Water and Waste Water Management
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Module No # 12
Lecture No # 56
Residual Management

Hello everyone, welcome back to the latest lecture session. Very quick recap of what we have been up to, we looked at waste water treatment, we looked at water treatment. Let me summarize that waste water.

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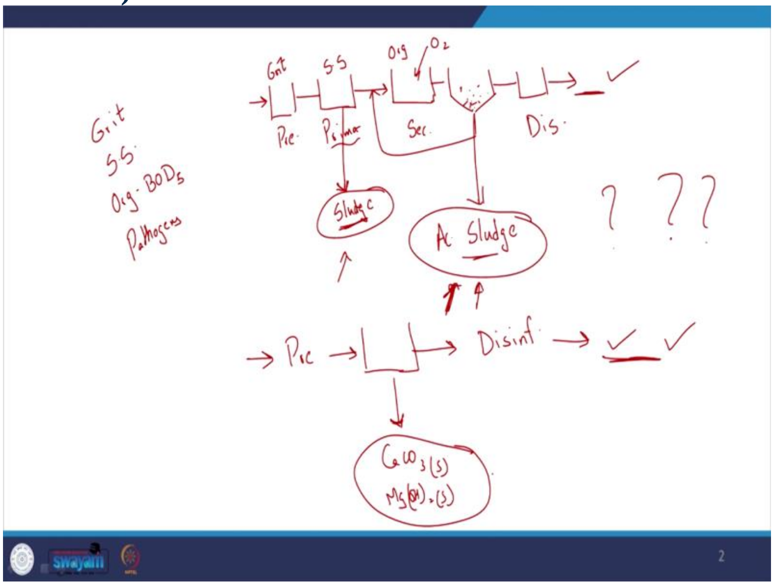

What do I have? I have different aspects, I have grit, I have suspended solids some of which will be organic, I have organic content which is dissolved which I am measuring by BOD or BOD5. And then I need to look at pathogens, how did I go about it? Preliminary treatment and head works, that is the one preliminary treatment and depending upon the wastewater system

They might not have primary treatment that is up to the relevant plant operator. If you have primary treatment, what are you going to get? You are going to get some deposits of these particular sludge and then after primary you are going to have secondary treatment where we pumped in oxygen. Here we looked at grit and other materials, here we looked at suspended solids, here we are looking at the organic content.

You are pumping in oxygen and then floc forming bacteria, this I do in the reverse manner. We have that the sludge is going to or the flocs are going to settle down more at the bottom.

Some of it will be recycled, some of it will have to be wasted as activated sludge. This is activated sludge because you have microbes, here secondary treatment I am not going to look at or speak about nitrogen and phosphorus or the tertiary treatment here.

And then disinfection, to look at the pathogens so this is one aspect and water treatment preliminary treatment primary where we have some sludge being formed. Depending upon irrelevant aspects but before that we have coagulation and flocculation. If I have lime softening, that will have its own sludge, $CaCO_3$ the relevant solid or magnesium hydroxide.

Even during sedimentation after coagulation and flocculation, I will have some kind of settled sludge and then I will have disinfection. We are not looking at the all the aspects, we covered this, the water is pure or relatively fit for discharge here. It is fit for drinking here. But what else do we need to look at? What are we missing?

As you can see here during this water treatment, I am producing sludge, activated sludge and some primarily inorganic based sludge or if it is primarily in organics are relatively inert sludge here. If I am going to treat the water, I am also going to have to look at what to do with the sludge that I am producing. The next couple of sessions are going to look at residual management, residuals we are talking about these residuals.

Maybe the term should not have been sludge here I should have used the term residuals or such, the settled solids here activated sludge is commonly accepted in this context. We have the residuals.

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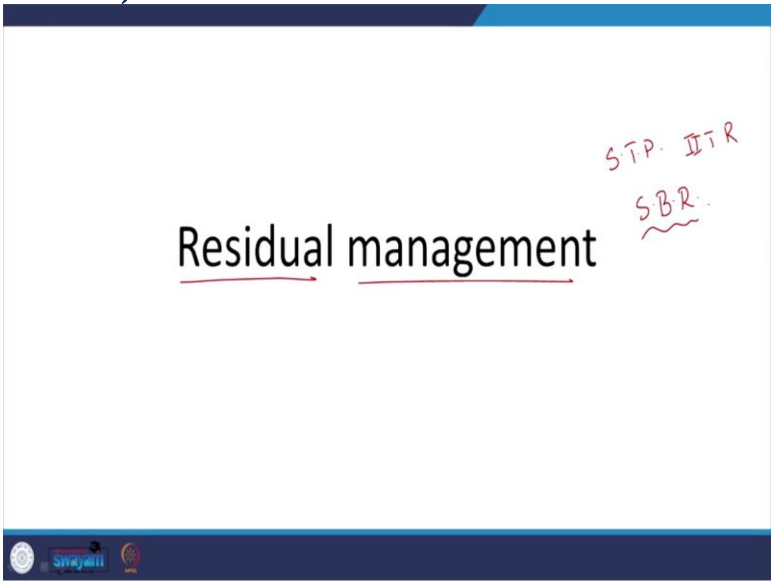

I need to look at residual management. Before that let us go back to the sewage treatment plant at IIT Roorkee. The one based on SBR sequential batch reactor, there we looked at sludge, let us just look at what it is they are trying to do there? Let us go there.

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If you see this was the one or if you remember we have something on the screen here. And this one as you can see is from the aeration tank, the sample taken when the aeration was stopped. Before settling was allowed to start and then we looked at it real time, you can see the time 7 minutes 45 seconds or so left. And within 1 minute you see that zone settling if I may call that.

What is going to happen to this particular settled sludge later? All this I mean this is within a minute settling two hours or so, here the cycle then you are going to have relatively thickened sludge that some of it we are recycling for the microorganisms to be maintained in our plant some of it what are we doing, we are trying to dewater it, let us look at that.

(Video Starts 05:18) Let me look at that picture if you remember this. Let me play it from the UV system, this was the UV we are done with water treatment, water is being discharged from here, we are disinfecting the water here with the UV that we are done with. What next? We also need to look at the relevant sludge. Here you see the sludge dewatering machine, sludge is coming via this particular system out here.

Here they are conditioning it, how are they conditioning it? They are adding a coagulant, I think a polyelectrolyte here, maybe alum and then they are going to have the dewatering.

Equipment here? I think it is a belt press if I am not wrong. What we have? Let me try to slightly press through that, we have sludge. **(Video Ends: 06:12)**

But here you see the solids concentration is relatively higher than the effluent on the supernatant. But you still cannot dispose that, why is that? Because this is cells, microbes cells you would not have a lot of pathogens, you will still have some pathogens though typically in this microbial community that thrives pathogens relatively less but you can still have some pathogens.

And more important I was mentioning this is cell organic matter mass, cell mass or organic content. If you just leave that out there that is going to degrade, you are going to have issues with smell, flies and if it has pathogens that is going to be an issue too and if it is from common effluent treatment plant, you can even have heavy metals in that sludge not in the activated sludge, what do I need to do? I need to treat it further.

That is what we are going to look at or I first before treating it or maybe transporting it somewhere for processing or such, one aspect that is typically looked at is dewatering. As the name indicates you have sludge with some solid content and a lot of water, still a lot of water is like a slurry, what are we trying to do? We are trying to dewater it that is what we are doing here. Let us just look at that though? It is a filter belt press here, let me just try to go ahead.

(Video Starts: 07:30) Here, what are we adding? We just looked at that particular picture. Sometimes you will have to condition it or you can condition it rather. Here they are adding the alum, if I am not wrong coagulant, they are using the term poly but I am assuming it is alum you want to form the relevant bigger collides and here you see the slurry or the sludge that is coming in, you can see the consistency here.

Near here you can see the consistency, you should have a considerable solid but still a lot of water. If you want to transport it, is the volume is going to be remarkably high? The volume is going to be remarkably high. This is not what I want to transport or treat or such not treat at least transport, especially in small plants when I am not treating it to a great degree later or if I want to decrease the volume.

I am going to have to dewater it. That is what you see it is a filter or belt press here. That is what we are seeing here. You are able to see the water coming out. The final product slowly but surely the solid content is increasing the volume or the water content is decreasing, percentage water. And here you see the kind of output that is out here. Here the solid content is relatively higher.

And the water content is our percentage of mass and due to water is less and also the volume is less that is easy for me to transport. Let me look at the other slides. There are different ways to look at this residual management. And in that context, we are looking at one example- IIT Roorkee sludge. What are they doing? Being a small plant, they cannot build digester or anaerobic digesters such it is not going to be economical.

But they cannot throw it out there because of obvious issues, decomposition relevant factors like flies coming in, what are they doing? We have a pilot scale rotary drum composter. This is glorified composting technique. You have a rotary drum that rotates from time to time, why does it rotate? Here we are looking at aerobic decomposition, aerobic degradation.

You are supplying air the relevant process oxygen and you are going to provide oxygen rather than turning it manually or in windrow piles or such, here you are doing this in that rotary drum composter where the kinetics are higher. On the left you are going to feed this particular way sludge with some of the solid waste that is coming in from our IIT Roorkee this is not dealing with only sludge or primarily not designed or built for sludge but some of the sludge only, some of sludge.

And mostly this solid waste from IIT Roorkee is being put in here and then you are going to have a composting occurring. this is rarely used but I wanted to mention what is that you can do a lot of permutations and combinations and come up with your solutions. Here it is now you see the sludge, what do we have in composting?

You have microbial content which they are trying to get by some of this sludge and you need to have carbon nitrogen and phosphorus, carbon you see the relevant leaves, good source of carbon and nitrogen and phosphorus typically your kitchen waste. After that what can you do? This is the solid waste but let us skip this, this is the case in India everywhere.

And then you can get this kind of relatively stable compost, this is what is composted, this is good fertilizer for your relevant plants, higher nitrogen and phosphorus relatively low biodegradability. It is pretty inert. Let me look at a better picture here. There you can see that now this is pretty good fertilizer but keep in mind that it depends on who is treating it.

And to what extent why is that important? For example, I came across a case where I think common effluent treatment plant was trying to sell it sludge as fertilizer for farmers, there is a common effluent treatment plant meaning typically catering to industrial wastes, their heavy metals are going to be high.

If I just composted, heavy metal concentration is not going to decrease and typically all that sludge from the common effluent treatment plants is supposed to go to a hazardous waste landfill and should not be sent to the farmer. These kinds of things you need to look at. Let us look at it composted, people are trying to sell this, if we have the relevant composition here. There is the composition, pH relatively neutral, moisture content.

You still have moisture, nitrogen. Let me see if we have a better nitrogen, 2.0% nitrogen and phosphorus, that is what you have relatively nutrient rich material that is relatively inert. **(Video Ends: 12:37)**

And that is good for your relevant gardening or at least for farmers to apply or use in their fields, that is one thing to keep in mind. Residual management, we just looked at one example to get your juices flowing. Let us move on and look at the other aspects.

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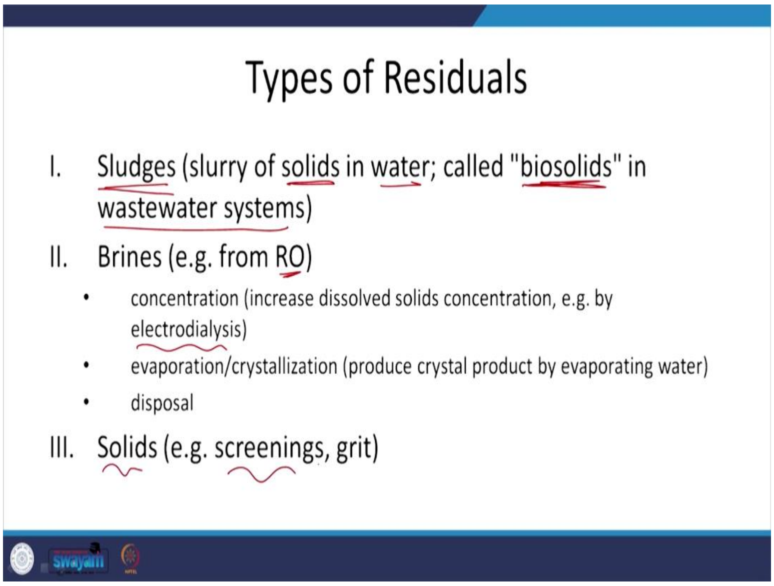

Types of residuals, we looked at the holistic view, one is sludge's slurry of solids in water. Solids in water that is when we call that sludge just if it is when we call bio-solids? For wastewater systems typically the ones from activated sludge. And we also looked at RO or even the other membrane based techniques you are rejecting or you have considerable reject.

In that reject, you have high concentration of your relevant compounds. Even that you need to look at it but we are not going to look at that in great detail. And this is a great disadvantage with our RO, what do you do with these brines. Concentration increased dissolved soil concentration example by electrodialysis that is something you can do. Evaporation or crystallization produce crystal product by evaporating water and then disposal so solids from screenings and grit what are we talking about.

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For example, from preliminary treatment we have the screw auger and then the grid washing chamber out here, let us look at what the grid looks like.

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Here you see an example and here we see coarse screening or coarse screens and then wash grid out here.

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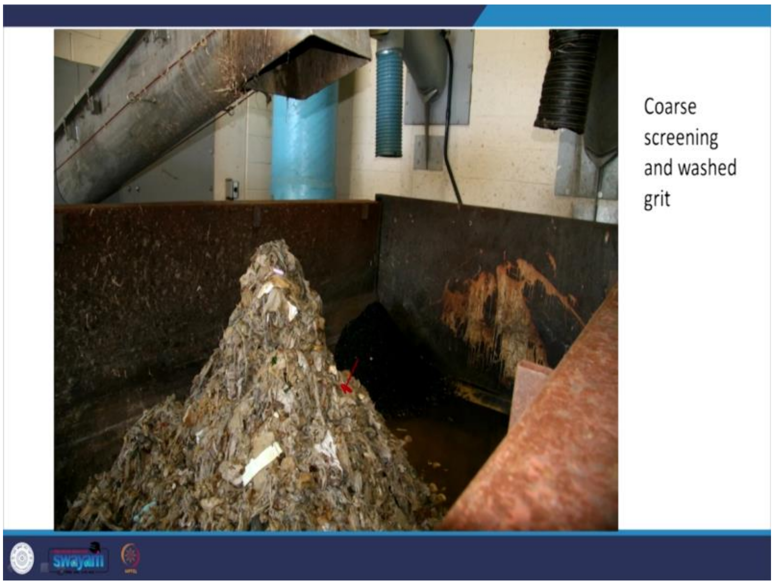

This is what we are looking at but here this is relatively more inert, different kinds of disposal this will not go into any composting techniques or such.

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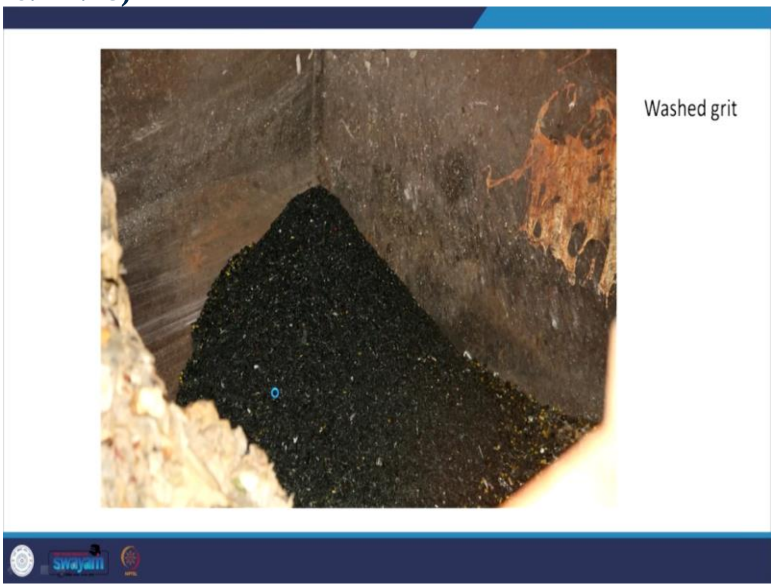

You see washer grit and how it looks like but typically this is pretty inert.

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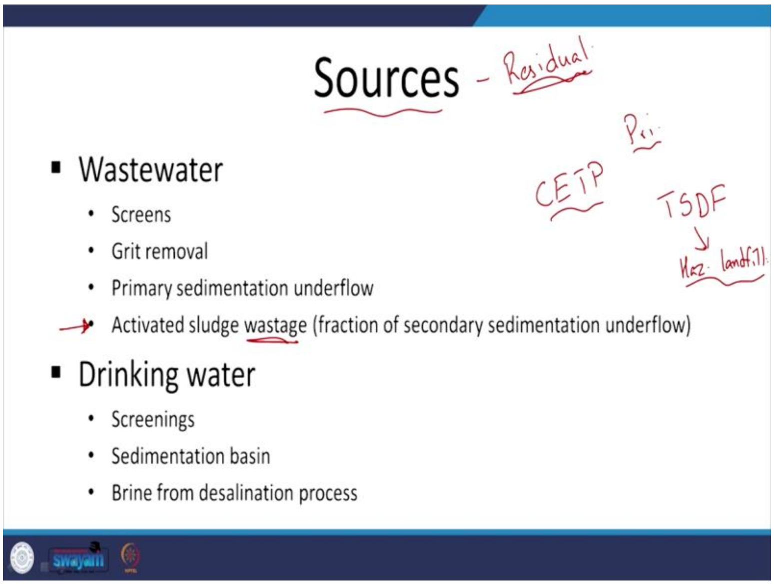

In general, the sources of various residuals what are they? We know that they come from water and wastewater. In wastewater they can come from screens, from the grit removal, grit primary sedimentation tank, underflow activated sludge wastage in the activated sludge process, some of the sludge is being wasted, some of it is recycled, some of it is wasted that particular aspect needs to be looked at that source in drinking water.

Screenings, similar sedimentation basin and Brine from desalination process, these are the aspects that need to be considered when we are looking at residuals. In India though typically we are going to look at this and if it is a common effluent treatment plant and you have primary treatment and sludge from that primary treatment, that sludge has to go to a TSDF, treatment storage and disposal facility which is more or less hazardous waste landfill.

That is something to keep in mind. But the law does not say that the after biological process the sludge has to go to a landfill. But the issue is after biological process depending upon the kind of influent characteristics of the water and the heavy metal concentrations in the influent wastewater at this common effluent treatment plant, the sludge can have a high concentration of the heavy metals.

That is something to keep in mind. Maybe that is going to change. Let us move on so properties of this residual or the sludge that we are looking at.

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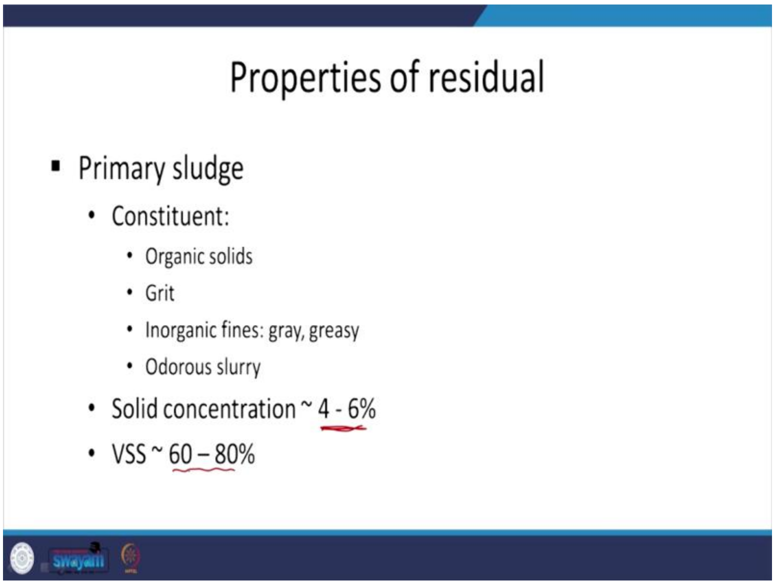

What is it that we are looking at? Typically, primary sludge if it is from primary sludge. Mostly or considerable organic solids, grit, in organic find some of it and it is pretty odourless and it is a slurry, salt concentration you can understand that it is not very high but this itself is high enough, salt concentration is 4 to 6% and organic content is high. Volatile suspended solids 60 to 80%.

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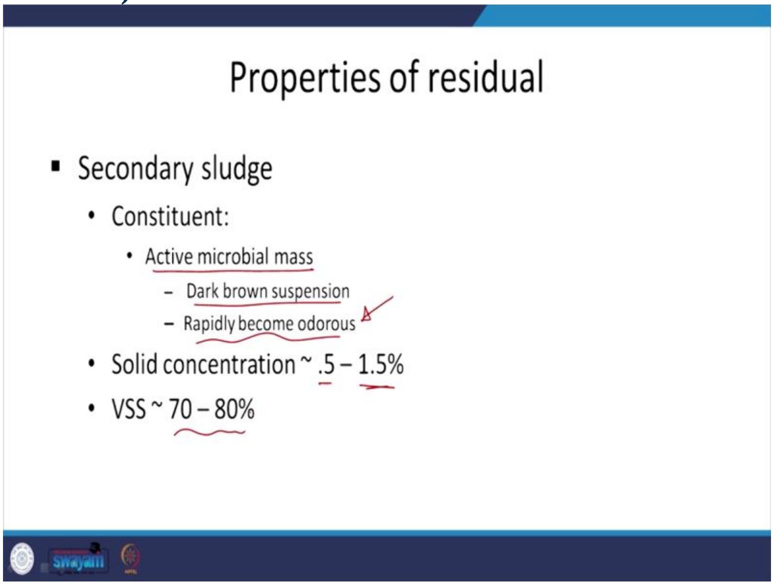

And next aspects secondary sludge or from the activated sludge. What is it mostly made of? It is made of or consists of microbial mass or microbes typically dark brown and it is organic matter, cells and these are microbes they will die without access to waste and oxygen and then this dead microbes, they are organic matter that will be degraded by other kinds of microbes .

That will rapidly become odours during in anaerobic conditions, salt concentration as you see is 0.5 to 1.5% it is not very much and suspended solids as expected, the organic content is considerable biodegradable or organic content. Let me leave it there.

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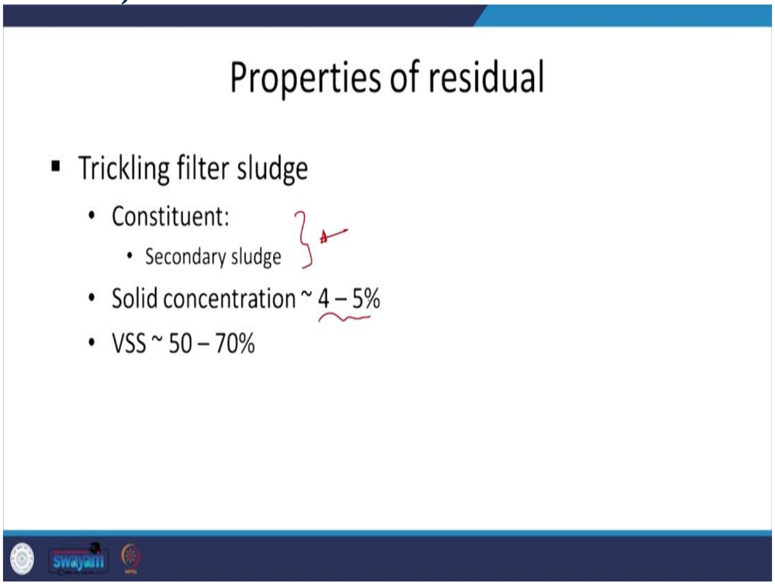

And what else? Trickling filter sludge, which we did not look at similar to that of the secondary sludge solid concentration due to the higher and suspended solids too in the similar range.

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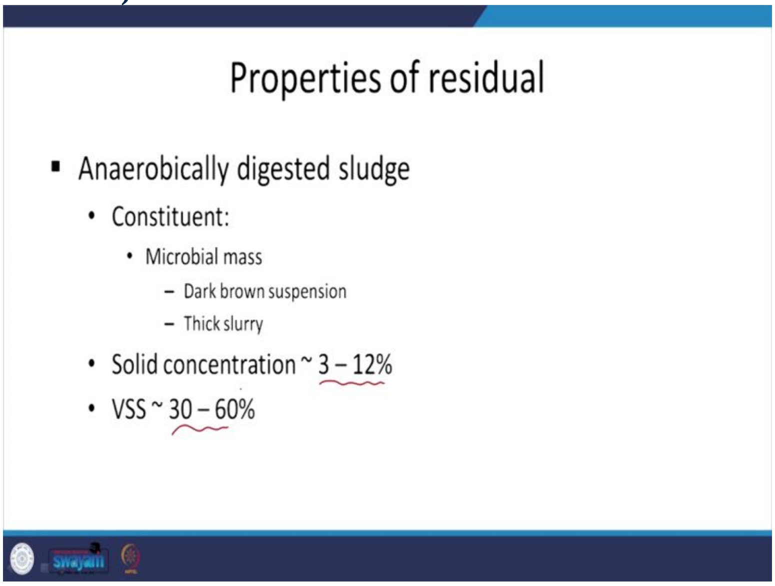

And anaerobically digested sludge, what we have after digestion of sludge by anaerobic process, what do we have? We still are going to have a microbial mass but this is going to be relatively inert though solid concentration as you see is increasing. And suspended solids concentration or percentage is decreasing. What about the one from aerobically digested sludge? Relevant aspect but here the issue is that the relevant mass that comes out or microbes are flocculant in nature, that is why dealing with that, later is going to be difficult. That is something to keep in mind. Soil concentrations too are 1 to 2% and suspend solids too relatively lower.

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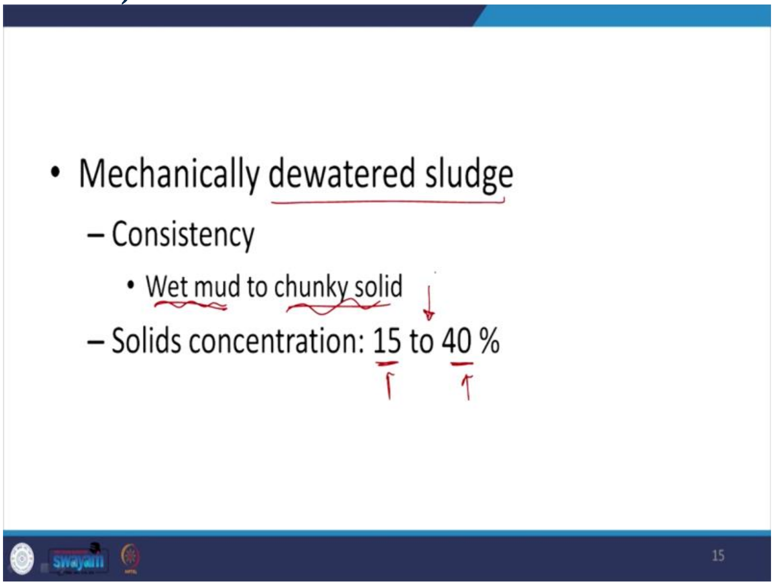

Mechanically dewatered sludge the one that we just looked at we know the consistency it is like wet mud or chunky solid, what we looked at the output from the belt press that we looked at is somewhere in between and for wet mud 15%, chunky solids 40%. Ours would have been somewhere in between, there are different ways to look at it. We will look at all these aspects.

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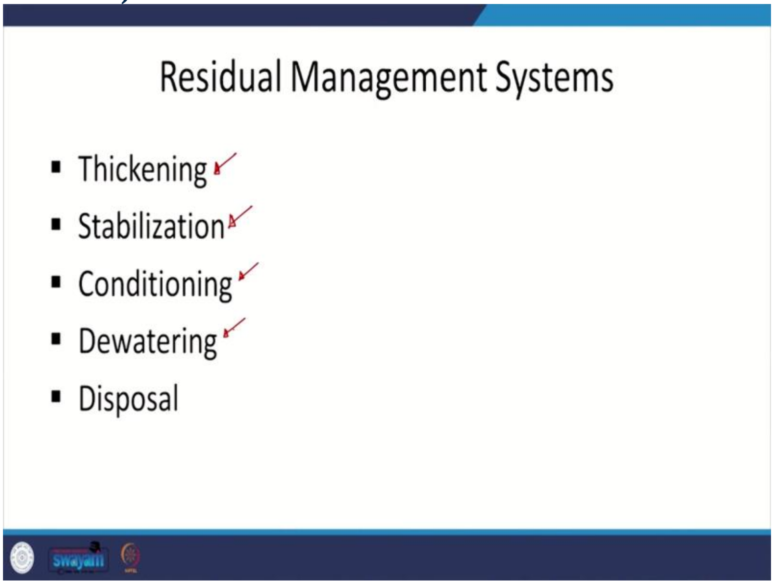

Residual management systems, what is the approach? Thickening. Firstly why am I concerned with thickening? Because if I did not thicken it well enough, if there is poor thickening and if I am recirculating this particular sludge to a particular process later ,what is going to happen? I am going to have very high volume so if I have higher volume, then the size of the relevant tank is going to be higher.

This is something to keep in mind. You want to have good thickening so that with relatively less volumetric flow rate, you will have more mass being transported. That is something to keep in mind, thickening is something that you typically strive for during your settling tanks and then stabilization. This is not required for inert residuals especially for water treatment or from water treatment.

But if it is activated sludge or even sludge from primary treatment of your wastewater treatment plant that has considerable organic content that is biodegradable and that will lead to our is putrescible, that is something you have to look at. You will have to stabilize it before you can dispose it. And one aspect is conditioning, you are going to condition it or you are going to prepare it that it can be dewatered, that is something to keep in mind.

Dewatering, we looked at that particular aspect, we are removing the water as much as possible so that it is relatively more compact and easy to handle and then we are going to look at disposal.

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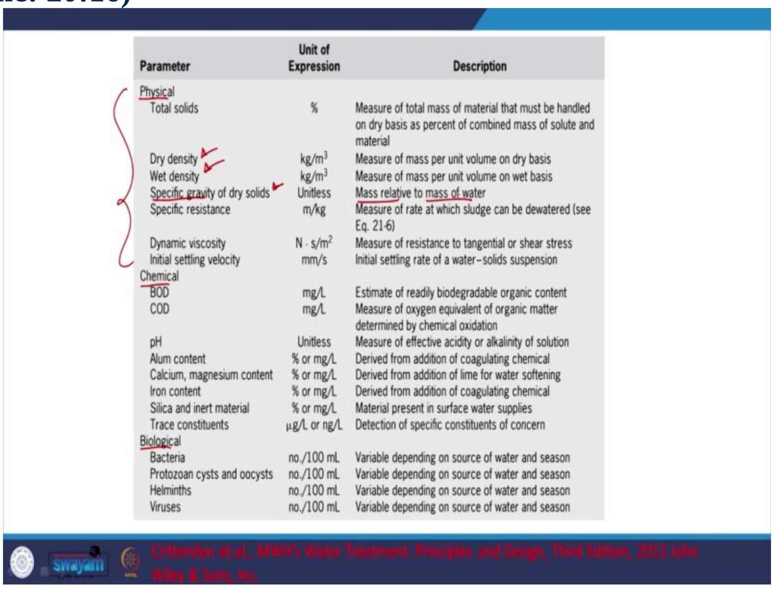

Parameter	Unit of Expression	Description
Physical		
Total solids	%	Measure of total mass of material that must be handled on dry basis as percent of combined mass of solute and material
Dry density	kg/m^3	Measure of mass per unit volume on dry basis
Wet density	kg/m^3	Measure of mass per unit volume on wet basis
Specific gravity of dry solids	Unitless	Mass relative to mass of water
Specific resistance	m/kg	Measure of rate at which sludge can be dewatered (see Eq. 21-6)
Dynamic viscosity	$N \cdot s/m^2$	Measure of resistance to tangential or shear stress
Initial settling velocity	mm/s	Initial settling rate of a water–solids suspension
Chemical		
BOD	mg/L	Estimate of readily biodegradable organic content
COD	mg/L	Measure of oxygen equivalent of organic matter determined by chemical oxidation
pH	Unitless	Measure of effective acidity or alkalinity of solution
Alum content	% or mg/L	Derived from addition of coagulating chemical
Calcium, magnesium content	% or mg/L	Derived from addition of lime for water softening
Iron content	% or mg/L	Derived from addition of coagulating chemical
Silica and inert material	% or mg/L	Material present in surface water supplies
Trace constituents	μg/L or ng/L	Detection of specific constituents of concern
Biological		
Bacteria	no./100 mL	Variable depending on source of water and season
Protozoan cysts and oocysts	no./100 mL	Variable depending on source of water and season
Helminths	no./100 mL	Variable depending on source of water and season
Viruses	no./100 mL	Variable depending on source of water and season

Before we go to that, I am not going to go through these aspects please note that we still are looking at physical, chemical and some biological aspects of sludge. In India, sludge we did not look at these in great detail. But I am just presenting this here so that you get an idea of some of the variables that we have to look at especially specific gravity. It gives you the mass relative to the mass of water, that is something to keep in mind. Other aspects too but we will come back to this later as and when needed.

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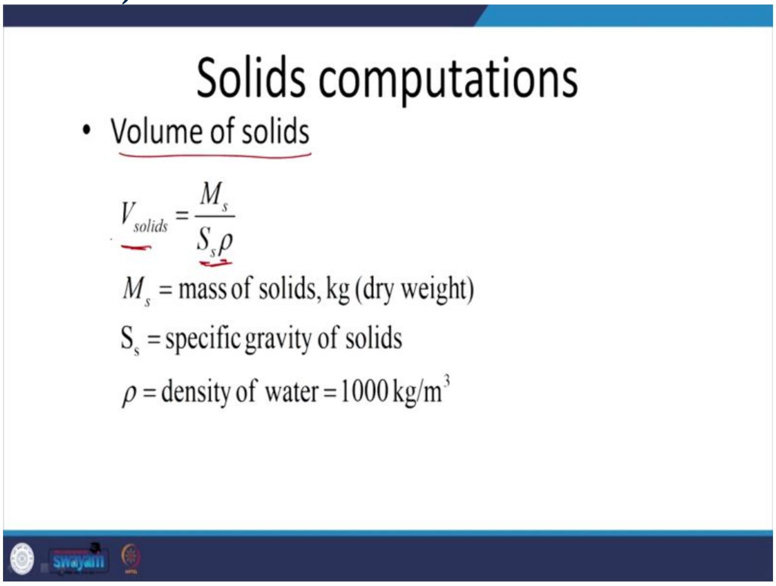

Solid computations, so we are concerned with the volume. When any design volume comes into play, so volume of solids and here we have the density. Density is mass per volume. From that you can get the solid volume too when you have the density but here we have the density of water but if I have the specific gravity of the relevant solids. I can get the density of the solids and thus from that I can get the volume of solids.

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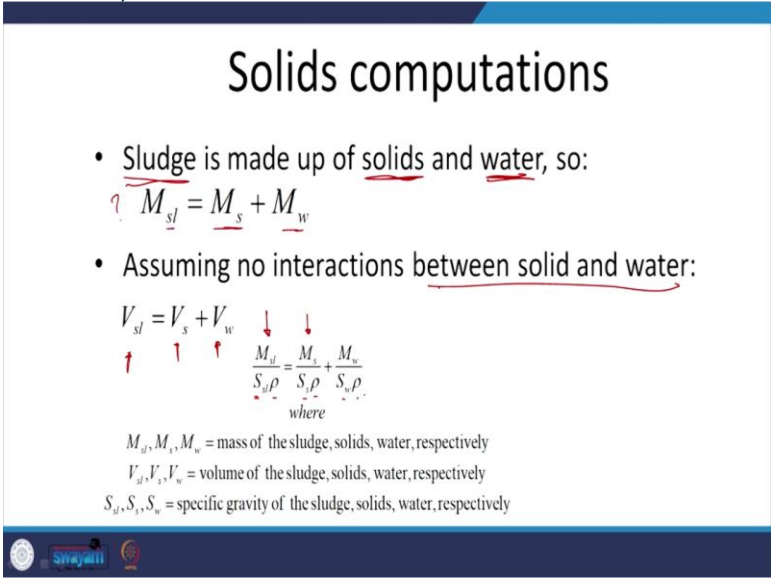

And here one aspect to note is that sludge, what is the sludge made of? It is made up of solids and water, suspended solids which are being settled out and also water. Sludge is made up of solids and water. Mass of sludge get two contributors, similarly for volume too assuming no interactions between solid and water decent enough assumption, volume of sludge is equal to the volume of solids and volume of the water.

And considering the relevant info that we had earlier or in the earlier ppt or the slide we are going to plug that in here. We have the mass, we have the specific gravity of the different aspects that are being considered such as sludge solids and water and then the density.

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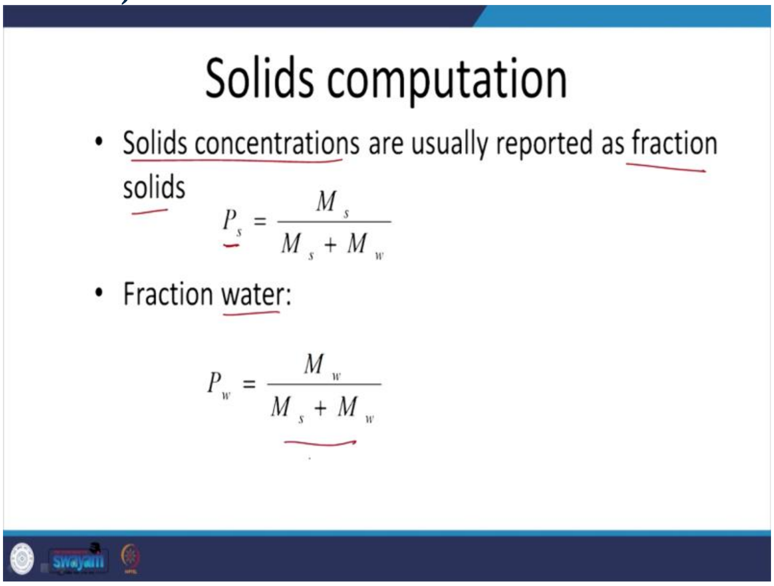

That is one aspect, we typically look at is that. We have this term called PS, solid concentrations are usually reported as a fraction of the solids. Mass by total mass, typically fraction of water mass with respect to mass of water by total mass.

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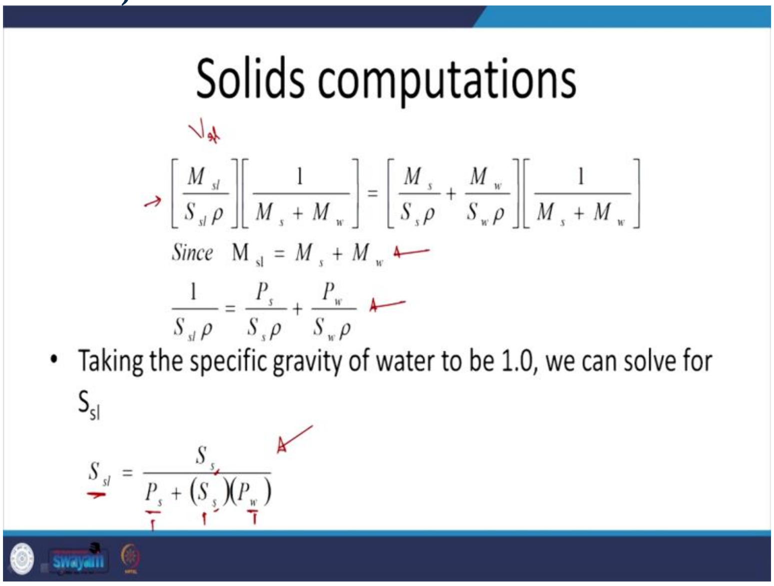

Using this set of variables, this is with respect to the volume of the sludge and then 1 by MS+ MW, total mass you can play around with it and noting that this is the equation, you can come to hear. And then playing around with these variables you will end up here. You are getting the specific gravity of the relevant sludge and that is dependent upon that of water. Specific gravity of the relevant solids and then the mass fraction of the solids and mass fraction of the water.

This is something that you can usually measure, these are things that you can usually measure.

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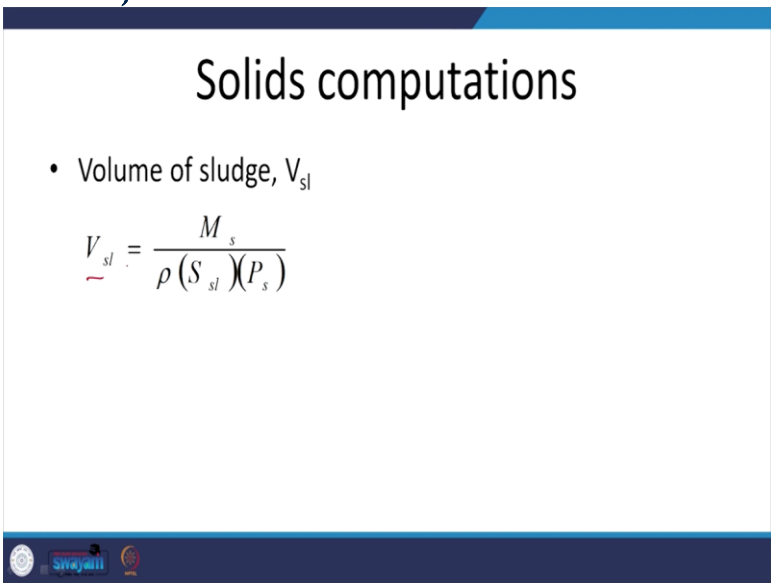

Similarly, volume of the relevant sludge can also be looked at or measured. Let us move on.

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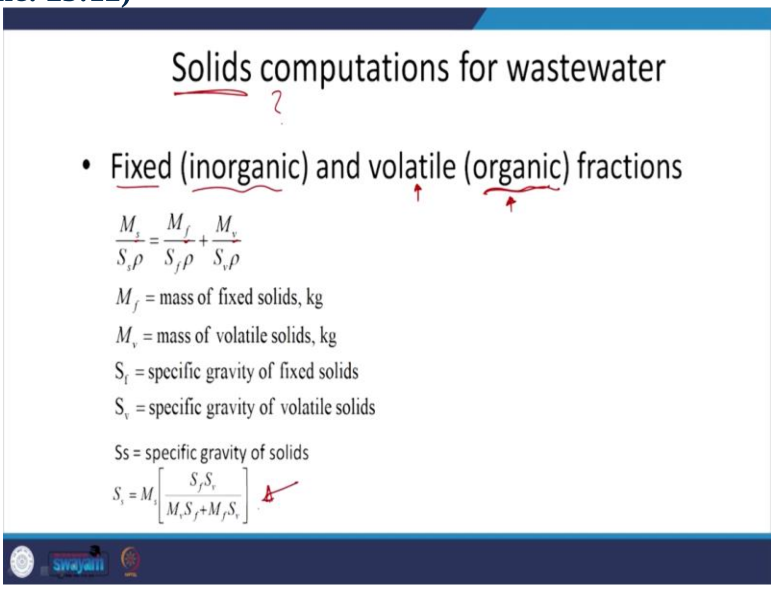

The solids, what do they consist of? We know that they consist of fixed meaning inert and inorganic and volatile which means or stands for organic. Please note that volatile typically means the compound does not want to stay in water. It wants to stay in the gaseous phase. But here we are using that based on the kind of measuring technique and that is used for referring to the organic fraction.

For solids, we have fractions one is for fixed or inert and then for the volatile, that is something to keep in mind. You play around with the above equation and variables, you will get to this particular aspect.

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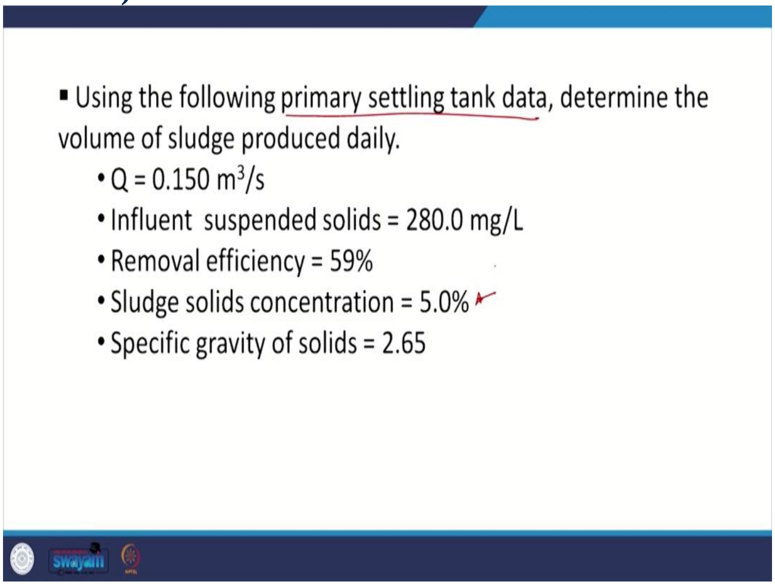

We have one example. Let us look at that. We have it from a primary settling tank, determine the volume of sludge produced daily. The flow rate is given suspended solids coming into the system is being given. Removal efficiency of these suspended solids is 59%. As expected within the expected range, the sludge solid concentration is 5%. Expected range, specific gravity of solids is measured, let us move on and see how to go about it.

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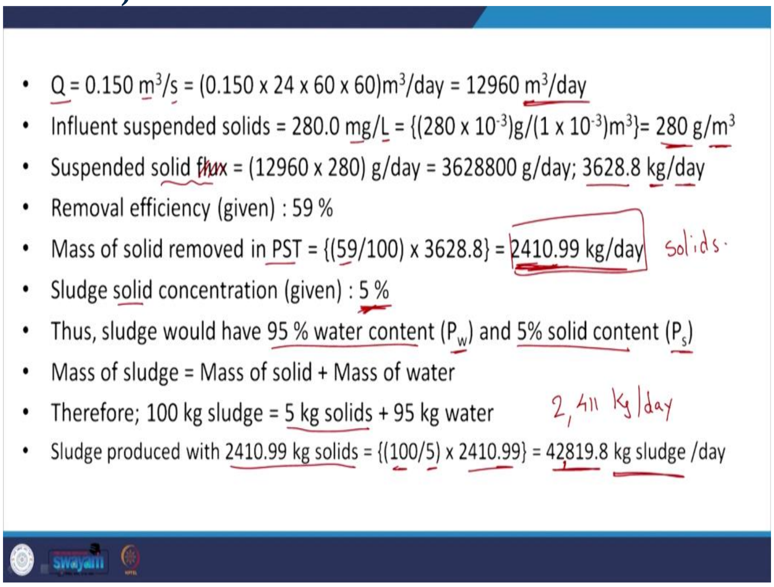

First aspect is changing the units as per requirement just with respect to meter cube per second going to meter cube per day. And then influent suspended solids concentration, you want the mass per time. Here you have volume per day and milligrams per litre. This I want to convert into milligrams per meter cube, that is what our grams per meter cube, that is what is being done here.

If there are any numerical errors, you can correct that here but we are just looking at the approach. Then the flux or I should not maybe call that flux, suspended solid mass flow per day or mass being generated per day, how much is that? It is kgs per day, 3628 kgs per day of suspended solids are coming in per day.

And removal efficiency, we know is 59%. Mass of solids that are being settled out or removed in the primary settling tank or sedimentation tank, it is going to be 59%. 59% of this 3600 seems to be 2410 kgs per day, that is the solids. But what is the solid concentration in the sludge? It is only 5%.

That is something to keep in mind. This 5% is from these particular solids, so sludge will have 95% water content and 5% solid content, these are the variables that are given in a way when they mentioned 5% solid content. Mass of sludge equal to mass of solid plus mass of water, this is something that we are aware of. If I have this particular fraction, this fraction is coming from these solids.

Sludge produced when I have this much solids, I will have to look at that ratio 100/5, that is what we are doing. This is the sludge that is being produced. For solids of 2411 kgs per day that is only 5% of the sludge done this total sludge is 42820 kgs of sludge per day is being produced. You understand the issues with respect to handling this mass and then the volume of the relevant sludge, that is going to be considerable. You understand the need for dewatering.

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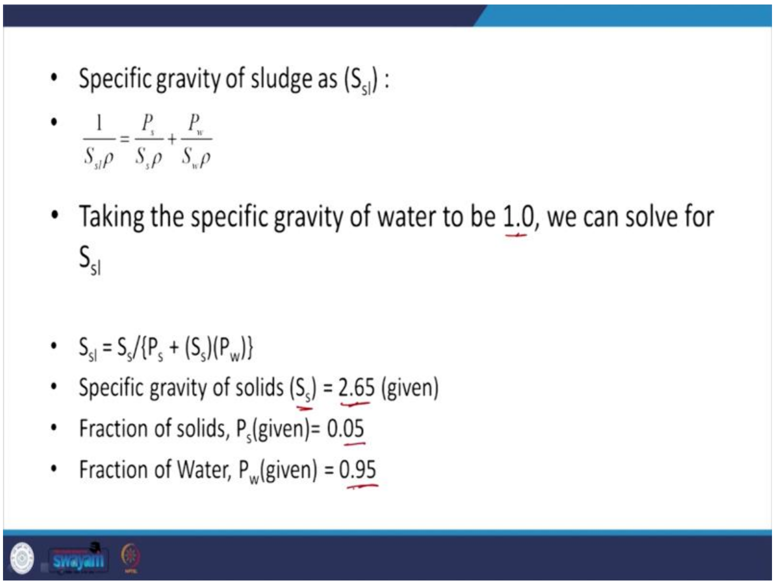

This is one of the equation that we looked at earlier and we have most of the relevant variables in this particular equation, taking the specific gravity of water to be 1, we have the relevant equation, specific gravity of the solids is given 2.65 and Ps and Pw are also given, 5% solid that means 95% water.

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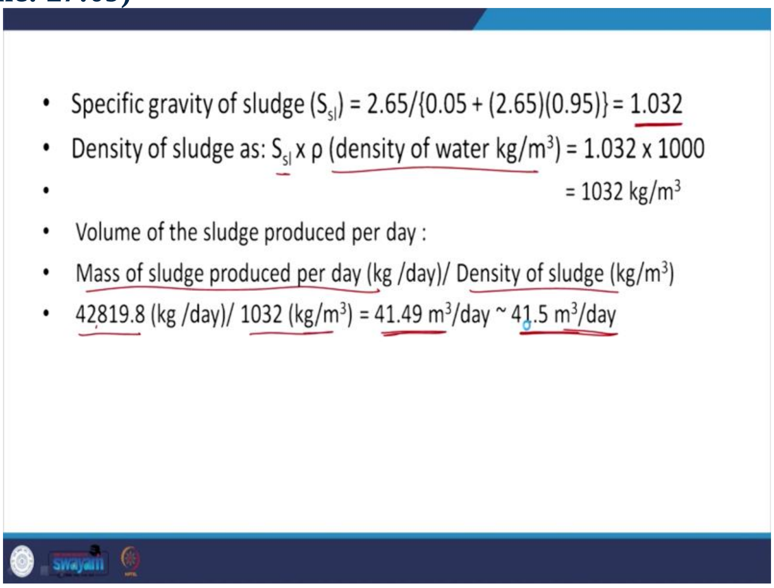

You plug it in and looks like the specific gravity of sludge is 1.032, so slightly higher than that of what denser than that of water. Density of sludge, specific gravity times density of water which is the reference. We are going to get the density of the relevant sludge. Volume of sludge produced per day, mass of sludge produced per day by density of sludge produced per density is equal to mass by volume.

If I want volume, it is mass by density. I have the mass of sludge that was produced from the earlier case and the density was calculated. I have the mass of sludge. I have the density so the volume is calculated. You see that considerable volume, 41.5 meter cube per day of volume is being generated.

With that I will end today's session. And in the next session we are going to look at what are the issues with sludge if I directly throw that or dispose that on to land. And we looked at different aspects- conditioning, dewatering, stabilization so forth. We will look at those aspects and we will end this course with that. Thank you.