Water and Waste Water Treatment
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Module No # 12
Lecture No # 57
Sludge Thickening

Hello everyone, welcome back to the latest lecture session. We are more or less at the end of our course, I think we have 3 or 4 more sessions to go.

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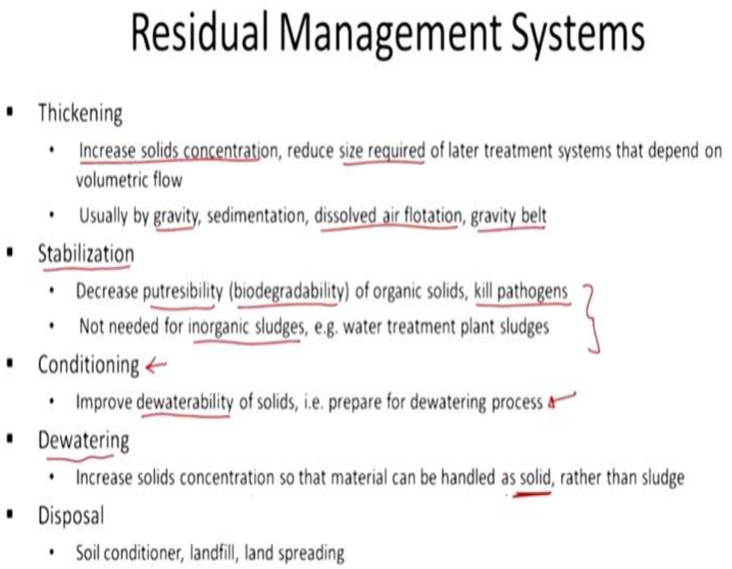

We are talking about the sludge that is coming in. As we look at various kinds of treatment, from primary treatment you have sludge, secondary treatment you have sludge. And we are looking at how to manage it. Let us look at the ways. Residual management. First one is thickening. What is it that I am trying to do? Increase the solids concentration, why?

Because that will lead to reduce size requirement for the later treatment systems and how do we achieve that typically? By gravity and depending upon the type of sludge. Dissolved air flotation or gravity belt and then stabilization, my secondary treatment unit sludge is biomass. It is active or itself that will decay if we do not stabilize it, that is what we are trying to do here.

Decrease the biodegradability meaning the putresibility of organic solids in the meantime or in the process, we want to kill any pathogens that we have in the sludge. If it is inorganic sludge from primary treatment during water treatment or such or if it is grit, we are not going to look at that specifically for organic sludges.

Conditioning, improve dewaterability of solids, later I want to dewater this solid, why is that? Well, I want to decrease the volume that I am going to handle and rather than sludge I want to handle solids which are easier to handle, to do that, I am going to condition it, improve the dewaterability of the solids, how do I do that typically? By adding the relevant cations or such, different polymers.

Then the final step is dewatering, increased solids concentration that as I mentioned, we will handle it as a solid rather than as a sludge and disposal to landfill or applied to soil. We will move through this.

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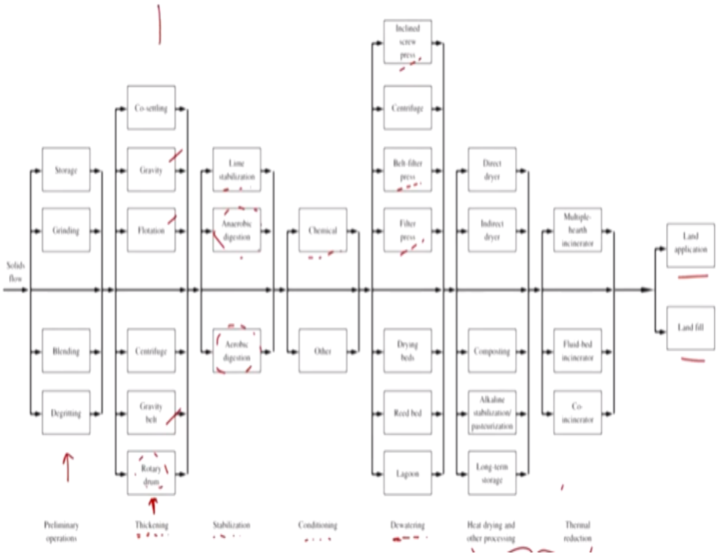

Let us look at the bigger picture here. Depending upon the kind of solids coming in, some preliminary options blending or grinding and then for thickening, increase the salts concentration. You see that we have different kinds, typically we have gravity flotation and gravity belt. These days people are also looking at rotary drum or belt press. And after thickening, we now have greater salts concentration, depending upon the type of solids that you have.

You are going to have stabilization as in anaerobic or aerobic digestion, lime stabilization too is required. That is with respect to pH, we will look at that later. Then conditioning typically, add chemicals so that the dewaterability is relatively better. Dewatering, what do you see here? We see different kinds of dewatering equipment, as I mentioned belt filter press which is also sometimes used during thickening itself or at the stage of thickening itself.

And incline screw press, filter press these are the different ways, then some thermal process if required and then land application, this is the whole cycle. Let us move on and look at where we are here, the first step would be thickening.

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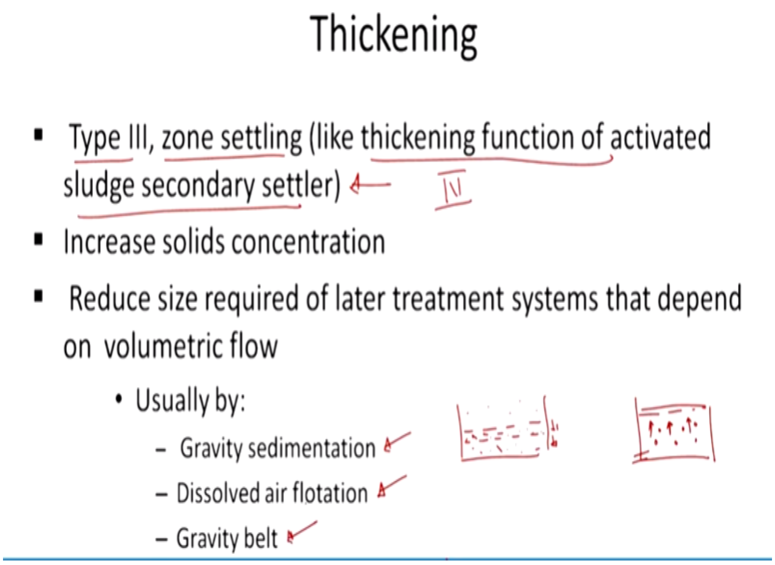

Before I move on to thickening, I just want to give you an idea about what is it that I am trying to do. If I say do something, I need to be clear what are the specific objectives at the end of the day. Maybe in the Indian context, we did not have them. What do we see spelled out clearly, but many countries have them spelled out clearly. I am trying to decrease the concentration of the pathogens in the relevant sludge.

There are other aspects to as I mentioned putresibility or the biodegradability that we want to decrease but major concerns are with respect to pathogens. Fecal coliform and salmonella and how do I achieve that? Aerobic 40 day solids retention time at a particular temperature or 60 days solids retention time at a particular temperature, air drying anaerobic digestion composting, these are different stabilization methods.

But we will look at these later but I wanted to mention them here. When we are talking about pathogen removal, when we look at stabilization. We are more or less taken care of the pathogens and under aspect. To be concerned about though is the metal contaminants depending upon the kind of sludge. If I know it has high enough metal concentration, you did not want to take that sludge and apply that to a land or agriculture land, it has to probably go to a landfill.

You will also need to be concerned about or be aware of the metal contaminants, the usual ones are listed here, that is something to keep in mind. Let us move on. Residual treatment we are talking about thickening up. Thickening, we want to increase the solids concentration, as I mentioned gravity one is the most usual and simpler one. Let us move on. In thickening think of our secondary settling tank there too.

You see some level of thickening there or even in the sludge once you collect it. And by gravity you are going to see thickening, there are different stages here. Upper stages typically type 1 and type 2 but most of the relevant depth you are going to see type 3 and type 4, settling type 3 zone settling. Where you have a clear interface between solids at low concentration or water that is relatively clear at the top and below solids at high concentration.

And then much further down you are going to see compression settling we discussed this earlier. We are not going to look at that in detail here. type 3 or zone settling like the thickening function of activated sludge settler secondary settler. We discussed this in that context you can go back and look at those aspects and much further down you will also have type 4 or the compression settling.

We are trying to increase the solids concentration. And we looked at these aspects, as I mentioned most widely used is gravity sedimentation sometimes dissolved air flotation especially depending upon the type of sludge that you have if you have sludge or the flocs or such that they are relatively more buoyant. Then rather than trying to settle them down, you will inverse the process, you will introduce air under pressure.

That these buoyant sludge particles or solids will move up to the surface where they will be removed in sedimentation. I am trying to see to it that this is the interface, this is moving down here, I have relatively clear water with less solid concentration. Here the solid concentration is relatively high.

This is what I am doing in dissolved air flotation, I am introducing air under pressure and bubbles are formed, they will go up and along with it. They will take some of the buoyant solids and at the top you can remove the solid, you can see it is an inverse of the gravity sedimentation in a way, let us move on gravity belt to especially for primary sludge from water treatment plants.

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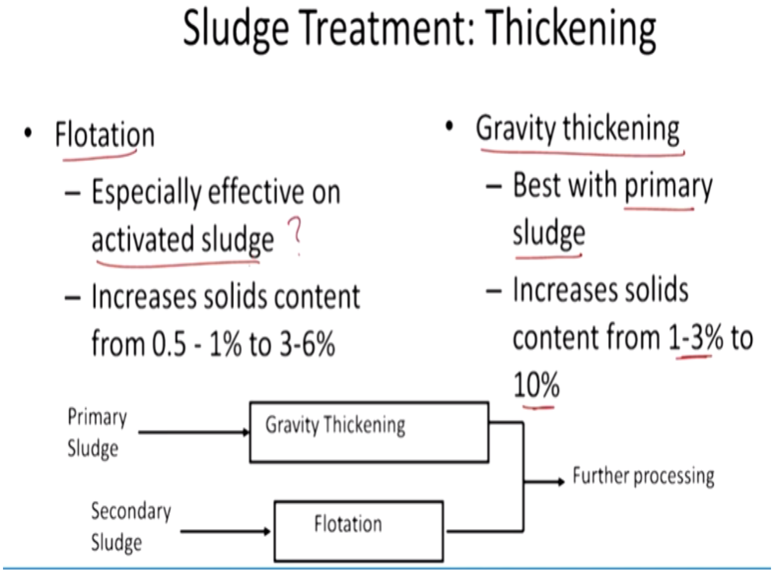

Flotation and gravity thickening, so this is best with primary sludge, it increases the solids concentration from 1% to 2% to 10% or 3% to 10% flotation. It is as effective with respect to activated sludge thickening. Why is that here? The activated sludge is flocs and flocs we have filamentous sump and floc forming bacteria. Note that the cells itself have a lot of water and also there is a lot of water entrapped within the relevant flocs itself.

With that you have flocs coming together one is water inside the cell of the microbes and even for water trapped between the flocs. In those cases especially when you have sludge or particles that are relatively more buoyant are salts which are relatively more buoyant. You will use dissolved air flotation and we can concentrated to 3 to 6% primary sludge typically gravity thickening and secondary sludge flotation and then for further processing later on stabilization or such as required.

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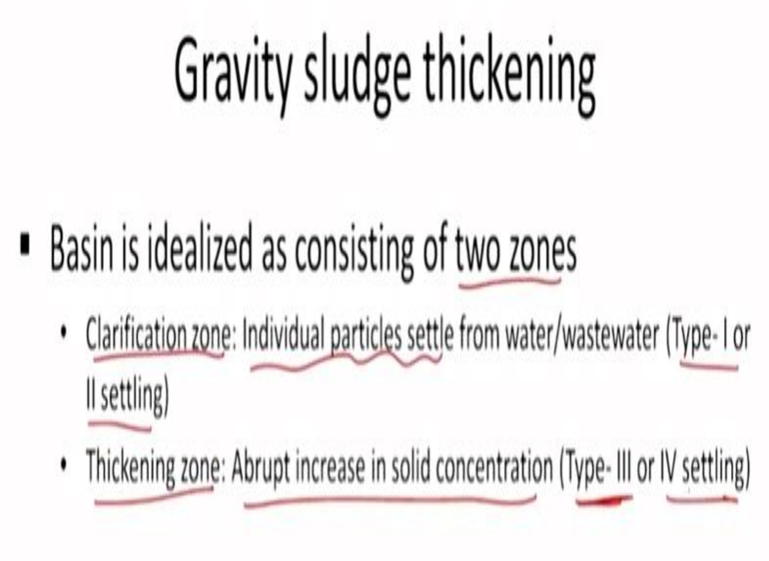

Gravity sludge thickening, so it has 2 zones the first one upper zone is the clarification zone the one below it is the thickening zone, here as I mentioned earlier we are going to witness type 1 and type 2 where we have relatively discrete settling, individual particles settle. Thickening zone, where we have increase in concentration and typically we see the zone settling and much further down.

You can maybe see the compression settling, these are the aspects to be looking at. Let us look at the figure if I have it.

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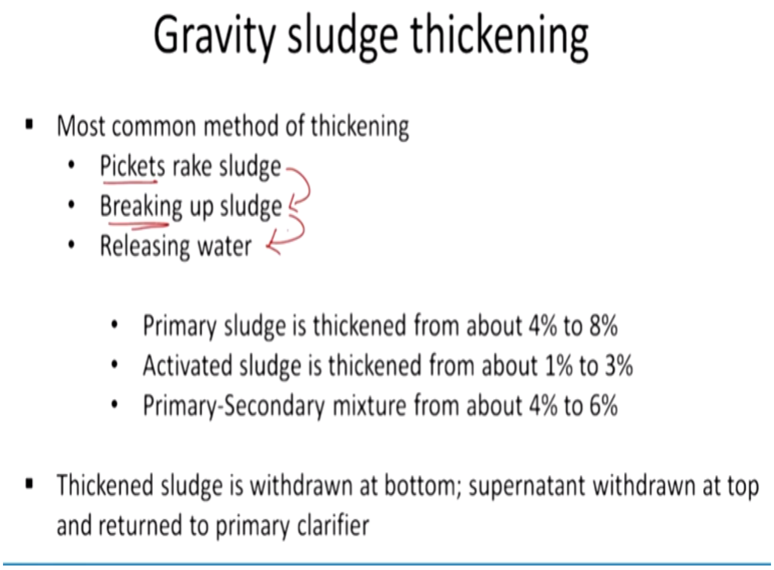

As I mentioned pretty commonly used is gravity sludge thickener and you want to gently break up this irrelevant sludge. You have going to have pickets that rake the sludge. We will come back to that. Why is it we want to break up the sludge? so that it can release the water.

That is the key issue. Why do we have them to break up the sludge? Why do we want to break it up? It is easier to release the water.

Primary sludge can be thickened from 4 to 8%, activated sludge 1 to 3%. Even that is considerable.

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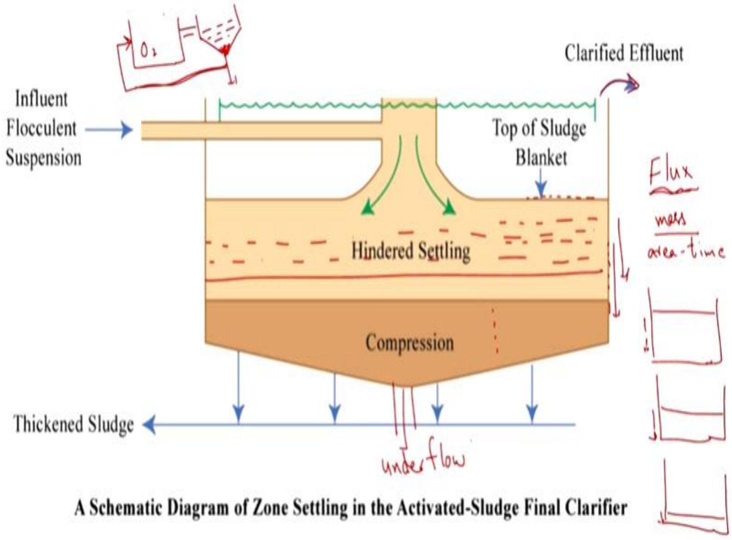

And I figured this is easier to look at, here I have influent or flocculent suspension. And here I have the top of the sludge blanket where we can see the zone settling, and then maybe the type 4 settling at the bottom here. Here we have the supernatant, which is clarified effluent. Here there are 2 aspects to note here because of the zone settling.

There is one kind of flux, the term I am using is flux. Flux here is mass of the solid source such per area per time or through a particular cross-sectional area which is this, how much mass is going through per time. And as I am in steady state, But in general, if I take a batch system, that it is going to decrease. It is going to come down as an initially my interface is here, after some time the interface comes down.

And maybe further down here, so there is a velocity with which this interface comes down. Let us so that itself will lead to a certain flux mass per area per time and what is the other flux that is going to be relevant here? The sludge that is going to be collected at the bottom, you are not going to let it accumulate all the time. What are you going to do? You are going to take it out.

For example, if it was the secondary treatment system for the wastewater, we know that we have the aeration here where we give oxygen. And here, we let it settle down. Here it is not entirely sludge, what are we doing here? Even there you are going to have type 3 settling but this sludge, what are you doing. You are not wasting everything you are recycling it here.

We are going to have an underflow because you are removing the flow from the bottom or the solids from the bottom. Similarly, here also you will remove the solids from the bottom, the ones that have been or the solid or the sludge that has relatively thickened, you are going to remove it. It is similar to what we are doing in the secondary settling tank, this sludge is going to be remote.

There are 2 fluxes, one because of the zone settling, and the one because of the underflow. One because of the underflow that is something to keep in mind, let us move on and look at what we have.

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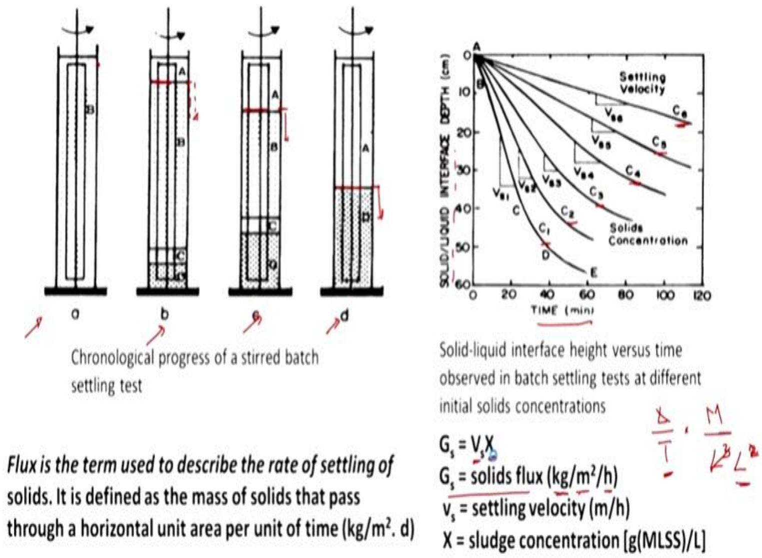

To be able to get that you sometime need to conduct batch tests this is what I was mentioning earlier. Here, you have different batches and you can see that the zone settling you can see this particular interface coming down with time. And it is gentle mixing and batch so the zone 3 or type 3 settling.

There is a velocity with which this interface is going to come down and that velocity you can plot for different concentrations, why is that relevant? We will look at it what do we have. We have time and we have solid to liquid interface depth and we can plot that for different concentrations. As I mentioned the solid flux? Solid flux is mass per area per time.

What is it equal to? It is going to be equal to the velocity, this velocity that you are measuring into the concentration of the sludge, velocity's dimension is L per time and what do we have here? This is the concentration. If I have mass, mass per what is it? Per volume litre cube, so l it becomes L square.

Mass per area dimension square per time, that is what we have. Velocity of that particular interface into x the concentration of that particular sludge. That is something to keep in mind.

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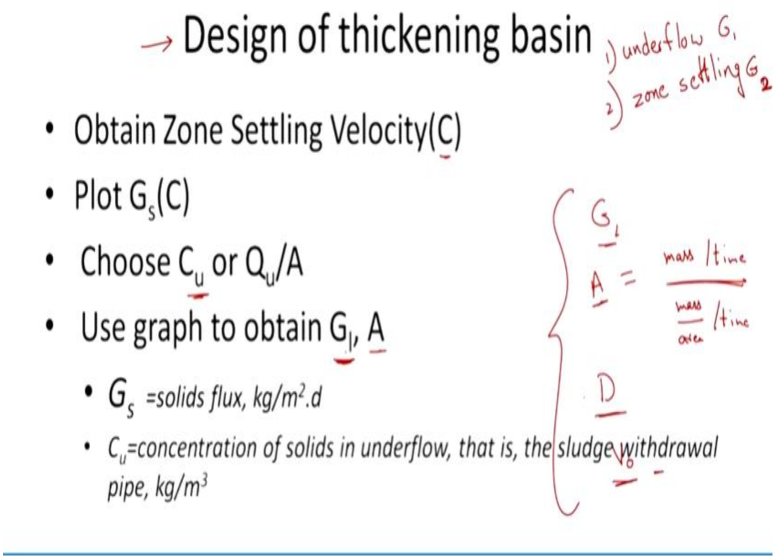

Design of thickening basin, 2 aspects to understand here. There are 2 fluxes as I mentioned 1 due to the underflow and the other one due to the zone settling. In this context we have 2 fluxes, let me call the G1 and G2, we will look at the relevant aspects later, understand this, I am putting in sludge at particular rate into the relevant thickening tank, our gravity thickener.

And I am removing it under flow at a certain rate. But also, this thickening is occurring due to type 3 at a particular rate. You have 2 fluxes, if the rate at which I am putting it in is greater than this overall flux or the total flux, the limiting flux, we will look at that later. What is going to happen? This interface which has been at steady state or which is at steady state, you want it to be 1 meter above the relevant bottom, it is going to increase.

And if I am still putting in a lot more than I can remove or that then I am removing, what is going to happen? It can even lead to overflow and your effluent will not be clear, that is one some something to keep in mind. And that is why we need to design for the thickening basin.

Let us move on. We can obtain the zone settling velocity, we will look at the graphs, you know how to do that.

The previous one and you are going to plot G and from that you will choose the Cu, or Qu by A, we will look at the relevant graph and use the graph to obtain the limiting flux and from that you can get the relevant cross-sectional area. For example, once I get the limiting flux G limiting and I know the mass loading rate or the rate at which the solids are coming in mass per time.

I have mass loading rate, mass per time and I have the limiting flux which is mass per area per time. From this as you can see if I divide the loading rate by the flux, I am going to get the cross-sectional area that is required, from this cross sectional area if it is circular, I can get the diameter and then check for that particular diameter.

And then I will also have to calculate the overflow rate and see if the over flow rate is acceptable or not, that is one way to go about it. Let us move on and see how we can get this limiting flux solids and concentration in the under flow.

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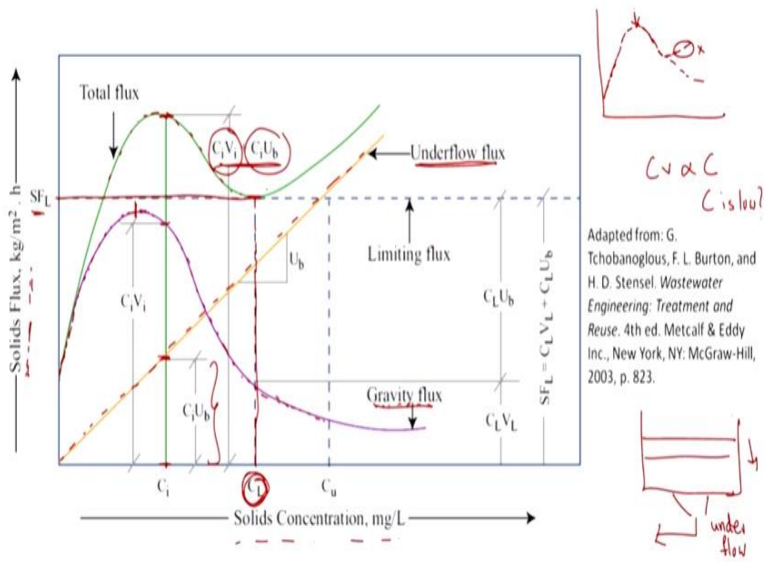

Here we see 2 aspects, first let us understand the figure. We have solids flux here and here we have solid concentration. Note that if this is the graph and now, I am talking about this gravity flux, the one due to gravity or due to the zone settling. At low concentration, more or less, it is going to be equal to the flux, concentration into this particular velocity, which term are they using? V. C×V is going to be proportional to the concentration when the concentration is low, why is that?

Because when the concentration is low it is more or less like the particles are not being affected by one another when they are settling down, it is more or less like discrete settling, there you are going to have relatively low velocity, soft settling of that particular interface. And then you are going to reach an optimum where you are going to have optimum due to this zone settling.

And then it is going to decrease because then you are going to have compression settling, that is what you see here. The gravity flux first when at low concentrations, it is like discrete settling, initially only and then at relatively higher concentrations, you are going to see the zone settling or the type 3 settling and that is when you have the peak. And then you are going to have hindered settling if you keep increasing the concentration.

And that is what you are going to see. And then hindered settling, this is the peak that you are going to have but as we know that in the treatment gravity thickener, one is the flux due to the zone settling the other one is because you are also removing the sludge due to the underflow, there is a flow here, that is the under flow flux and that is what we have here, under flow flux.

There are 2 fluxes as I mentioned earlier, one is due to the gravity flux and other is due to the underflow flux. The total flux as you can see is this green one. And this here is the limiting flux in the operational range. This one will be the limiting flux and this is how you can get it from the relevant graph. And that the concentration is called CL.

That is something to keep in mind, CL. This is the relevant aspects. If we look at it at this particular point or this particular concentration, what do we see? There are 2 aspects of the total flux, one is due to the underflow, that is what we have here. The other one is due to this particular gravity flux, which is this particular part, so that is something to keep in mind.

The total flux will be one due to the underflow, one due to the gravity flux, that is something to keep in mind. And from this figure at this particular point, you will have the limiting flux.

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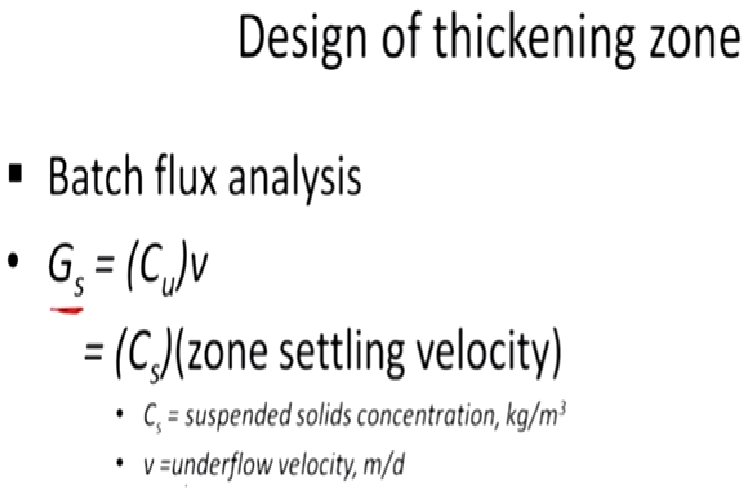

Let us move on, design of thickening zone. As I mentioned we will have the batch flux analysis. And this will be equal to CS into the zone settling velocity, where CS is the concentration of the suspended solids concentration and V here is the underflow velocity.

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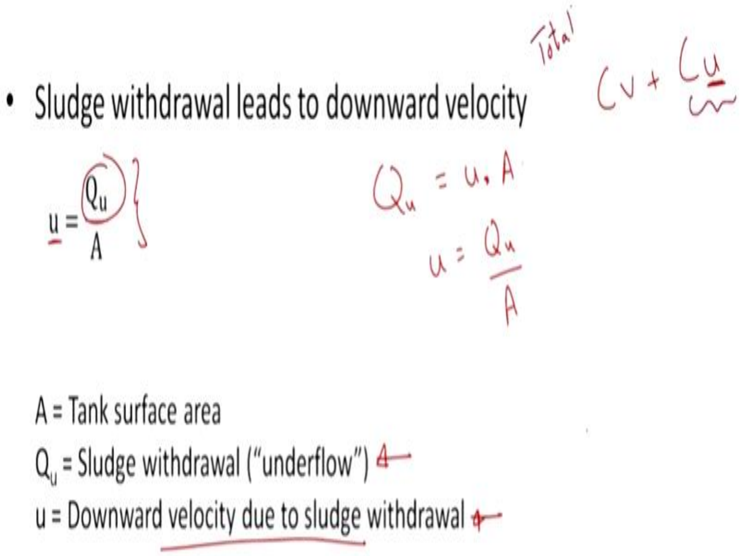

One aspect to note sludge withdrawal rate, Qu is the sludge withdrawal rate which is the underflow Qu, it is going to be velocity times cross sectional area, this velocity how do I get that? It is equal to Qu by A. Why am I looking at this? Because as in the total flux, I have 2 aspects one is concentration into the velocity of that particular gravity flux interface.

And the other one is concentration into the downward velocity due to the sludge withdrawal, this one too I need that. How do I get that? I get it from relevant tank surface area and sludge withdrawal, that is the second term here when we are calculating the total flux.

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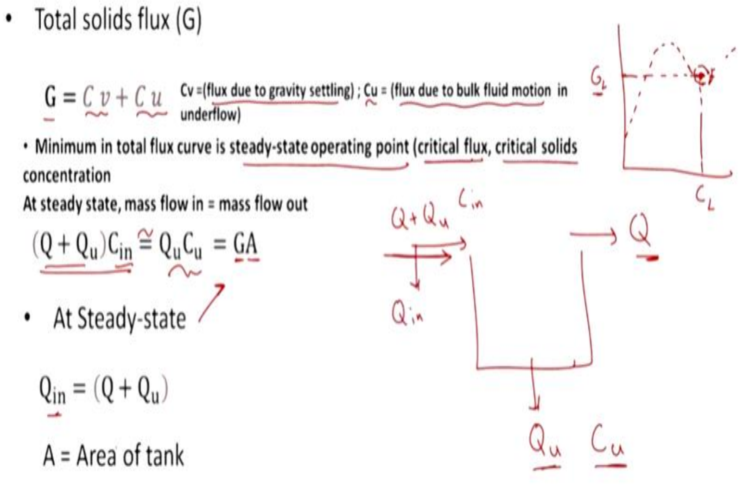

Total flux G is equal to C into v, flux due to gravity settling and C into u is flux due to the bulk fluid motion due to the underflow which I am withdrawing. And typically, the minimum total flux or minimum in total flux is the steady state operating point or critical flux there. Earlier we saw this particular kind of graph, this is the critical flux.

G critical or limiting and at this point you are going to have this critical solid concentration. This is what we are talking about critical flux and critical solids in the previous one, that is something to note. In general, you would want to maintain your steady state, once you start operating your gravity thickener, you are going to maintain it at steady state.

In that context you have to maintain it around GL, this limiting one at steady state and if I add much more, what is going to happen? And if I add much lesser to the tank, what is going to happen? We will look at that. Before I go further, how is the sludge coming in or how is it coming in? Here I have the tank, Q + Qin and Qu under flow is coming here, Q is going out.

This is the supernatant which is relatively clear and here I have the Q underflow and here the concentration is Cin and here the concentration is relatively higher, Cu, that is something to keep in mind. And here it is relatively clearer or lesser concentration. First, Q + Qu into C in the mass of solids coming in is more or less or approximately equal to Qu into Cu.

We are assuming that most of it is coming down in this underflow, so Qu into C and that is going to be equal to the total flux, total flux into the cross sectional area that is something to keep in mind. And this is what at steady state as Qin is equal to Q + Qu, Qin and A is the area of the data that is something to understand.

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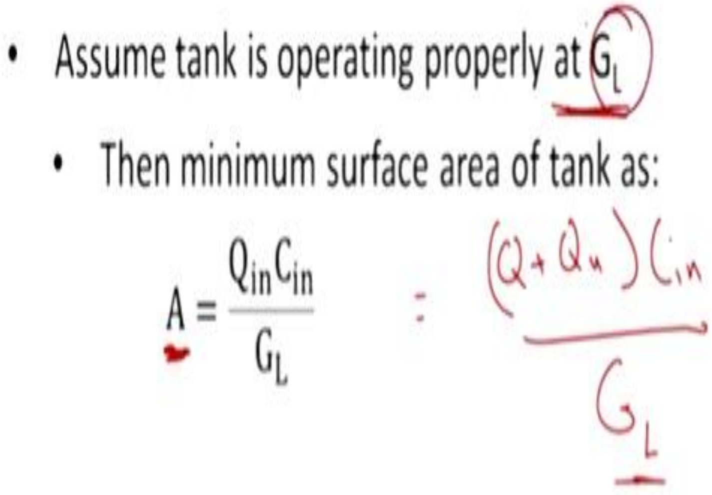

The cross-sectional area A is Qin and Cin is Q + Qu into Cin by GL, this is what I mentioned earlier in the design the loading rate by the limiting flux then you will get the cross-sectional area, this is what we discussed earlier to if you remember this is the minimum surface area of the tank, that is what we see required assuming that we are planning the plan properly at steady state flux of flux that is equal to G limiting that is something to keep in mind.

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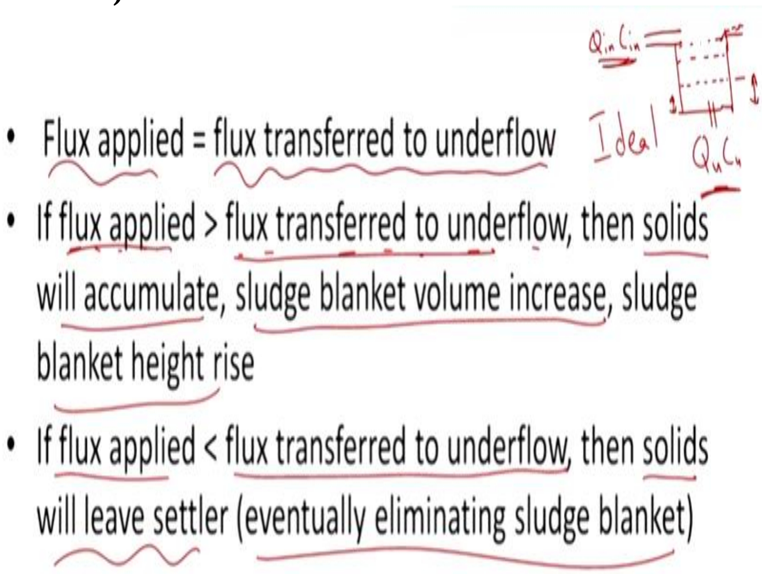

Flux applied is equal to the flux transferred to underflow, that is the ideal case, this is the ideal case. The flux that is coming in, Q in C in will be equal to Qu Cu, we are talking about the solids here. Most of solids we are assuming are being removed from here, it is not what we say. We are assuming that relatively little is going out, that is something to keep in mind.

Let us look at that but if the flux applied is greater than the flux transferred to the underflow. If the total underflow one is relatively lesser than the flux that is coming into the tank, then what is going to happen? Solids will accumulate in the system earlier if my zone is somewhere here maybe now. Depending upon how much more I am putting in the zone which was here or the interface will be here.

And if I keep adding much more, it is going to go somewhere out here and then you can have overflow. The sludge blanket volume will increase and sludge blanket height. This is the sludge blanket height, it will also rise if the flux applied is less than the flux being removed through the underflow or to the underflow then what is going to happen? Here this sludge blanket depth will decrease.

And then solids will leave the settler solids will leave the settler, eventually eliminating this sludge bracket. And that is something also that you do not want to have eventually eliminating the sludge blanket, that is something to keep in mind. We want to see to it that the flux applied is more or less near or such equal to that flux from calculated from that G limiting, so that is something to keep in mind.

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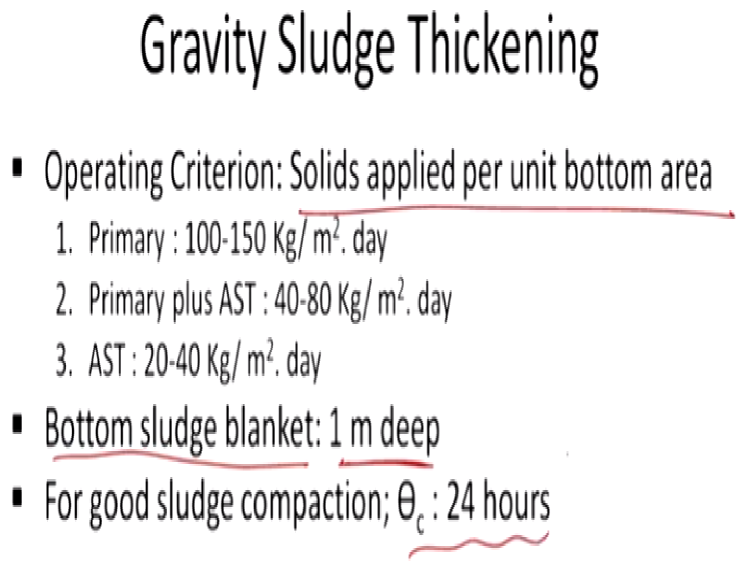

Gravity sludge thickening, let us look at what we have. What are the operating criterions? Solid applied per unit bottom area. How much solid am I applying per unit bottom area? That is something to keep in mind. And typically looks like for primary, it is 150 kgs per meter square per day. And for primary it is relatively lower. And for AST, it is much lower, depends upon how easily the relevant particles can be separated or the velocity of that particular zone settling.

That is something to keep in mind. And as I mentioned, the bottom sludge blanket. It should be one meter deep, let us write ideal one. For good sludge compaction, we want retention time to be around 24 hours, typical 24 hours, this is what we see out here.

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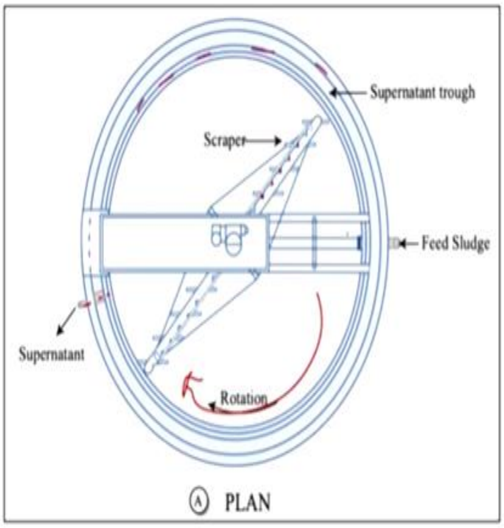

Figure by MIT OCW. Adapted from: Reynolds, T. D., and P. A. Richards. *Unit Operations and Processes in Environmental Engineering. 2nd ed.* Boston, MA: PWS Publishing Company, 1996, p. 631.

I am feeding it here and you can see the relevant pickets, I think, this is the top view and it is rotating in this manner and slowly but surely you are going to have the supernatant leaving from these troughs which are at the periphery.

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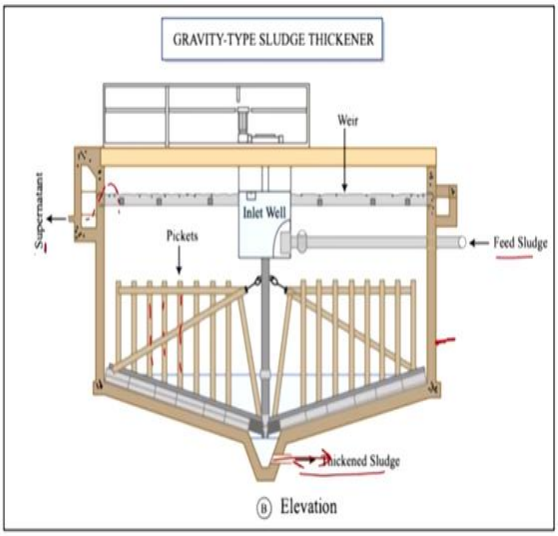

Figure by MIT OCW. Adapted from: Reynolds, T. D., and P. A. Richards. *Unit Operations and Processes in Environmental Engineering. 2nd ed.* Boston, MA: PWS Publishing Company, 1996, p. 631.

Let us look at this. These are the pickets, we are not going to have mixing, that is going to share the flocs are such. You are just going to have gentle mixing so that you are going to have some concentration of the relevant solids that is something to keep in mind. Here you are going to have the thickened sludge removed, this was the underflow, that is something to keep in mind. Feed sludge coming in.

And then you are going to have the sludge blanket somewhere here or such. And then the underflow out here. And then the supernatant, it is going to be removed in this way, that is something to keep in mind.

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Another one is the gravity belt thickener. Here the principle is that typically used for water treatment plant primary sludge, you have a belt keep in mind that here is still gravity. And on the belt, you are going to have different rakes or such says the sludge moves in these rakes, they are going to part or cleave the relevant sludge. And then you are going to have a relatively permeable belt.

And by gravity, the water is going to be collected at the bottom. There is one more aspect. Let us look at that. When we see the figure, gravity belt thickness, what do we have? Sludge is applied to a fabric belt which will allow the water to flow through it. Water drains through the belt as I just mentioned, and sludge is turned over by blades, depending upon the type of sludge polymer coagulation will be needed.

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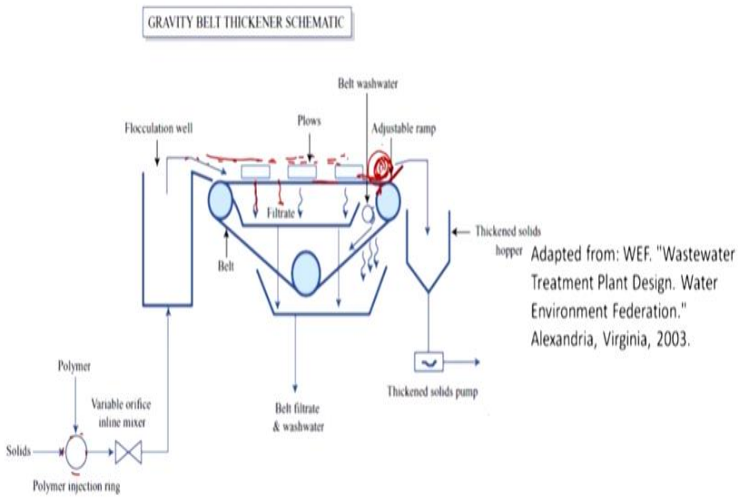

What we have here? I am adding the polymer and here is the flocculation tank, I am going to have the flocculation. And then as this particular sludge moves here, I am going to have ploughs or sometimes rakes that will cleave the relevant sludge. In the meantime, the water is going to filter through this fabric. This is my fabric, let us write sometimes you will have more layers as you can see here sometimes not less.

And so this sludge after it comes here, it is going to back up here and it is going to fall back here, the sludge is moving in this direction gently and it is going to fall back here. Here you are going to have more retention time and also more dewatering at this stage, that is one aspect to keep in mind. That is why they have this adjustable ramp here depending upon the time they want the sludge to spend here, that is something to keep in mind.

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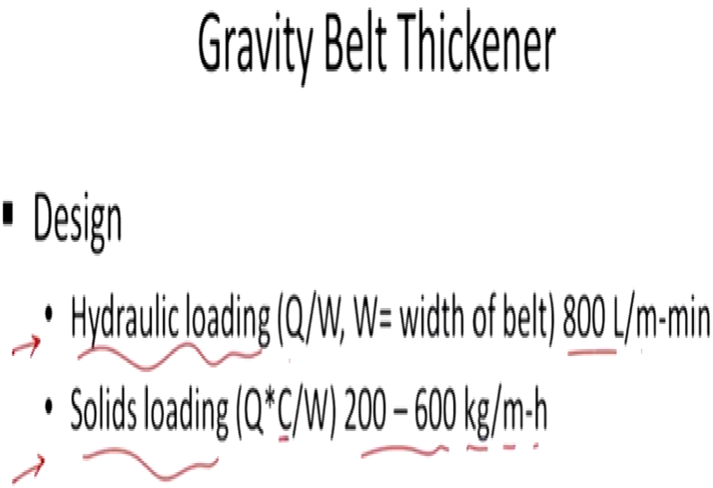

And what else gravity belt thickener, it is about hydraulic loading and looks like that is around 800 litres per meter per minute. And solids loading is around 200 to 600 kgs per meter per hour. General values, you do not need to mug these up for the exam or such or even for the homework.

These are general values that we want. To mention them here one is hydraulics loading with respect to water. And here with respect to solids, that is why we are multiplying it with the concentration, that is something to keep in mind.

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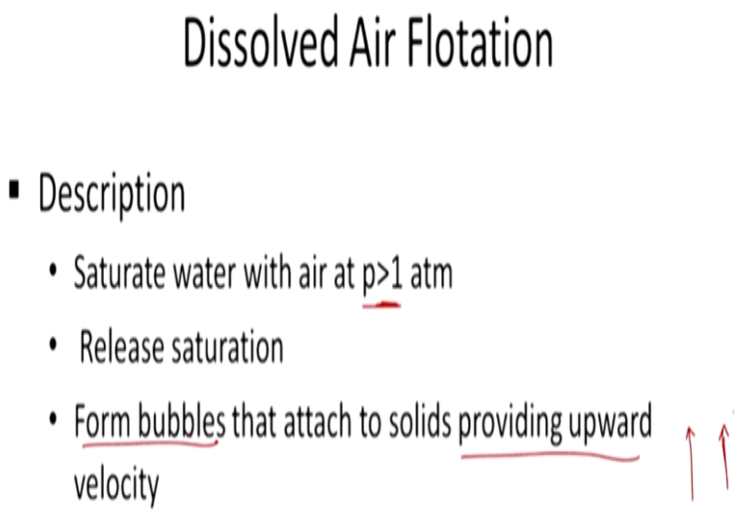

Dissolved air flotation, as I mentioned especially in the context of secondary sludge settling tank sludge where the flocs are relatively more buoyant. And you have water entrapped in the flocs, that is when you will typically look at dissolved air flotation. Let us look at what we have. We already discussed this. I am going to move on.

Saturated water with a relatively higher pressure is going to be pumped in and you are going to reach saturation. And what is it that we are trying to do? We are going to form bubbles and they are going to attach to the solids. And these solids are now going to be moving up, this is the reverse of the gravity settling or thickner that we looked at earlier.

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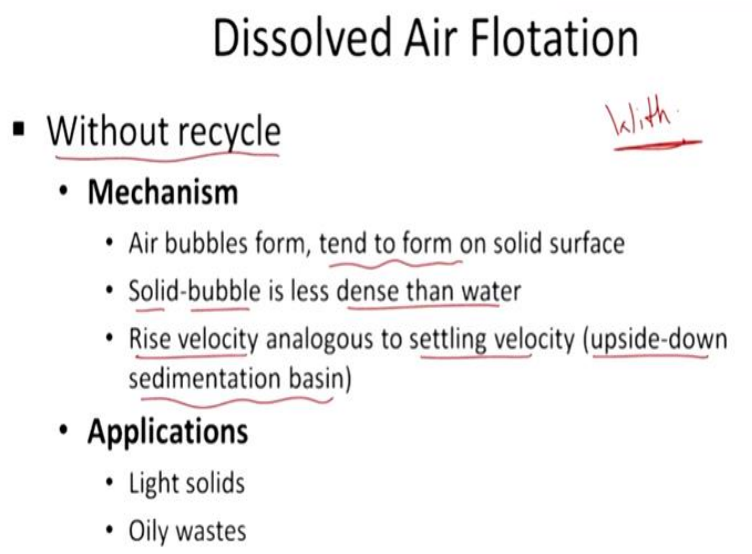

Let us see there are 2 ways or 2 modes of dissolved air flotation. One is without recycle and the other one is with recycle. We will look at the figure for with recycled soon. Without recycle the mechanism air bubbles form and they will take the relevant solids onto the solid surface and solid and that bubble part is going to be less dense than water, that is why it is going to move up.

This rise velocity is similar to the settling velocity as I mentioned, it is upside down or similar to the upside down sedimentation tank. Applications, where is it? Typically for light solids or oily sludge.

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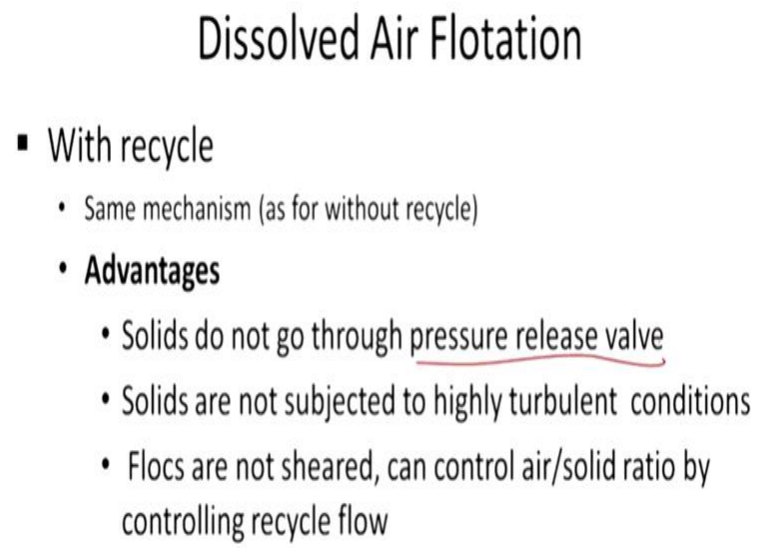

As I mentioned, so with recycles same mechanism as without recycle. But what are the advantages, we will look at the figure. Solids do not go through the pressure release valve, let me look at the figure and then we will come back to these advantages.

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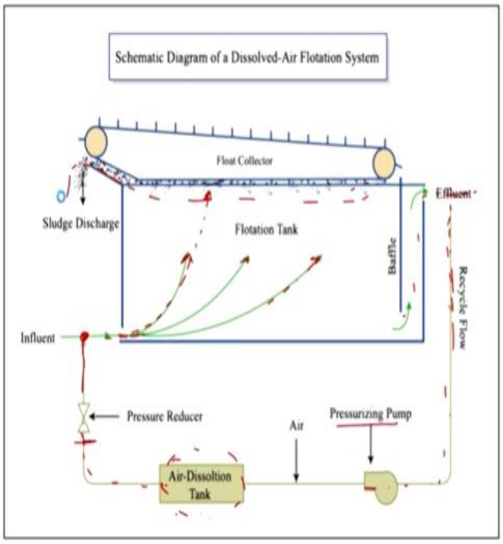

Figure by MIT OCW.
Adpated from:
Viessman, W., Jr., and M. J. Hammer. *Water Supply and Pollution Control. 7th ed.*
Upper Saddle River, NJ: Pearson Education, Inc., 2005, p. 678.

Here we see that we have the pressure reducer or pressure release wall, we are going to have the pump which is going to pump the air. And here we have the air of dissolution tank, air is being dissolved it is mixing with the influent. And then it is coming in here. And as you see, some of the effluent is being recycled. In the earlier case though, that would not have been it, the water or the air would be directly spent up here, that is why there are some disadvantages in the system without the recycle.

Let us look at and see what are the advantages with this recycled, as you can see the recycle flow, you are pumping the air into that recycled flow. And then that is coming in contact with the influent. And here you have the relevant lighter particles being formed because of the air bubbles and the solids on the air bubbles. And these solids being lighter than water, less dense, are going to be collected up and you have a float collector where the sludge is being taken out or collected, that is the relevant aspects.

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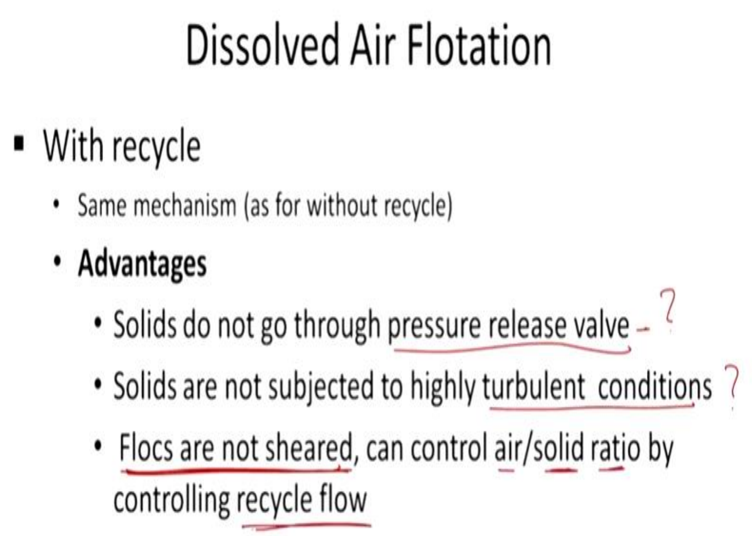

Now let us look at the advantages, solids do not go through the pressure release wall, why is that an advantage? Because of that there are no turbulent conditions. Why is that important? Because then the flocs are not sheared, this is the relevant aspect, flocs are not sheared, if flocs are sheared, you are going to have issues with respect to thickening.

The flocs have not sheared it, that is not thickening with respect to separation and being taken up. And we can control the air to solid ratio by controlling the rate of recycle flow by the rate at which you can recycle it. You can control the air to solid ratio which is analogous to controlling the amount of water we say discharge or the sludge that is going to be collected at the top.

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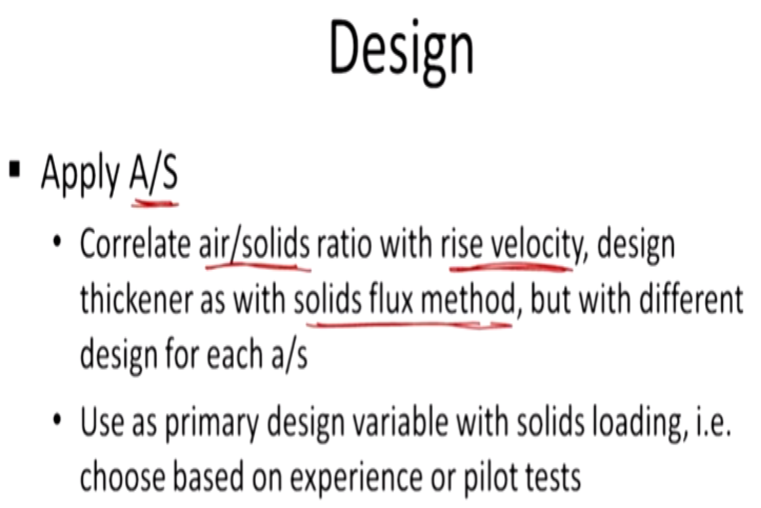

Design aspect, typically we look at air to solid ratio and then we are going to correlate this ratio with the rise velocity and the design thickener as with solid flux method earlier with respect to the solid flux method in the gravity thickener we looked at it. In the similar manner, here we are going to look at the air solids ratio and look at it in conjunction with rise velocity, that is something to keep in mind, let us move on.

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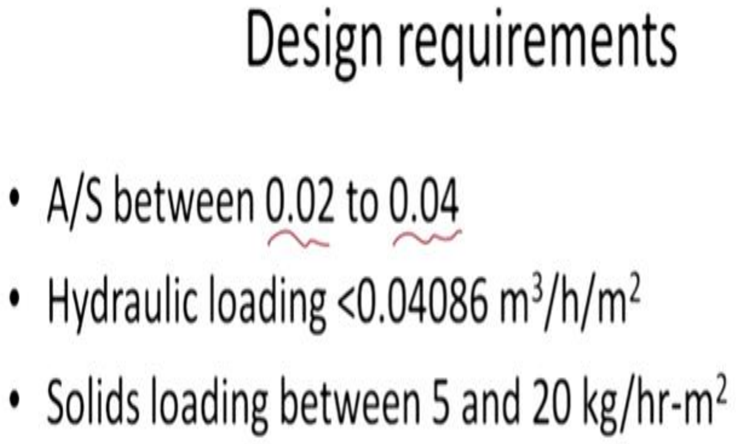

Design requirements, typical air to solid ratio as you can see is not very high but significant enough 2 to 4% and hydraulic loading rate. And one aspect to note is that typically because of the mode of operation, the area required for dissolved air flotation devices is going to be relatively lesser than the one that is required for your gravity thickener. That is something to keep in mind. But the kind of sludge that the gravity thickener

Can deal with and the kind of sludge that the dissolved air flotation can deal with are relatively different. Some people mix it but note that lighter sludge relatively better with dissolved air flotation. In the next session, we will move on to stabilization. Until now, we looked at increasing the solids concentration, removing as much Water as we can, or increasing the concentration of the solids in my particular sludge.

That is what we have done. In the next step, we are going to look at decreasing the organic concentration or the biodegradability of the relevant sludge. With that I will end today's session.