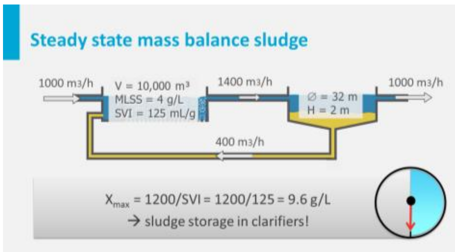
So did you start with the mass balance over the system? Very good. You learned that we assume biomass discharge with the effluent negligible. So now you have an equation with one unknown, leading to your answer: 9 g/L.



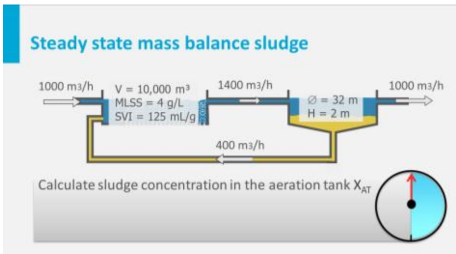
Now it starts raining, doubling the influent flow. I have the same question: what is the sludge concentration in the sludge recycle? So you found 14 g/L? Great! But now we must check if this is this possible, since this concentration is pretty high.



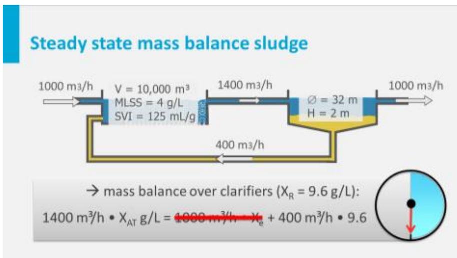
Calculate the maximum recycle concentration, based on the SVI.



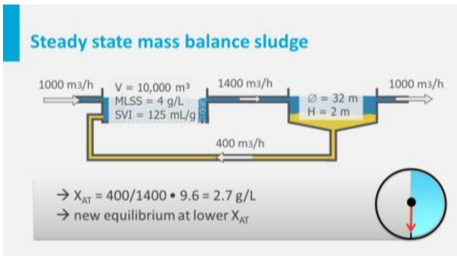
So now you found that the recycle flow can contain a maximum of only 9.6 g/L. What do you think will happen with the activated sludge? Indeed, it will wash out of the aeration tank, but cannot all be pumped back with the recycle. Therefore it will accumulate and be stored in the final clarifiers.



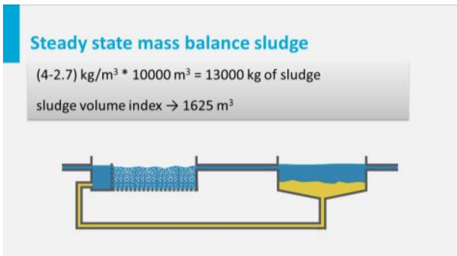
Could you calculate the new equilibrium sludge concentration in the aeration tank?



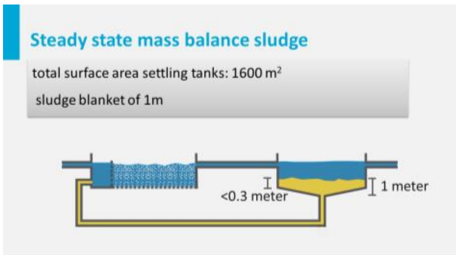
If you take the maximum return sludge concentration of 9.6 g/L, and the mass balance with the storm water flow of 1000 m3/hr,



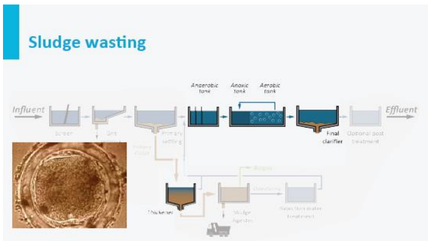
you can calculate that the new concentration in your aeration tank will become as low as 2.7 g/L. This is fine, since one of the rules of thumb is that the concentration in the aeration tank is not allowed drop below 2 g/L.



So the amount of sludge stored in the final clarifier will be (4---2.7) kg/m3 * 10000 m3 = 13000 kg of sludge. With the sludge volume index, you can find that this amount of sludge will take 1625 m3.

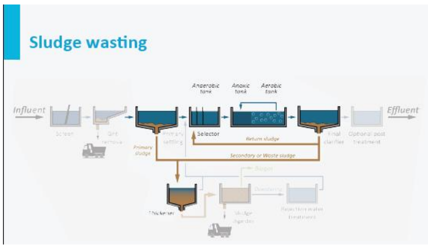


Since the total surface area of the two settling tanks is around 1600 m2, this would mean that the sludge blanket that is stored in the final clarifier is approximately 1 meter. One of the rules of thumb is that storage of more than 30% of the total amount of activated sludge in the final clarifier should be avoided. Furthermore, the sludge level should not increase more than 0.3 meters above the side depth. The situation in this example could therefore indicate uncontrolled biomass wash out.

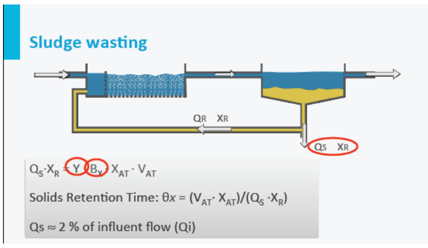


This leaves us with sludge wasting. I told you in the previous lecture that biomass is grows when you feed it, so in order to keep a stable biomass concentration in the aeration tank, the sludge growth needs to be removed from the system. We call this fraction the waste activated sludge or excess secondary sludge to distinguish this flow from the primary sludge,

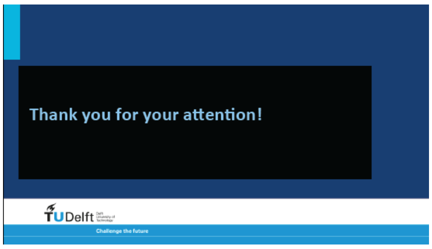
coming from the primary settler.



The two sludges will be transported to the thickner and sludge handling, which will be discussed in Module 6.



The quantity of waste sludge depends on the biomass Yield and the Sludge loading rate. If the amount of sludge wasted from the system is known, the solids or sludge retention time, or SRT in short, can be calculated. The SRT is the average time sludge stays in the process. It is equal to the total quantity of biomass in the system, divided by the quantity of sludge wasted per day. The concentration of the waste sludge before dewatering will be equal to the sludge in the recycle flow. Therefore, the waste sludge flow can be set based on a target SRT. Typically the waste flow rate is much much lower than the influent flow rate.



With this information you are one step further in the design of a wastewater treatment plant. See you next time.