Water and Waste Water Treatment
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Lecture -15
Sedimentation: Discrete and Flocculant Settling

Hello everyone, welcome back to the latest lecture session, very quick recap of what we discussed in the previous session. We were talking about sedimentation in the context of removing the suspended particles in the waste water or for that matter whatever let us see and why are we doing that? Because it is easier to do, if not you are going to have issues down the line and also if you remove some organic content.

It is cheaper than providing oxygen and trying to remove the organics later. But, here the stress is not on removing organic contents per say the stresses on removing or the goal is to remove the suspended matter and then during that removal some of the organic content or BOD will also be removed. In that context, we saw that there were two four types of sedimentations or settling.

Type 1, 2, 3 and 4; the first one is discrete as in the particles do not interact and in that context we saw that Stokes law, or is applicable for laminar flow conditions for spheres and then we also looked at coefficient of drag and relevant laminar conditions turbulent conditions . Then we looked at the critical variable which is the surface overflow rate.

In the context of both the upflow and the rectangular flow we saw that let us see, now let us look at this particular upflow clarifier let us see. Up flow, the water is going up particle wants to settle down. If this velocity is higher than this, the particle will move out along with the water but if the settling velocity is higher than this particular water velocity , the particle is going to settle down.

In that context, we came up with the surface overflow rate and we also looked at the same aspect for our rectangular flow not rectangular pardon me for the horizontal flow conditions. In the horizontal flow, we saw that V_0 is the relevant threshold. If the settling velocity is greater than or equal to that, yes we are going to have removed but if it is less than that, it is not going to be 0% or such it is going to be a fraction.

Why are we assuming that the particles are uniformly distributed? If the relevant particle comes in at the certain height, it might be removed just be removed but the ones above it might not be removed and we looked at that. Let us look at it in relatively greater detail.

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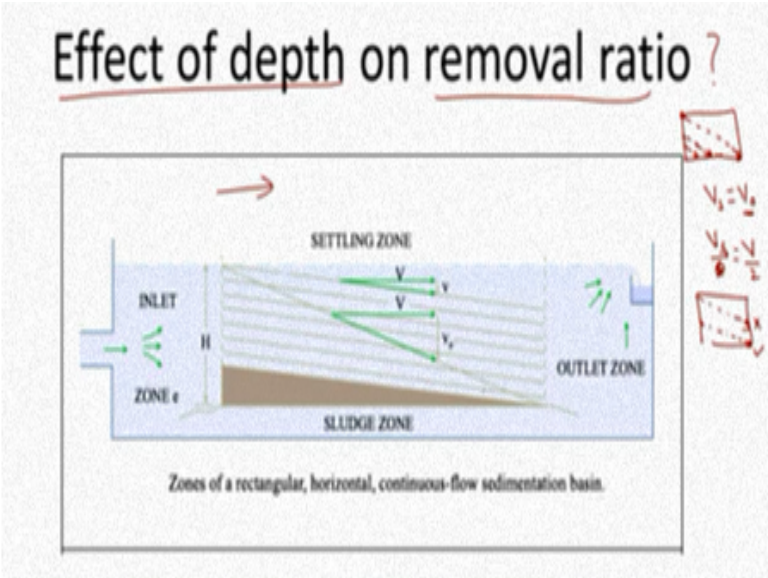

What is the effect of depth on the removal ratio is it? We have this basal and this is the relevant V_0 and if V_s is equal to V_0, it will just be removed. If it is coming at the topmost location but, if it is coming at the bottom location not bottom less than the top when V s equal to V_0 that particle will be removed.

But what about the case when the V_s is half of V_0 now, what is that going to be the case? In that context, if the particle is coming up at the top, so it is going to get out here. Let us see get out here so, it is not going to be removed but if it is coming out at H / 2, then you are going to have removal.

But you are going to have fractional removal. Let us look at this effect of depth on removal ratio, so what we discussed, just discussed is what we have out here let us see keep in mind that the flow rate is relatively constant, the horizontal flow rate is what do we see not horizontal flow rate, horizontal velocity is constant let us see, we are dealing with this what we say theoretical value of V_0.

Here we have relevant conditions V and V_0 and we can see which one will be removed or in which case it will not be removed let us say. That something we already just discussed in detail.

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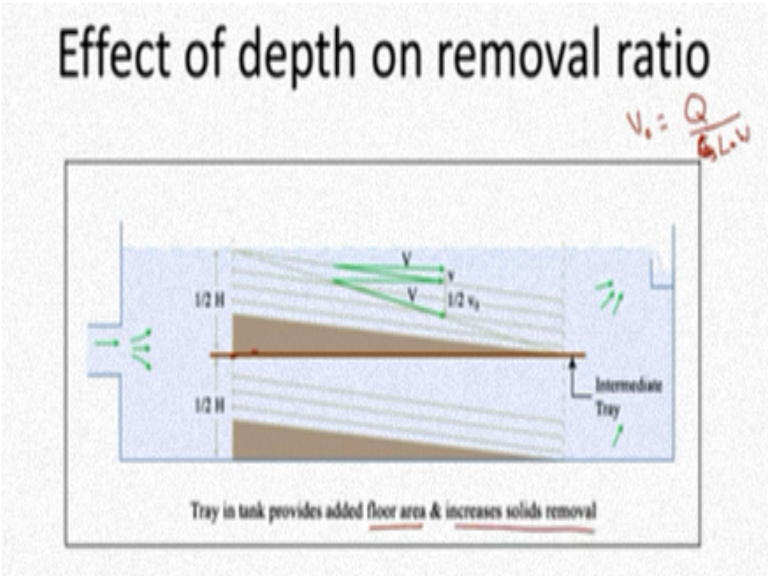

Let us look at this if I decrease the relevant height what is going to happen will it increase, decrease or not be affected, as you can see and as we also saw from the relevant equation, we see that the tank depth does not increase or decrease the removal ratio let us see because the flow rate is also going to what is it now the flow rate is relevant or relatively the constant.

Flow rate is constant though, even though if you decrease the height it is not going to change your relevant efficiency of removal of the suspended solids, because what we are concerned about is just this V_0. If I decrease the height, the horizontal flow velocity will increase compared to this case. That is what we have a particle which at H would be somewhere out here.

It is now somewhere out here because, this horizontal flow velocity you has increased, bbecause you are decreasing the height reduced tank depth as we can see does not really affect it but what can you do? You can provide a tray an intermediate tray out here how is that going to help half H and half H that will help by increasing this surface area.

As we saw what is it now V 0 will be depend upon what is it Q by surface area a s for rectangular basins it is from the top view we know that, it is length into width let us see that is what we have, so here by what is it providing in the tray we are effectively decreasing this V 0 if we may say so ? , you see that train the tank provides added floor area and thus leads to increased solids removal.

That is something to keep in mind. We just looked at the effect of depth on removal ratio.

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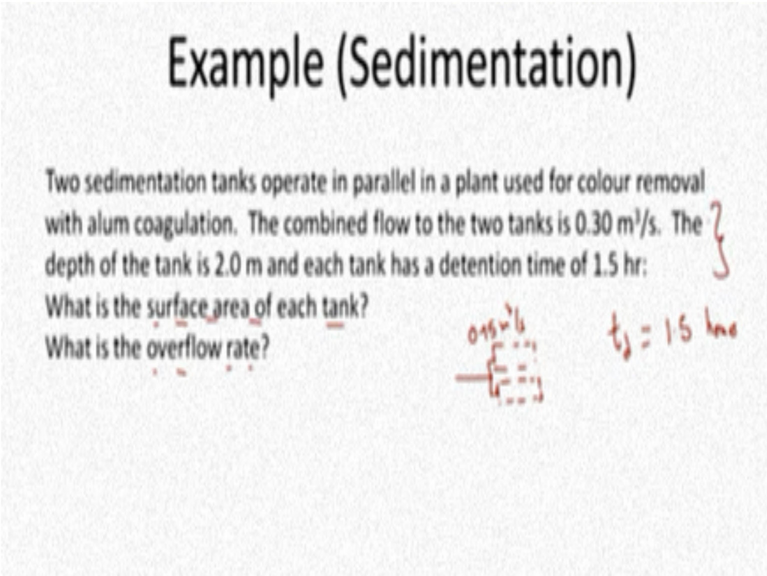

Let us just look at one example; so two tanks in parallel flow is coming in and we have two tanks in parallel and they are used for colour removal but looks like with alum coagulation but we are not concerned with the coagulation flocculation part out here we are only concerned with the sedimentation. This example, I should have used after type 2 but, never mind it is a general example.

The combined flow rate is 0.3. Through each it will be 0.15 meter cube per second and the depth of the tank each tank is 2 meters and each tank has a detention time of 1.5 hours. What is the surface area of the tank and what is the overflow rate that is going to be relevant to these particular variables.

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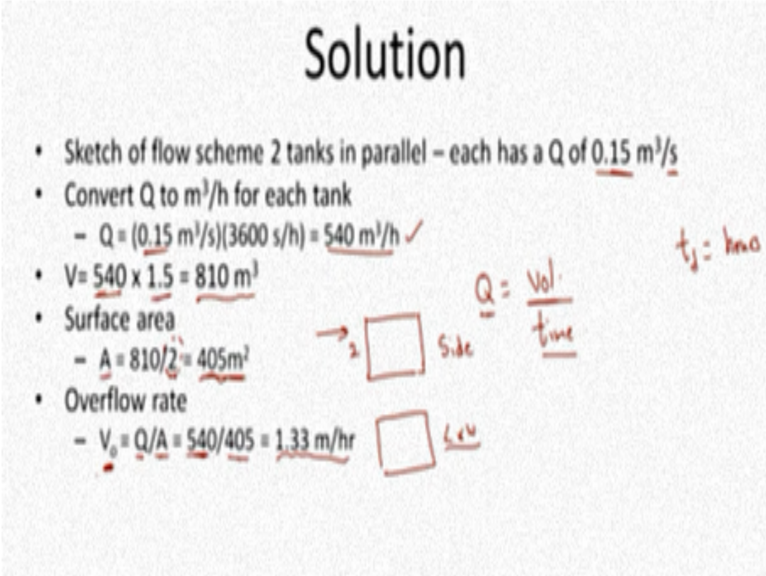

Well pretty simple calculations. Two tanks in parallel, so flow rate is half of the total Q from meter cube what we say convert Q to meter cube per hour for each tank. Looks like it was given in seconds but our time for detention was given in hours. If there are errors in the calculation that is fine you can just correct that yourself and volume is what is Q is equal to volume per time.

If I want to calculate volume I need to multiply Q the flow rate with the relevant time and I get the relevant volume of the relevant tank. This is the volume for each tank because the flow rate that I have used is the flow rate through each tank, let us see. I have the relevant volume and now the depth is given, so depth was given to be 2 meters.

From that I can get the so this is 2 meters and the flow is going in this direction, this is the side view but I need the surface area from the top if I look at the top view l into w is what I want let us see, so what is it that we have that turns out to be 405 meter square let us see. Now, I once I calculate the surface area, I can calculate the overflow rate it is pretty straight forward Q by surface area lets 540 by 405 also looks like it is 1.33 meter per hour.

That is just some algebra but this is not the design we will look at the design in greater detail later. Q and time was given, so we calculated the volume and we already had the depth we calculate the relevant surface area and from the surface area we calculated the overflow rate which gives us the relevant threshold, so let us move on.

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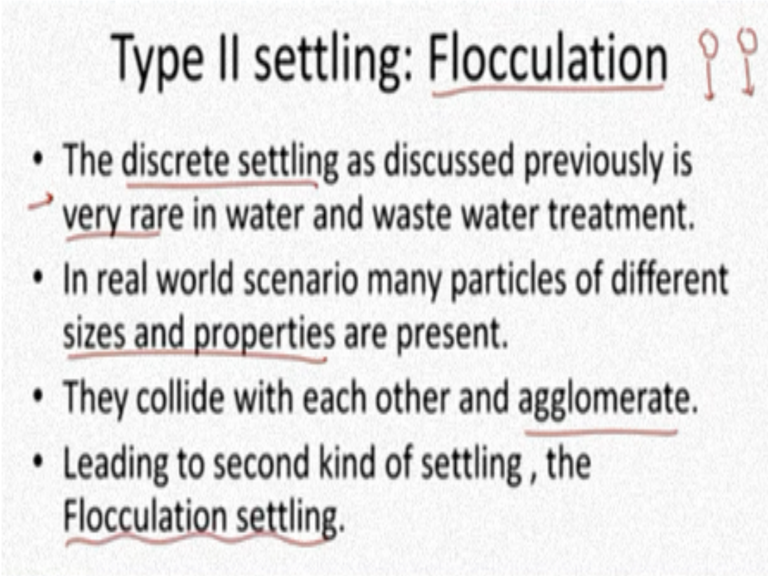

Type two settling; so the type one settling each particle settled independently. Type 2, you are going to have flocculation occurring. Flocculation generally you can promote it by adding relevant what we say coagulate, if not to you can observe it but, why is it that we are going to observe flocculation or what are the driving forces, as discussed earlier discrete settling ideal case very rarely in water and wastewater treatment.

Why is that? Many particles have different sizes and properties, so what do they do they have different settling velocities this one starts out here and this one is out here but this is heavier and that settling down at a faster rate, so what is going to happen and this one is what is a relatively less heavy and has a less settling velocity.

What is going to happen? You are going to have this particular flocculation occurring. They collide with each other and agglomerate and that leads to what we have or what we are calling as type 2 settling or flocculation or flocculation settling.

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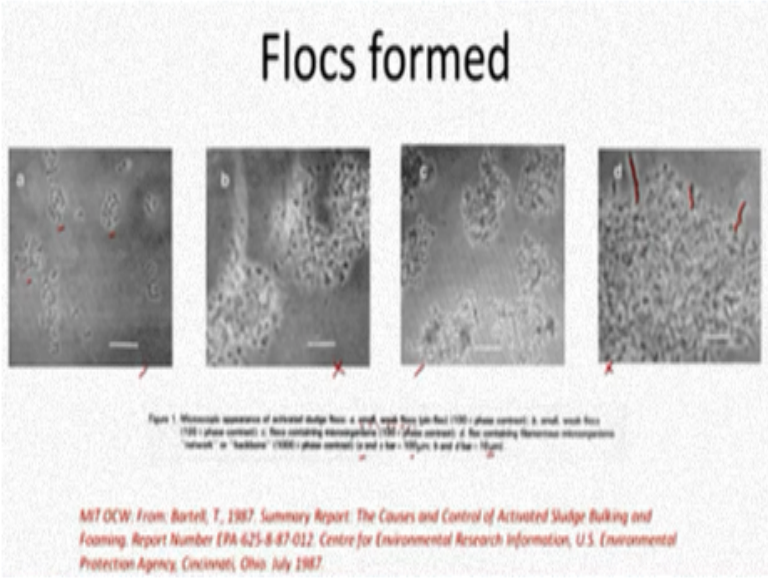

Flocs form you have the relevant source here let me just point out some aspects here as we mentioned in the biological process you have certain kinds of bacteria forming, filamentations are flocs forming and filamentations. You are going to have flocs being formed flocs forming bacteria and with the backbone being the filamentatious bacteria there has to be a balance between both.

We will discuss that later, why is that? If not if everything is suspended and never settles down I am going to have issues. After my aeration I want these kinds of bacteria to be such that they form flocs, now are they are bigger and then they settle down relatively fast. That is what we see here initially we see small weak flocs or pin flocs out here which would not settle as fast small weak flocs.

But with what is it now a and c, zoomed in that is what you see out here b zoomed in and then here we have flocs containing micro-organisms and flocs containing filamentous micro-organisms as the backbone. You have these two are at the same magnification and these two are at a different magnification.

Let us see similar but different from a and c let us see as you can see now from b and d the kind of flocs that you have relatively bigger particles or bigger flocs and with the relevant filamentous micro-organisms or filamentous bacteria, which form the backbone around which the flocs forming bacteria are going to agglomerate.

Now you are going to have bigger particles and settling now different not application example of flocculation.

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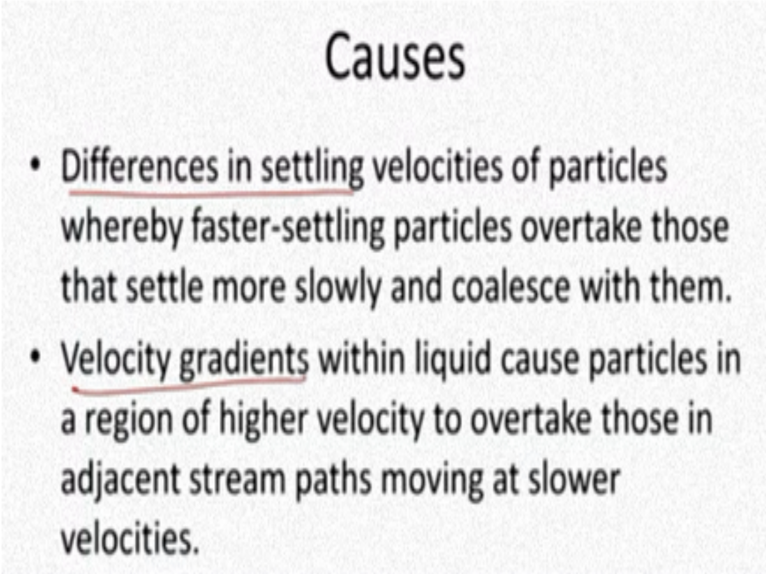

Causes as I mentioned earlier differences in settling velocity and also you can also have let us say, different pockets of water having different velocities itself. One is the particles being different, different densities and colliding or the particles I mean and also the velocity of water itself might be different or you might have gradients in the velocity.

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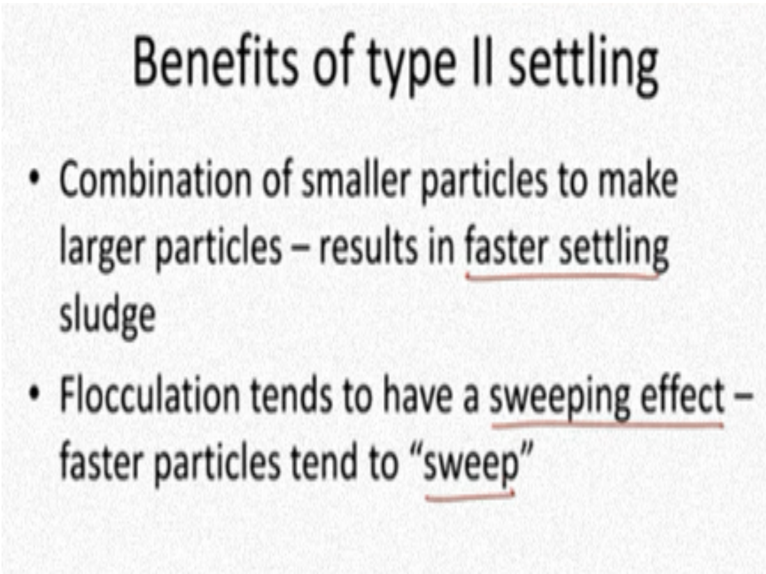

That is what you are going to look at and what are the benefits now? When two particles combine typically have a bigger particle and then I am going to end up looking at faster settling or observing faster settling sludge. Flocs that are relatively smaller first as they settle down, they can get bigger, why is it? Because they have a sweeping effect and that is why these we see sweep flocculation, that is something to keep in mind faster particles tend to sweep.

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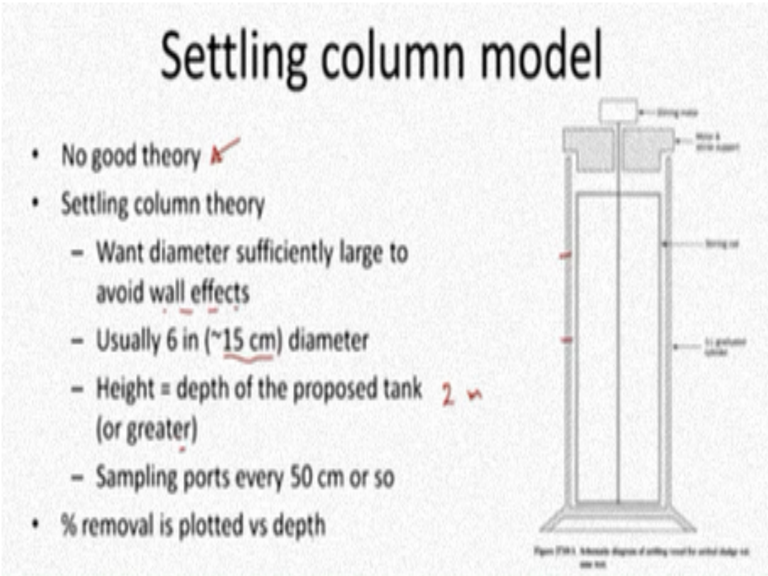

There is no good theory that is one aspect to keep in mind why is that if I am trying to design a segmentation tank, a new segmentation tank and if I want to look at the relevant design and I just want to look at it or come up with the design by developing a model why is that difficult because unless you have the actual waste water it is difficult to mirror it.

Also you do not know how the flocs are going to behave because, the relevant velocities are going to be different in your model and the actual tank so you are always going to have issues but for what we say looking at the performance of the current tank or for what we say improving the size or upgrading the facilities you can look at this column theory.

First the diameter is large enough to avoid wall effects, typically 15 centimeter height equal to depth of the proposed tank whenever possible or greater. Typically, it will be around 2 meters or 3 meters in sludge and you are going to have sampling ports let us see and then percentage removal is plotted versus depth let us say.

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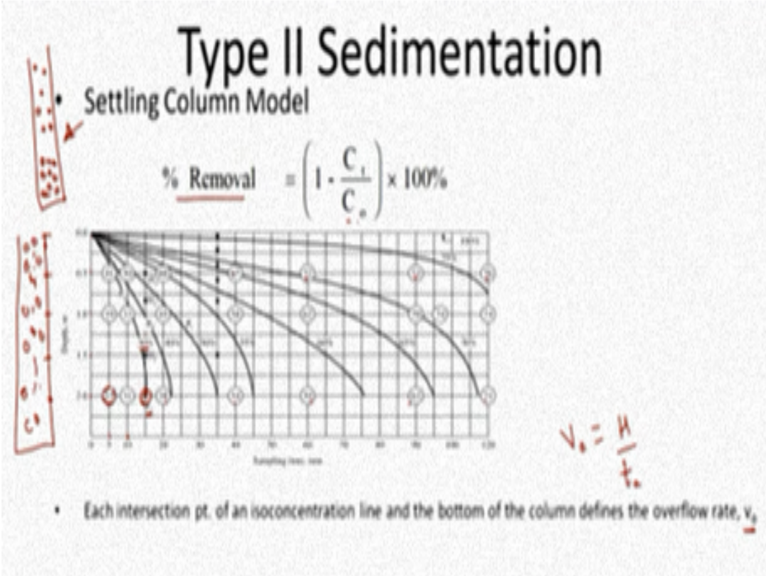

How am I going to plot it? Let me, let us just see here I have the different depths at which this is my vessel or my model and I have sampling ports at different depths and I am going to calculate the percentage removal in this manner C_t by C_0 concentration; time t, remaining at time t and initial concentration let us see percentage removal will be 1 – C_t by C_0 into 100.

$$(1 - \frac{C_t}{C_0}) \times 100$$

What is it now after 5 minutes I will measure by taking a sample what is the percentage removal at 2 meters at 1 meter and at 0.5 meters at the shallow depths you will see relatively clearer water and here it is still settling. Here situation at C0 is this situation after five minutes; what will you see relatively clearer at the top but relatively less clearer, but with in the middle regions.

That is what I am trying to what we say point out by drawing a relatively poor figure. We will see relatively greater removals even at shorter time periods at the shallower depths but not as much removal at the deeper depths let us see. With increasing time at the same depth, you see that the percentage removals the measured values are given in the circles they are going to increase let us say.

That is what you see out here and with depth the percentage removal will decrease, at 2 meters with time you see that the percentage removal will increase and here once we measure it I can now come up with these particular curves which are more or less interpolated what you see based on interpolated data as in I have this removal 41.19 .

For 30% removal I can interpolate and get the relevant curve let us see and this point of intersection with the bottom of my particular tank will define the overflow rate let us see; V_0 will be equal to what now H by t_0 , so that is the relevant aspect let us see. Depending upon that you can calculate the relevant removal for that particular overflow rate V 0 for this particular detention time.

$$V_0 = \frac{H}{t_0}$$

This is the detention time and how do we get this line this is based on your particular interpolated data for this detention time, I can calculate the overflow rate and how is the, what is the removal at that particular overflow rate?

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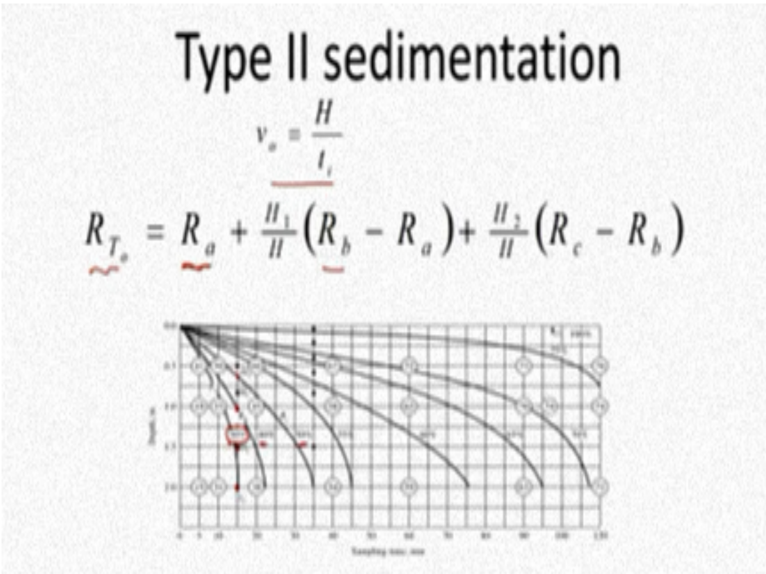

Overflow rate is given and how do I get that so that is going to be R_a, R_a is already 30% for this particular case, total removal at that particular t_a, what is that equal to R_a? 30% plus what is this H_1, H_1 by H is nothing but the midpoint between these two particular points of intersection, H_2 is nothing but the midpoint between this point and this point.

$$R_{T_a} = R_a + \frac{H_1}{H}(R_b - R_a) + \frac{H_2}{H}(R_c - R_b)$$

You have this line out here at t_a and the midpoint between these two particular iso-concentration lines will give you H_2 and H_3. R_b is in this case the second one what is the R_b? If that is 30 maybe this is around 40% and R_c is 50%, . You will be able to get that rather than what we say just speaking out loud let us look at the relevant data and see how to go about it.

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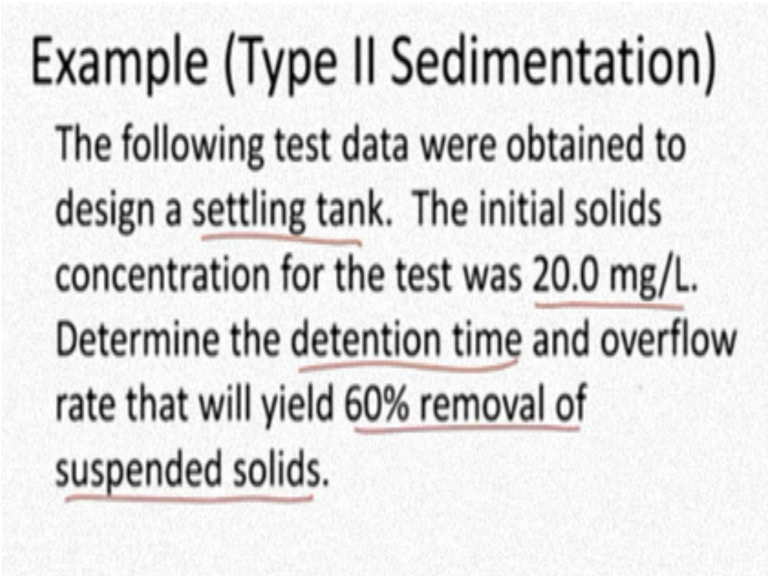

The following data were obtained to design a settling tank, initial solids concentration was 20 milligram per liter and we want to determine the detention time and the overflow rate such that we will get 60% removal of the suspended solids, so we have to see how to go about it.

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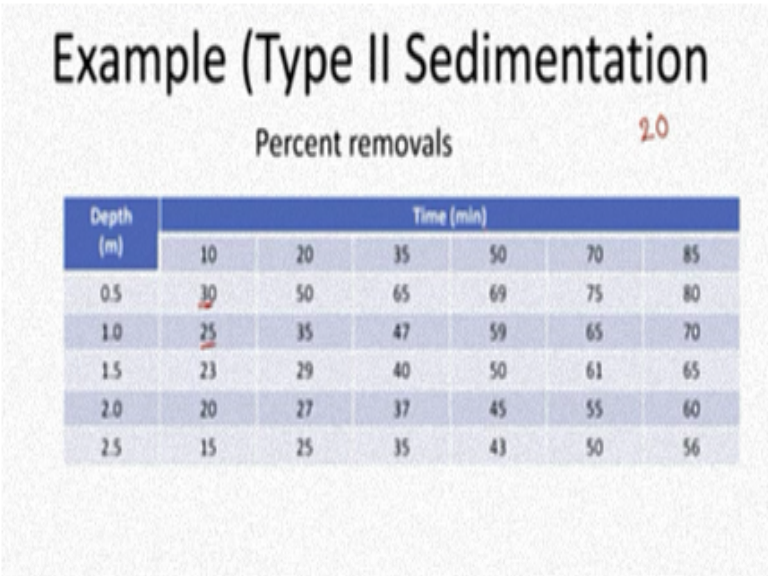

Depth (m)	Time (min)					
	10	20	35	50	70	85
0.5	30	50	65	69	75	80
1.0	25	35	47	59	65	70
1.5	23	29	40	50	61	65
2.0	20	27	37	45	55	60
2.5	15	25	35	43	50	56

Let us look at the data first here so we they measured the depth at five levels and times time intervals at different time intervals ? Then they gave us the data as in this is the suspended solid concentration, at 0.5 depth after 10 minutes as you see the concentration decreases with time at the same depth but, increases at the same time with increasing depth.

That is something we already discussed and let us move on. Percentage removals I can calculate the percentage removal from that because I know that the initial one is 20 for example here it is 14, 20 – 14 is 6, 6 by 20 into what we say let us say, 100% or in the other case it was 15 so 5 by 20 into 100. 1 by 4 into 100, 25%, so that is what we see this.

You can calculate the percentage removals at these particular sampling points and times let us see and what will; that allow me to do that can allow me to interpolate the data and then let us see how we can get this.

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Example (Type II Sedimentation)

	20%	30%	40%	50%	60%	65%	70%
Time [min]	Depth [m]	Depth [m]	Depth [m]	Depth [m]	Depth [m]	Depth [m]	Depth [m]
0	0	0	0	0	0	0	0
10	2	0.5	0.35	0.23	0.18	0.12	0.05
20		1.4	0.75	0.5	0.35	0.25	0.15
30			1.22	0.75	0.55	0.42	0.23
40			1.8	1.1	0.75	0.57	0.34
50				1.5	1	0.72	0.46
60				1.95	1.25	0.85	0.6
70				2.5	1.55	1.03	0.75
80					1.85	1.33	0.9

Now I want these iso-concentration lines for 20, 30, 40, 50, 65 and 70% let us see and at different times I will get this iso-concentration lines by interpolating the data between these particular data points, I am not going to go into interpolation here, so, we will get this data.

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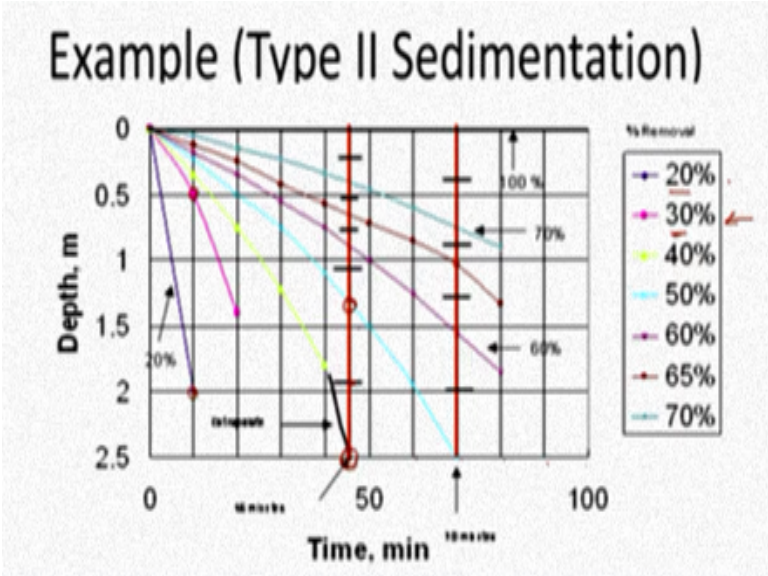

From this data I can plot these supposedly iso-concentration lines for example let me just look at how we got this blue line? , we see that at what is it 10 minutes, we will have 20% removal at depth of 2 meters. That is why we see at 10 minutes 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, so 10 minutes we will have 20% removal at depth of 2 meters.

Then here we will have 30% removal after 10 minutes at a depth of 0.5, so the next one is 30% 30% and we will have it at 0.5 and let us see what else 30% removal and more, more or less we will plot this data in this fashion ? Let us move further so I plot all these iso-concentration lines and they are more or less ranging from 20 to 80% and we get this.

As we mentioned we will look at this point of intersection and draw a vertical line and, what is this point this point will be the middle of the point of intersection of these two points there are two iso-concentration lines here. This is extrapolation though we have the data only from here, we extrapolate and assume that it is going to intersect 2.5 out here and then I am going to get this midpoint let us see this midpoint.

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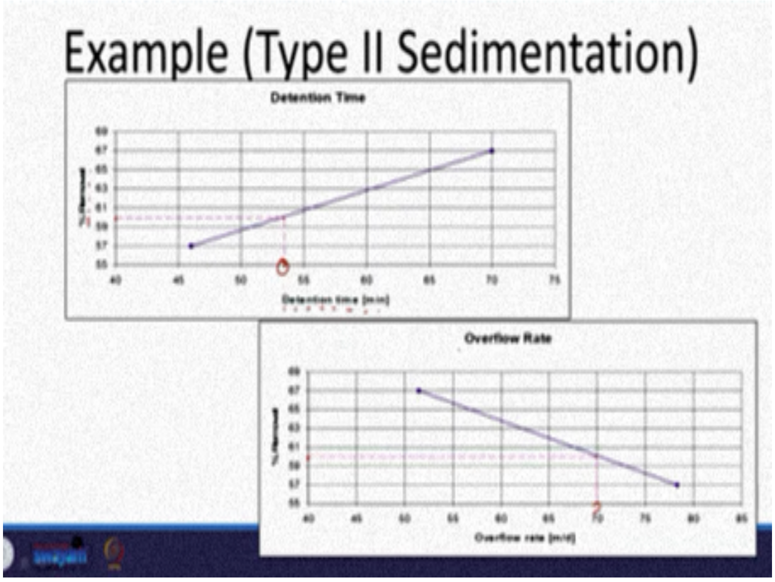

Why do I need to get the midpoint? Because, if we looked at the relevant equation out here the percentage removal we need to get this midpoint and H_1, H_2 . That is what is needed out here. From that after I calculate that what will I be able to do I will be able to calculate the percentage removal not calculate plot the percentage removal and the detention time.

From this what was the percentage removal that was requested it was 60% let us look at it 60% removal was required. What do we see so for 60% removal from this graph I see this relevant detention time may be 53 minutes or so is required and what is the overflow rate, I can either calculate that or plot look at the plot so for the 60% removal.

If I calculate the overflow rate , it comes out to be 70 meters per day and the detention time is around 55, but there will be some values because we need to look at factor of safety or to when we design this. 1.75 and 0.65 but we will provide that in the exam. If we look at that one aspect is you will have different levels of removal and that is what you see out here.

I am almost out of time for this session and I will continue looking at or we will continue looking at some of the relevant pictures, that will give a clearer idea of what happens out there in the actual sedimentation basins but that will have to wait until the next session, as usual thanking you for your patience I will end the session.