Water and Wastewater Engineering
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UASB (Continued)
Sludge Treatment
Lecture – 29

Last two classes we were discussing about anaerobic process. We have seen what is the fundamental of anaerobic process and what all are the parameters or the environmental conditions required for the proper functioning of anaerobic process and why the anaerobic process was not becoming popular in the recent past. We have also seen in detail about the high rate anaerobic processors or anaerobic reactors commonly used nowadays which can retain last quantities of biomass inside the system.

We were discussing about UASB reactor the Up flow Anaerobic Sludge Blanket reactor which is the one most commonly used for domestic wastewater treatment especially in tropical countries. We have seen how to design the reactor, how to design the settling zone, how to design the gas, liquids, and solid suppression systems etc in detail. Now we will discuss about the design of inlet as well as the outlet arrangements in the UASB reactor and further we will discuss about how the sludge coming from the biological treatment systems as well as chemical treatment systems can be handled.

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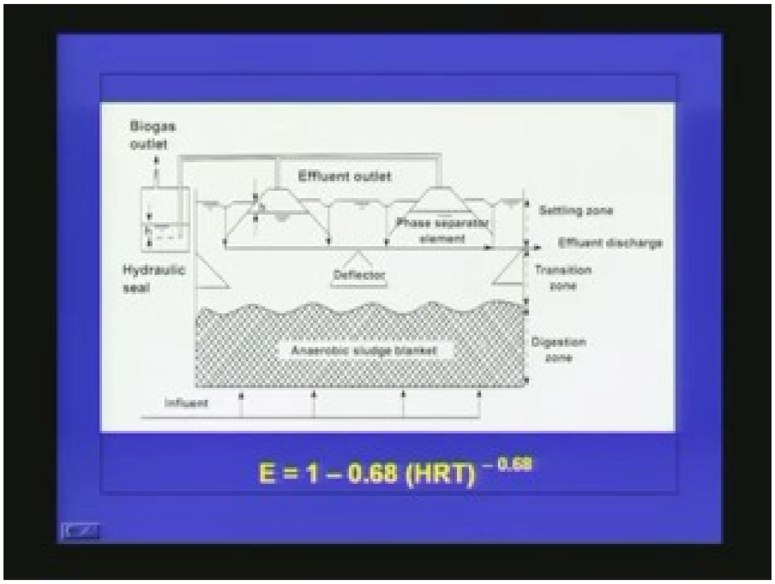

This is the picture or figure we were discussing about in detail last class. This is the schematic of an Up flow Anaerobic Sludge Blanket reactor. We have seen how it is functioning. The wastewater is coming like this (Refer Slide Time: 2:32) and the influent is getting equally distributed in the bottom of the reactor and the biological sludge which is flocculent in nature will be in the bottom of the reactor and as the wastewater passes through that one will pass through this sludge which is nothing but the active biomass. So the biomass will be in contact with the organic matter present in the wastewater so it will be undergoing degradation. As a result new biomass will be generated and the biomass will be coming up as well as the biogas whatever is generated as the byproduct of microbial degradation also will be coming up but if the solids escape along with the liquid then the efficiency of the system will be coming down. So we are providing a specific system here including this deflector beam and this corn arrangement (Refer Slide Time: 3:25) and this is known as Gas Liquid Solids Separator.

We have seen in detail how to design this one. the basic objective of this GLSS is to separate solid phase, liquid phase and gas phase so that all the biomass will be retained in these digesters and the biogas will be collected here and used for other purposes so we get a completely treated clear effluent here which can be discharged without any problem. This will be meeting the effluents standard.

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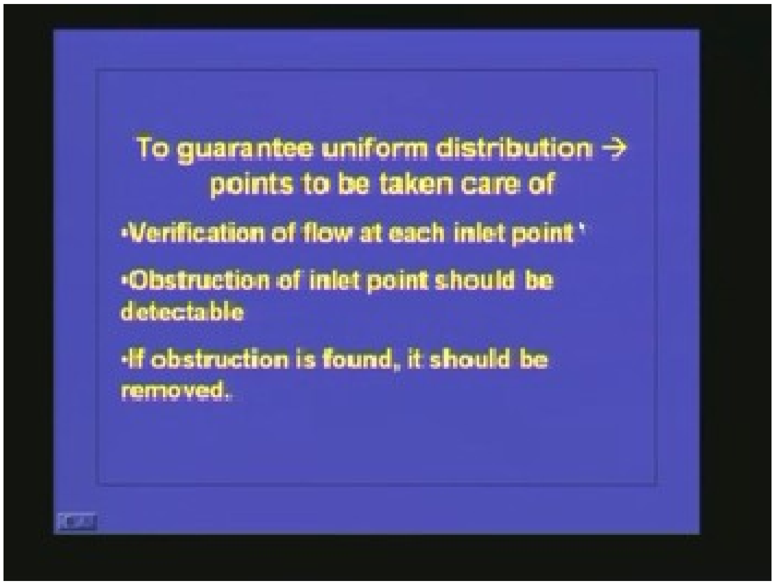

We have discussed in detail about the digestion zone design, settling zone design and GLSS design. Now we will see how to design the influent distribution device. The distribution of wastewater in the reactor is very, very important because if uniform distribution is not there then the contact of organic matter and the microorganism will not be proper so the efficiency of the system can come down. If the distribution is not uniform short circulating can take place in the system so only a very little amount of organic matter will be coming in contact with the active biomass so naturally that treatment efficiency will be coming down.

So, for the proper functioning of an anaerobic reactor or UASB reactor the uniformed distribution is essential, this is done using flow splitting devices. The recommended value is that at least one inlet should be there for every one to two meter squared of the reactor area. Why this uniform distribution is essential or how can we guarantee the uniform distribution. Thus, we have to verify these points or we have to take care of the following things. One should verify the flow at each inlet point.

Though we provide a proper distribution system if choking takes place in certain points then the distribution of the wastewater in the reactor zone will not be proper so definitely there will be short circuiting and some zones will not be getting any organic matter so that will be advisably effecting the reactor performance so verification of flow at each inlet point is very very essential and obstruction of inlet point should be detectable and if obstruction is found it should be removed. These are the important points to be taken care to get a uniformed distribution in the reactor.

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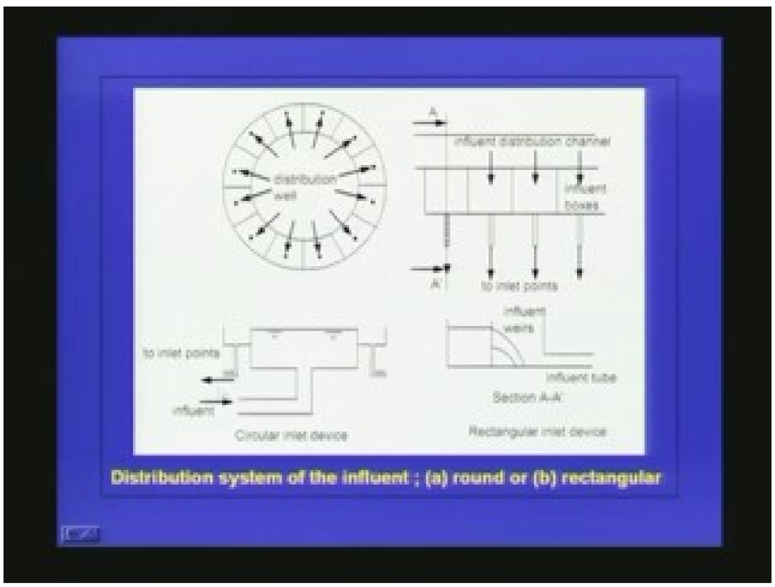

This shows a distribution system. This is the way the water is coming here and (Refer Slide Time: 6:00) this is the distribution well it is going to different points. As you can see this one from here it is coming to each inlet point and the main influent is coming like this and this is the rear and from here it is getting distributed to various inlet points and it will be going down. This inlet either it can be from the bottom of the reactor using a nozzle and the nozzle opening will be in the bottom of the pipe the reason is if the nozzle is facing to the sludge then the sludge will be entering the nozzle opening and the nozzle will be getting clogged.

So usually what will happen is a ball type or bell type arrangement will be there in inlet of the inlet tube and that will be covering or that will be providing the tube getting clogged because of the sludge and the wastewater will be entering from both sides and it will be going up so it will provide a proper distribution of the wastewater.

In some other cases what is usually done is the inlet will be coming from the top of the reactor straight to the bottom so because of the hydraulic pressure it will be getting distributed so choking can be avoided in that case. This is the arrangement usually used in circular devices and this is a rectangular inlet device. And the effluent collection devices are also very, very important. The effluent collection devices usually employed in UASB reactor are very similar to the wall which we use in sedimentation tanks.

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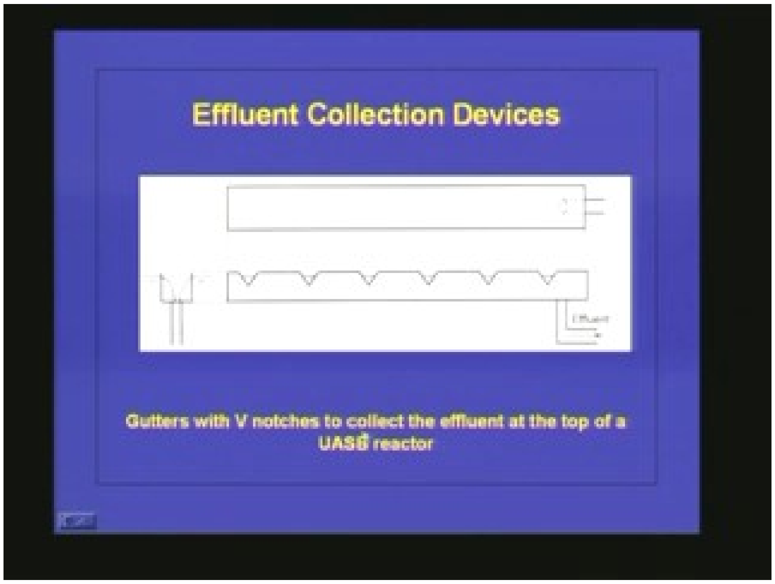

We have Gutters with V notches to collect the effluent at the top of a UASB reactor. Here we can see the Gutters with V notches so it will be getting collected here and the effluent is coming from here and it will be going either for treatment or for disposal. So this is the alternate design for effluent collection systems. So whatever we have designed or we have discussed in detail of the sedimentation tank is the same type. We know that in the UASB reactor the top portion will be acting as a sedimentation tank so the same type of an effluent collection device can be used for the USAB reactors.

We were discussing till now about the anaerobic treatment systems. But these anaerobic treatment systems in most of the cases cannot be used as a single treatment process for meeting the effluent discharge standards. The reason is anaerobic process will not be able to take care of the pathogens whatever is present in the wastewater or the microbial concentration whatever is present in the wastewater will be getting reduce only in one log order or two log order so we have to have a proper post treatment unit to take care of these things.

Moreover, in UASB reactor as we know the substrate is not getting oxidized and the biomass synthesis is very very less we have seen that the organic matter whatever is entering in the system only 8% is going for anabolism or the sludge generated in anaerobic process is very very less compared to the aerobic process. We know that for the microbial synthesis the nutrients are essential so if more cells are synthesized then definitely more nutrients present in the wastewater is used for that purpose.

But in anaerobic system since the microbial concentration is so less the nutrients used for cell synthesis is very very negligible. So, as a haul treatment unit if you take the anaerobic process there will not be any nutrient removal like nitrate or ammonia whatever present will be remaining as such but the one which has escaped through the gas base will be getting removed from the system otherwise everything will be getting accumulated in the wastewater treatment or in the anaerobic treatment system itself.

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Similarly, phosphorus also will be getting accumulated or it will not be getting removed from the system. So if you want to use it as a treatment unit and if you want to meet the effluent discharge standards whenever we go for an anaerobic treatment system we should have post-treatment. That is what I have given here; no nutrient removal is taking place in an anaerobic system and very little pathogens removal is taking place. So usually after the anaerobic treatment process we give post-treatment and most of the time the post-treatment is either an activated sludge unit or an oxidation pond or a maturation pond or an extended aeration system.

We know that all the minerals or all the inorganic substance whatever is present in the wastewater will be in the reduced condition when it comes out of the anaerobic reactor. Because in anaerobic reactor complete anaerobic condition or an environment which is contusive for reduction exists so whatever is there it will be coming out in the complete reduced form. So when we discharge it with the existing water bodies this reduced form of the minerals or the material will have a tendency to get oxidized so definitely there will be an oxidation or oxygen demand in the system. So, if you directly discharge the anaerobic effluent to a water body there will be some BOD exerted by the treated effluent. So it is always advisable to go for a post-treatment which can take care of the oxygen demand as well as the nutrient removal along with the pathogen removal.

Till now we were discussing about how to remove the organic matter from the wastewater. We have seen in detail aerobic process, anaerobic process both attached systems and suspended systems. And when we were talking about aerobic systems we have seen that in activated sludge process itself there are various process modification and depending upon the process we are selecting the sludge and the sludge generated will be varying.

For example, in a conventional activated sludge process whatever organic matter we are giving say if you are giving 1 kg of organic matter around 400 to 500 mg will be coming as sludge or active biomass and we will be removing in the secondary sedimentation time and it will be coming out as a sludge. But if you go for extended direction system then most of the biomass whatever is generated in the system will be getting auto oxidized and we will be getting only very little amount of sludge.

Similarly in anaerobic process also we will be getting a certain amount of sludge whether it is microorganism or the inorganic material whatever is present in the wastewater. So there is a need for the proper handling of this sludge or sludge treatment is very very essential. Not only in biological systems but also in physical chemical processes we have seen that whenever we go for coagulation flocculation what will happen to the sludge whatever is collected in the flocculation or sedimentation tank after the coagulation flocculation, so, that sludge also we have to take care.

Now we will discuss about the sludge treatment. What all are the different ways we can handle the sludge or what all are the precautions we have to take while handling the sludge. We will talk about the sludge treatment.

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Nowadays the sludge treatment is known as biosolids treatment. Sludge means something not useful or something not desirable. But once we call it as biosolids that means if you can give some treatment and we can get something which is having a certain beneficial value then definitely we can call it as biosolids. In the new or recent edition books they talk about biosolids treatment. It is in finding out what treatment can be given in order to get a beneficial use for the end product that we get.

Before going for the sludge treatment we have to see what are the different sources of this sludge and what is the characteristics of the sludge coming from different treatment units and what is the amount of the sludge coming from the treatment unit, so only after finding them we can go for or the selection of the process which is most economical or most viable for that particular system. So if you talk about a water treatment plant or a wastewater treatment plant sludge can be generated from various sources so these are the solids sources.

First one is screening. In screening we will be getting coarse solids because we know what the purpose of a screen is and in grit chamber we will be getting grit and in pre-serration system unit we get grit and scum again and in primary sedimentation unit we get primary solids and scum.

Primary solids means it will be basically organic matter and in biological treatment system either it is an activated sludge process or a trickling filter or in anaerobic process we will be getting suspended solids as the sludge. In secondary treatment secondary biosolids and scum will be coming and in solid processing facilities we will be getting solids, compost and ashes. These are the different sources of sludge or the biosolids whatever is coming in a wastewater treatment unit.

Now we will see; what are the characteristics of this sludge or the solids we are getting from different treatment units. The characteristics will be entirely different because each unit is having its own purpose. For example, for a screen we know what the purpose of a screen is as it will be removing all floating and large size particles. And if you compare the grit chamber we know that its main purpose is to remove grit or inorganic material which is having high settling velocity.

We know that the purpose of a primary sedimentation tank is to remove the suspended organic matter. When we come to a biological treatment unit the sludge will be a completely active microorganism. When we talk about the chemical treatment units the sludge will be a mixture of pollution as well as the chemical. So it is essential to know the characteristics of the sludge before going for a particular treatment. Now we will see the characteristics of the sludge from each unit.

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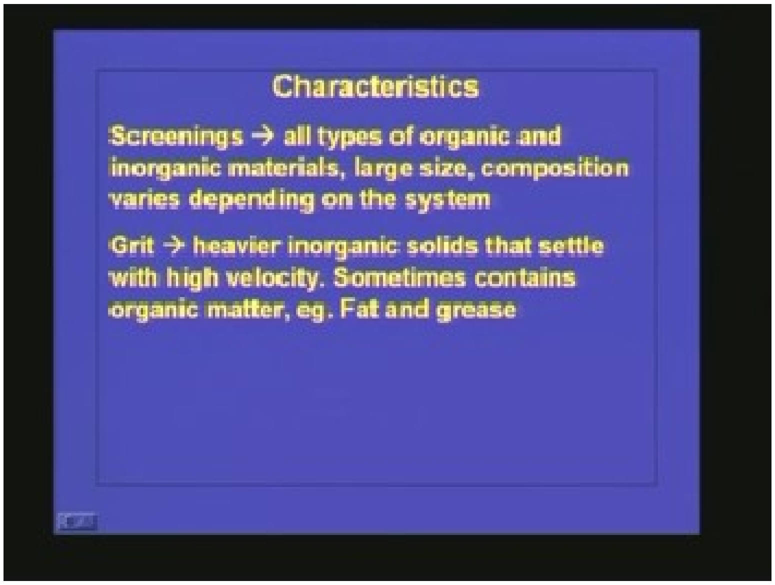

Screenings: whatever solids collected in the screen will be having all types of organic and inorganic materials and they will be large in size and the composition varies depending on the system. This is the characteristic of the screenings or solids collected in a screen. Now coming to grit chamber the material collected is what we call as grit, it is heavier inorganic solids that settle with high velocity because the basic design itself is meant for removing heavy inorganic materials from the wastewater. If it goes for further treatment or a secondary treatment unit then it will be adversely affecting the pumping system because it will create lot of wear and tear and unnecessarily we will be getting the sludge which is not active.

So, to prevent that one we provide the grit chamber so this is the basic character of a grit and sometimes it contains organic matter for example fat and grease. Because if the settling time whatever we are providing is very high then definitely along with inorganic material the organic material also will be settling down so the grit may contain some portion of organic matter like fat and grease. And this grease can get attached to the inorganic material and it will be settling or floating along with that one.

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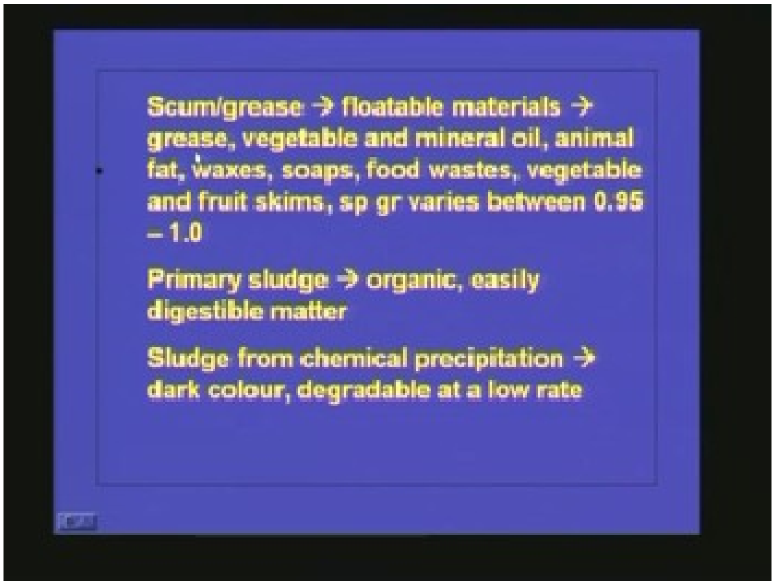

Now coming to scum and grease, we know that in certain cases we put the scum remover or grease remover. Definitely the solids coming from there is floatable in nature and it consists of grease, vegetable and mineral oil, animal fat, waxes, soaps, food wastes, vegetable and fruit skims and its specific gravity varies from 0.95 to 1. This is the characteristics of scum or grease.

Now we will see the characteristics of primary sludge. whatever we are collecting in the primary sedimentation tank mostly will be organic in nature and it is easily a digestible matter because it is not undergoing any biodegradation there and we know that lot of suspended solids will be present in the wastewater so in the primary sedimentation tank around 50 to 60% of the suspended solids present in the wastewater will be getting removed.

We have seen that the screens and grit chamber will be removing almost all the inorganic material which is heavier and having high settling velocity. So definitely this primary sludge will be organic in nature and easily digestible.

Now we will see the characteristics of the sludge from a chemical precipitation unit. Usually the sludge will be darkling color and degradable at low rate. The reason is organic matter will be there and from inorganic matter will be there so to remove that one we are adding certain chemicals to change the property of the material or the solids present there so because of that chemical addition we will be getting mixture of organic as well as inorganic sludge. Definitely because of the presence of this inorganic material or the chemical the degradability of the sludge we are getting from a chemical specification or chemical treatment plan will be less compared to the sludge we are getting from a primary sedimentation tank.

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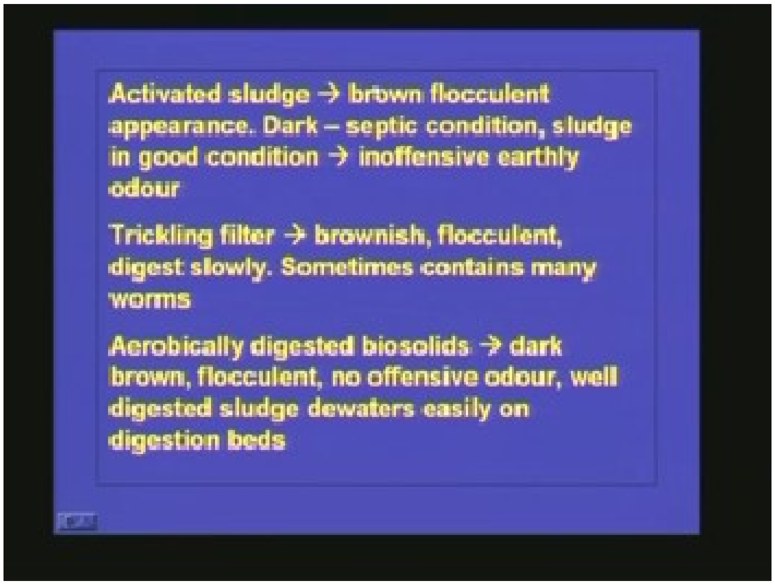

Sludge: Usually the color of the sludge will be brown and it is flocculent in nature.
And if the sludge becomes septic then it will become dark. And if the sludge is in good condition it doesn't have any smell or it is inoffensive and it will be having an earthy odor. But if it is dark and septic it will be generating offensive odor. This is the nature of activated sludge and mostly it is organic matter.

Now coming to the trickling filter we know whatever biomass is present in the trickling filter. Once it is (slow….21:20) from the material or the support media what will happen is it will be coming along with the liquid whatever is trickling through the bio filter and in the sedimentation tank the biomass will be settling down so that is the sludge whatever we get from a trickling filter.

The sludge from a trickling filter is usually brownish in color and they are flocculent in nature. Compared to this activated sludge the trickling filter sludge digests slowly and sometimes this sludge contains many worms. The reason is it is getting exposed to flies and as those flies lay eggs on the trickling filter definitely many worms and larva will be present in this sludge.

If you want to find out the characteristics of aerobically digested biosolids that is whatever sludge we are getting from these processes either from primary sedimentation tank, activated sludge process or trickling filter we can take care of or we can treat the sludge or reduce the volume of the sludge by further aerobic digestion. So if you go for this aerobic digestion and if you want to find out what is the characteristics of the sludge whatever is left over after digestion they will be either dark brown in color, of course there also flocculent in nature and there is no offensive odor. The well digested sludge dewaters easily on digestion beds that is one advantage. If you take the sludge from activated sludge and trickling filter and if you try to dewater it then it is very very difficult. But once we digestive sludge then if you want to dewater it then it will be much easier to dewater it compared to the undigested sludge.

Now we will see the characteristics of anaerobically digested biosolids. Most of the time these biosolids are completely stabilized and it is black in color and it contains large quantities of gas and if you want to find out the property of dried sludge it is having well cracked surfaces resembling that of garden loam. Hence this anaerobically digested biosolids are the sludge we can directly dispose off in drying beds because that doesn’t have any odors or anything.

Now coming to compost, compost is a method to treat the biosolids. So, after composing also we will be getting some solids left over. So the solids whatever we are getting from composting is dark brown to black in color and they are well digestive sludge and inoffensive and we can use it as manure or soil conditioners. This table gives as the basic properties of the sludge whatever we are getting from various treatment processors.

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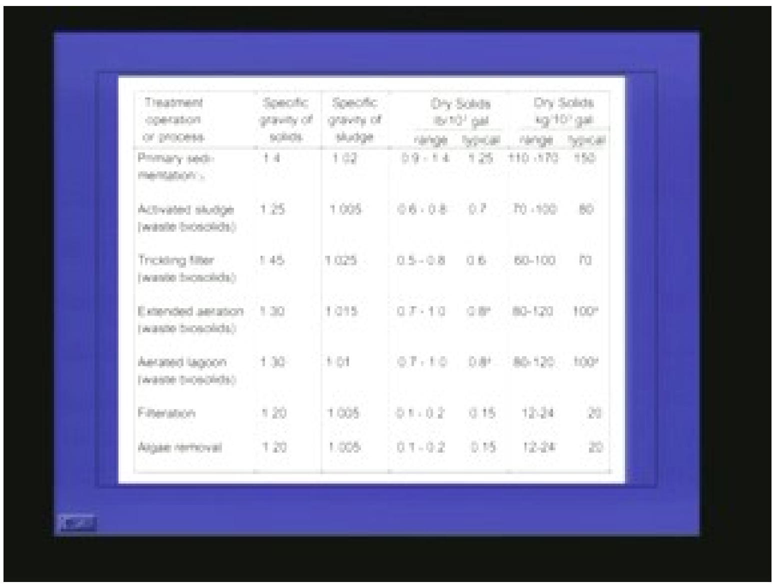

Treatment operation or process	Specific gravity of solids	Specific gravity of sludge	Dry Solids lb/10³ gal		Dry Solids kg/10³ gal	
			range	typical	range	typical
Primary sedimentation	1.4	1.02	0.9 - 1.4	1.25	110 - 170	150
Activated sludge (waste biosolids)	1.25	1.005	0.6 - 0.8	0.7	70 - 100	80
Trickling filter (waste biosolids)	1.45	1.025	0.5 - 0.8	0.6	60-100	70
Extended aeration (waste biosolids)	1.30	1.015	0.7 - 1.0	0.8[a]	80-120	100[a]
Aerated lagoon (waste biosolids)	1.30	1.01	0.7 - 1.0	0.8[a]	80-120	100[a]
Filteration	1.20	1.005	0.1 - 0.2	0.15	12-24	20
Algae removal	1.20	1.005	0.1 - 0.2	0.15	12-24	20

If you take the primary sedimentation tank the specific gravity of the solids is in the range of 1.4 but if you want to find out the specific gravity of the sludge it is only 1.02 because though the solids are having high specific gravity. We know that the sludge will be containing lot of water around 95 to 96% of water but the solids is only 2 to 4% so the net specific gravity of the sludge will be very very less almost equal to the water 1.02.

Activated sludge: Whatever is coming from the secondary sedimentation tank waste the specific gravity of the solids is around 1.25 and specific gravity of the sludge is only 1.005.

Trickling filter is having a better specific gravity of 1.45 but the sludge specific gravity is only 1.025.

Extended aeration is 1.3 and it is 1.015 because extended aeration sludge will be mostly inorganic in nature because whatever organic matter or the biomass present in the system will be getting auto oxidized during the aeration process. And in aerated lagoon the specific gravity of the sludge is 1.3 and specific gravity of the sludge is 1.01 this is the solid specific gravity.

Filtration is 1.2 and 1.005 and if you want to remove the algae from the oxidation pond the specific gravity of the solid is 1.2 and specific gravity of the sludge is 1.005. These values are very very important because it decides the volume of the sludge we have to handle. The volume is very very important when we design the treatment system. Similarly I have put the specific gravity of the solids and sludge for chemical treatment. if you go for line treatment the specific gravity will be 1.9 and 1.04, if it is high line process it is 2.22, 2.2 is the specific gravity of the solids and special gravity of the sludge is 1.05 and de-nitrification 1.22, 1.005 and roughening filters is 1.28 and 1.02.

If you want to find out what is the solids concentration coming out because we have the sludge and we know what is the volume of sludge coming so if you want to get an idea what is the amount of solids present so this cable gives this idea; for primary sludge from a primary settling tank the percentage of solids varies from 5 to 9 and typical value 6. Similarly I have given primary sludge with low lime addition for phosphorus removal the solids concentration vary from 2 to 8 and iron salt addition for phosphorus removal the solid concentration is 0.05 to 3. So we know what is the treatment unit and we can get corresponding solid concentration here.

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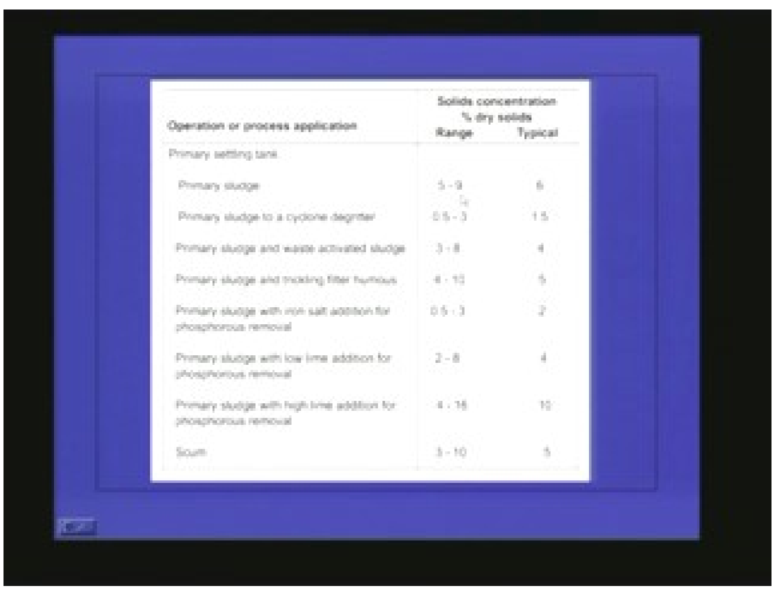

Operation or process application	Solids concentration % dry solids Range	Typical
Primary settling tank		
Primary sludge	5 - 9	6
Primary sludge to a cyclone degritter	0.5 - 3	1.5
Primary sludge and waste activated sludge	3 - 8	4
Primary sludge and trickling filter humous	4 - 10	5
Primary sludge with iron salt addition for phosphorous removal	0.5 - 3	2
Primary sludge with low lime addition for phosphorous removal	2 - 8	4
Primary sludge with high lime addition for phosphorous removal	4 - 16	10
Scum	3 - 10	5

So we will know what the amount is or what is the mass of solids we have to destruct and what the volume of sludge is. Similarly this gives the secondary treatment, waste activated sludge with primary settling the solid concentration of the sludge varies from

0.05 to 1.5 that means around 98.5 is water because we will be having such a huge volume and the sludge is only very very little. The waste activated sludge without primary settling will be little more because the solids whatever is not removed in this one because some inorganic solids also will be there so definitely the solids concentration in the secondary sedimentation tank will be increasing.

And if you see what is the sludge concentration or solid concentration RBC it is varying from 1 to 3 similarly trickling filter also the range is 1 to 3 and typical design value we take it as 1.5. Here I have again given gravity thickener and flotation thickener and centrifuge thickener, the solids concentration varies from 5 to 10 and 4 to 8. So we can see that in any case we take, the solid concentration is most of the time less than 5% and the remaining 95% is water and this is anaerobic digester the primary sludge if you want to go for the solid concentration we are taking as two to five from waste activated sludge 1.5 to 4 because this solid concentration is essential especially when we go for the stabilization unit design.

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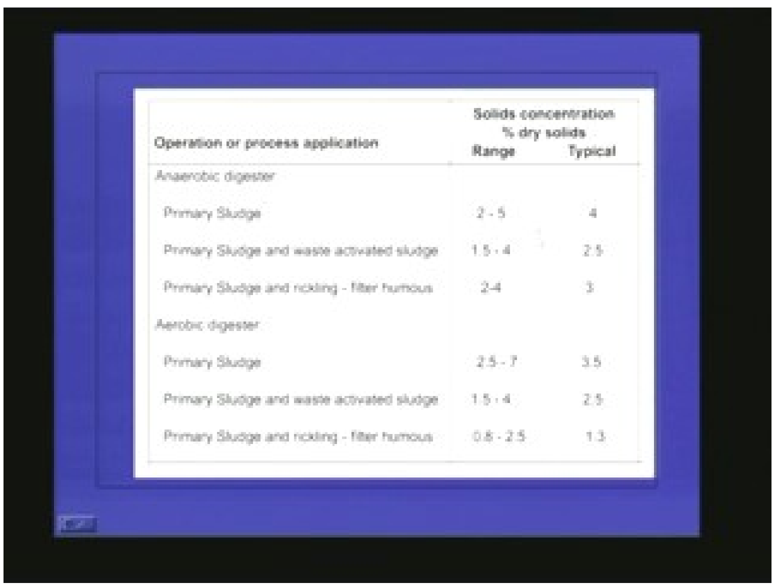

Operation or process application	Solids concentration % dry solids	
	Range	Typical
Anaerobic digester		
Primary Sludge	2 - 5	4
Primary Sludge and waste activated sludge	1.5 - 4	2.5
Primary Sludge and rickling - filter humous	2-4	3
Aerobic digester		
Primary Sludge	2.5 - 7	3.5
Primary Sludge and waste activated sludge	1.5 - 4	2.5
Primary Sludge and rickling - filter humous	0.8 - 2.5	1.3

This table is available in design manuals so we can get a rough idea about what is the solids concentration usually present in the sludge whatever we are getting from different treatments units. I have already told this is essential when we go for the design. We have seen that there will be lot of water present in that one and there will be different types of solids present in the sludge coming from various treatment units.

For example, if you take the sludge from an activated sludge process it will be having both volatile organic matter as well as fixed suspended solids or fixed matter that means organic and inorganic. So when we design a stabilization system or a biosolids treatment system we are not going to do anything with the inorganic solids because we cannot remove that one from the system that volume will be remaining as such. But we can remove the volatile solids or the organic solids by biological treatment systems or by chemical treatment systems. So it is essential to find out what is the volume of the sludge and what is the mass of the sludge and what is the mass contributed by the fixed solid and what is the mass contributed by the volatile solids and vice versa. So we can use this formula if you want to find out the volume of the sludge or what is the relationship between volume and mass of sludge.

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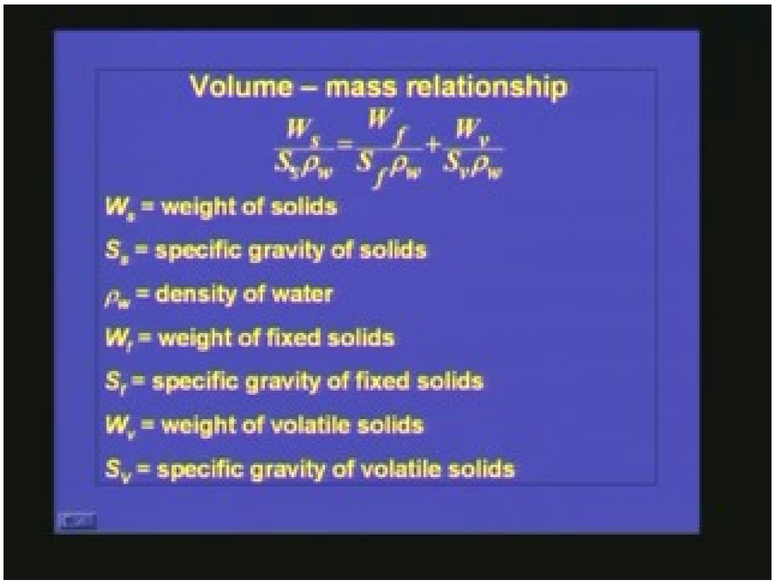

This formula is nothing but Ws by Ss by row w is equal to Wf divided by Sf into row w plus Wv by Sv into row w. Here Ws is the weight of total solids and Ss is the specific gravity of total solids. That means it includes more volatile as well as fixed solids. And row w as all of know it is nothing but the density of water and Wf is the weight of fixed solids and Sf is the specific gravity of fixed solids and Wv is the weight of volatile solids and Sv is the specific gravity of volatile solids.

So if you know what is the weight of fixed solids and volatile solids and the specific gravity of fixed solids and specific gravity of volatile solids then we can find out the volume of total sludge or the weight of total sludge etc. Now we will see a problem on how to find out the specific gravity of solids as well as sludge. This is the problem.

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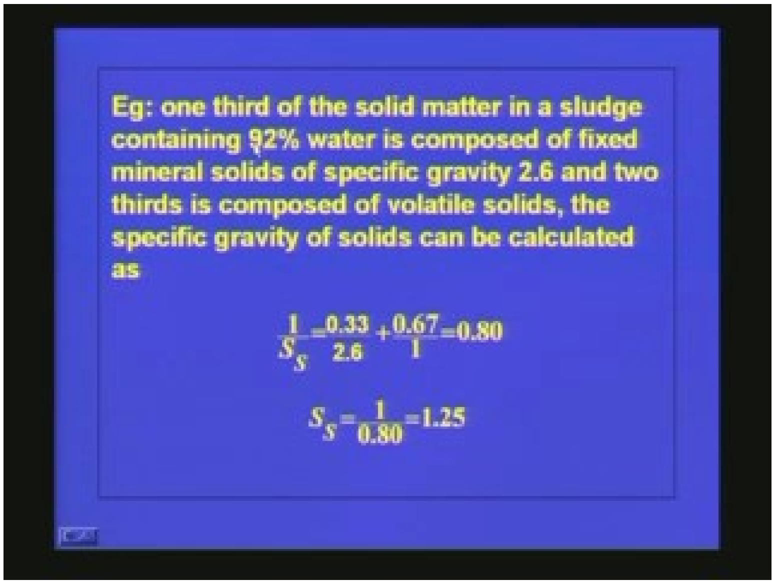

One third of the solid matter in a sludge containing 92% water is composed of fixed mineral solids of specific gravity 2.6 and two thirds is composed of volatile solids, the specific gravity of solids can be calculated as given below.

So before that, once again we will read the problem. The sludge containing around 92% of water and only 8% of solids and in the solids only one third is composed of fixed mineral solids and two third is volatile solids. And fixed mineral solid's specific gravity is 2.6 this is the information we have. Thus, first we have to find out the specific gravity of the solids alone. We are not considering the water initially but we are finding out the specific gravity of the solids alone so we can use this formula 1 by Ss is equal to what is the fraction of fixed mineral solids divided by its specific gravity plus what is the fraction of volatile solids by its specific gravity.

We know that only one third is fixed mineral solids so this will come as 0.033 divided by 2.6 plus 0.67 by 1. We are assuming the specific gravity of volatile solids is almost same as that of water. So we will be getting 1 by Ss or 1 by specific gravity of the solids as 0.80 or specific gravity of the solids as such is 1 by 0.80 that is equal to 1.25. This is the specific gravity of solids alone. But we know that in the total sludge around 92% is water and only 8% is solids.

Now the next step is we have to find out what is the specific gravity of the sludge as such. So if the specific gravity of water is taken as 1 then the specific gravity of sludge SsL this is the solid along with the liquids or the sludge that we can calculate as follows:
1 by SsL is equal to fraction of solids by its specific gravity plus fraction of water by its specific gravity. So we know that only 8% is solid so 0.08 by 1.25 + 0.92 by 1 which is equal to 0.984. This is the 1 by SsL or 1 by specific gravity of the sludge as such or the specific gravity of the sludge SsL is equal to 1 by 0.984 which is equal to 1.02.

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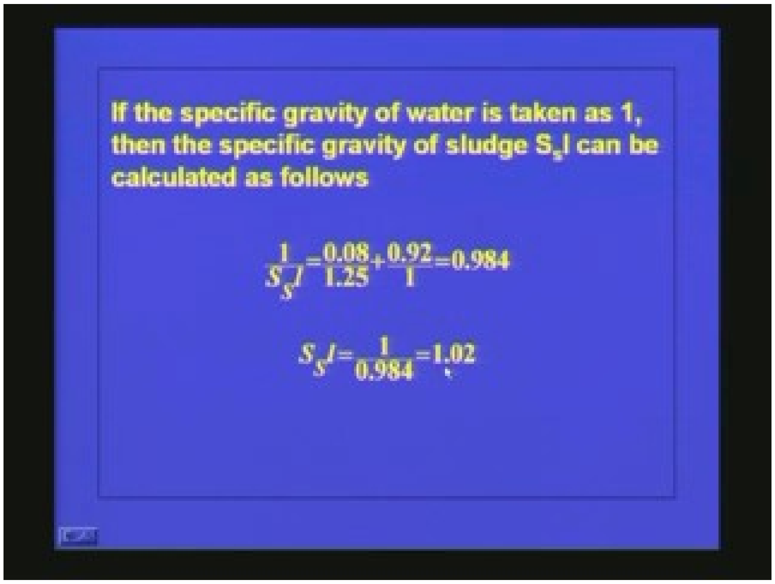

We can see that the specific gravity of the sludge is almost same as that of water and only a slight difference is there. And if you want to find out the volume of the sludge we can use this one. We know what is the total mass or weight of the sludge divided by row w into SsL into Ps where V is the volume of the sludge in meter cube, Ms is the mass of dry solids in kilogram, row w is the specific gravity of water and SsL is the specific gravity of sludge and Ps is the percent solids expressed as decimal. So if you know the percentage of solid present as a fraction and mass dry weight then we can find out the volume of the sludge.

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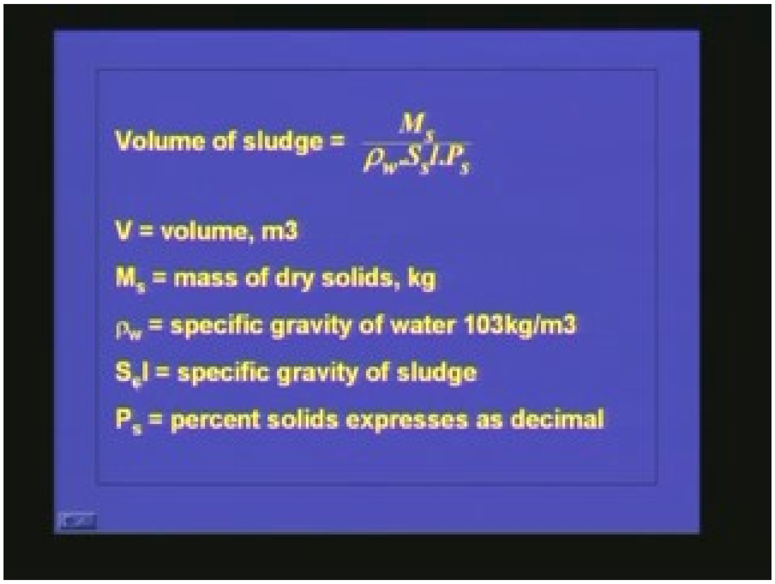

We have seen how to calculate the specific gravity of the solids as well as the specific gravity of the sludge. And if you know the solid concentration as weight then we know how to calculate the volume of the sludge. All these information are available and we know that from each unit what is the nature of the sludge that is coming and what is the amount of the sludge coming out and what is the solid concentration that is coming out, we have seen all those in detail.

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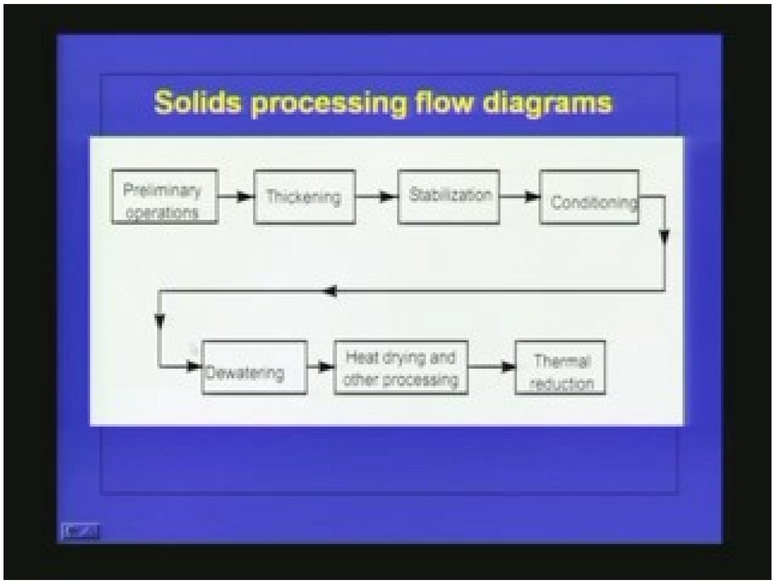

Now we will see the process we have to use for handling the solids. This is the solid processing flow diagram. It involves lot of processes. I tried to put everything in this single block diagram. The solid flow is coming like this (Refer Slide Time: 36:23) and initially it is going for the preliminary operations. The preliminary operations consist of grinding, degrading blending and storage. we know that the solids whatever is coming from different units such as screens, grit etc will be having very high sizes so we have to go for all these preliminary operations to get uniform characteristic solids.

We know that the water content in these solids will be very very high or the sludge solid content will be very less. So if you send the sludge just like that to the treatment unit definitely the treatment unit volume will be very very high and the chemical requirement will be very high. So it is always advisable to dewater the sludge as much as possible before sending it to stabilization. So the second operation in a solid processing flow diagram is thickening. Thickening is nothing but remove as much as water as possible. This can be achieved either by co-settling or gravity settling or by flotation or by centrifuging or gravity belt process or rotary drum. Therefore all these are the thickening process. We will see each process in detail afterwards.

Here I am trying to give a basic flow diagram on how we can manage the solids.
Once the thickening is over then we have to go for the stabilization. Stabilization is the process by which we stabilize the sludge. That means we remove the pathogens present

in the sludge, make the sludge in such a way that further purification is not possible. So this stabilization can be achieved either by chemical process that means most of the time we go for line stabilization then we can use aerobic process and anaerobic digestion. These are the most commonly used stabilization process. Once the stabilization is over again the sludge will be containing lot of water so it will be very very difficult to send it to sludge drying bed or another application.

The next one is conditioning. Conditioning makes us improve the quality of the sludge or it will be improving the dewatering property of the sludge, that is the purpose of this conditioning. Conditioning can be done either by chemical means or other means either thermal or other processors. Once the conditioning is over then we go for dewatering. Dewatering as we have discussed here in the thickening the same process can be used here either centrifuging, belt filter press or filter press or even we can go for sludge drying beds or read beds and even lagoons can be used for this dewatering purpose. The only thing we have to do is allow the sludge to stay there for long time, with respect to time whatever water is present in the sludge will be getting out of it and we will be getting relatively dewatered sludge.

Once the dewatering is over the next step is drying the sludge. Drying can be done either by direct layer in sludge drying beds or indirect layer method or composting alkaline stabilization and pasteurization long term storage. All these processes can be adopted for the heat drying process. After that one if you want to further reduce the sludge volume we can go for thermal reduction. That means we can go for different types of incineration process because we have got the sludge already thickened and dewatered and a dried one. We can apply to the land and if you don’t want to use that process and if you want to further reduce the volume we have to go for thermal treatment or incineration. Various types of incinerators can be use for this purpose.

Now we will see the processes we usually use in wastewater treatment plants. If the waste activated sludge is coming from an activated sludge process first we go for a thickener. We have seen in detail how to design a thickener. The secondary sedimentation tank itself will be acting as a thickener. So here the sludge from the activated sludge process as well as the sludge from the primary sedimentation tank can come and the thickening can take place then it will be going to anaerobic sludge digester and whatever supernatant is coming will be separated and sent for further treatment and whatever is the sludge coming from the anaerobic treatment system or the anaerobic digester usually it undergoes chemical conditioning if you are going for belt filter press for the dewatering.

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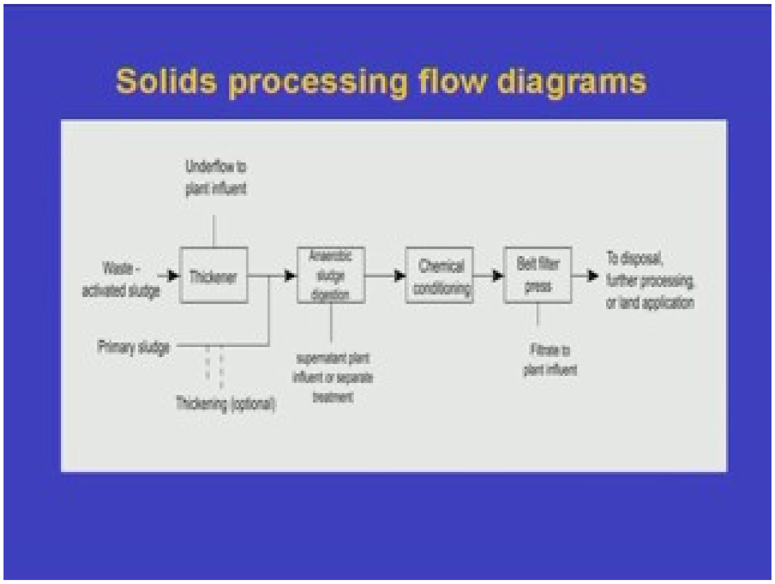

This is because chemical conditioning is required. When we discuss in detail we will know why this chemical conditioning is required. Once the dewatering is completed it can go for disposal or for further processing or land application. So this is one of the methods we can adopt for handling the sludge from a waste activated or the sludge from an activated sludge process. This is another system. This is a combined thickened waste activated and primary sludge so it is going for anaerobic sludge digestion then chemical conditioning. Here the only difference is instead of going for a belt filter press we can go for a centrifuge so definitely the centrifuge also will be dewatering the sludge and we will be getting dried sludge and we can send the dried sludge for disposal or for further processing or for land application.

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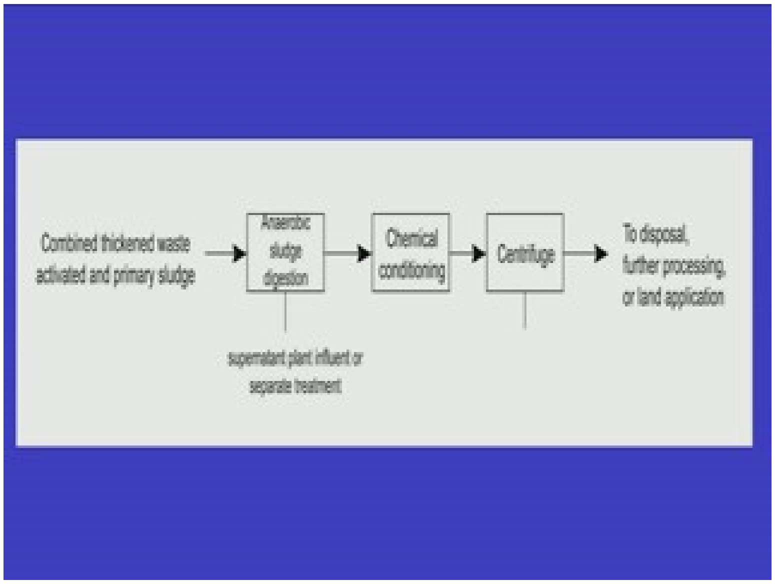

This is the third alternative the combined waste from the activated and primary sedimentation tank is coming and again we are going for anaerobic digestion and the plant effluent whatever is coming is going for further treatment.

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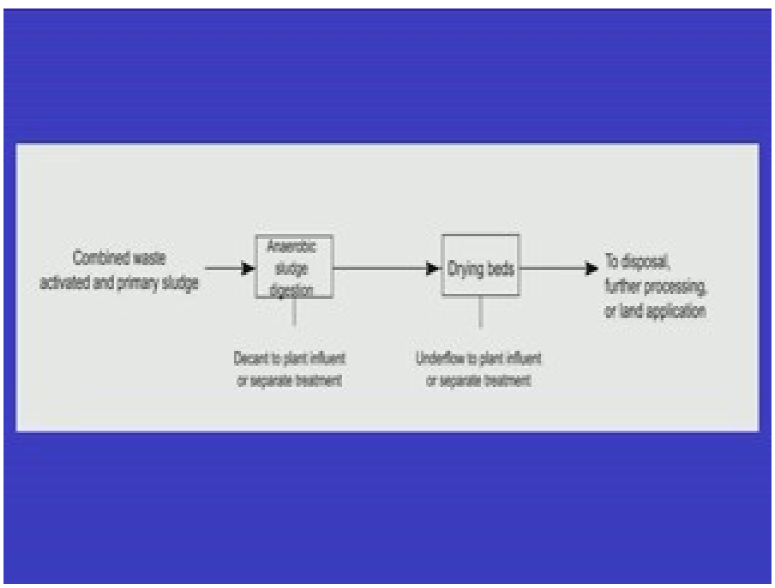

Here we are not going for any chemical conditioning or anything because the drying step is not either centrifuging or belt filter press, we are using only drying beds. So we are allowing the sludge to retain or stay there for a long time so within that time whatever water is present in the sludge will be drying out and because of the solar radiation or the temperature coming from the solar radiation the remaining water will be getting evaporated and we will be getting a dried sludge which can be disposed off or it can be process further or we can use it for land filling.

The flow chart we have seen so far tells us what are all the steps involved and we have seen them in detail. We have seen the process required for complete handling or complete treatment of these biosolids or the sludge generated from the various treatment operations and processes of wastewater. Now we will see each process in detail. First we will talk about the preliminary operations.

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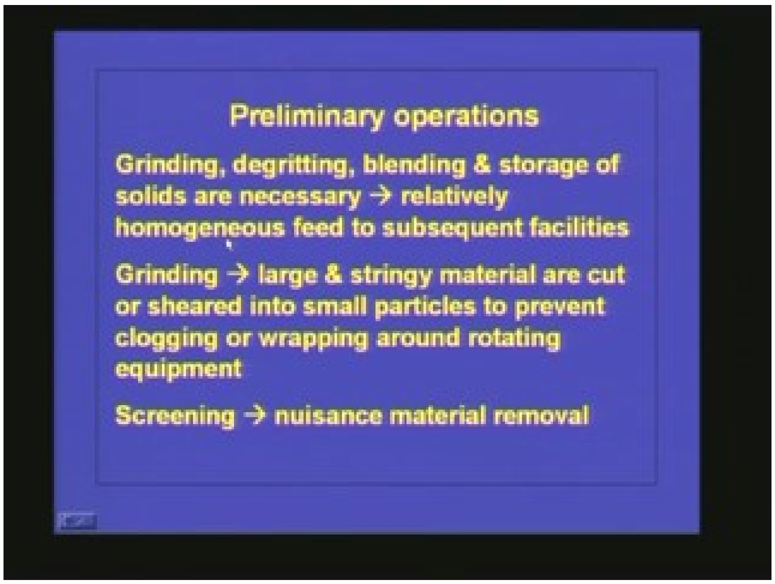

As we have discussed earlier the preliminary operations consist of grinding, degritting etc. What is grinding, degritting, blending and storage of solids?
These are the preliminary treatments. As we have already discussed the purpose of this preliminary treatment is to get a relatively homogeneous feed to the subsequent facilities. This is the major objective of these preliminary operations. What we are doing in grinding or why grinding is essential?
We know that the solids whatever is collected in the screens will be large in size so grinding is essential. Large and stringy materials are cut or sheared into small particles to prevent clogging or wrapping around rotating equipment. If you want do this one what will happen is that the large particles will be going to the next or the other treatment units so it will be clogging the perms and other operating systems which is having moving parts so it is essential cut them or shear them into smallest pieces.

Therefore, this grinding is essential for the screenings because the screening will be removing the nuisance material. Even after grinding some floating material which is larger in size which is not grinded properly will be getting removed in the screens and in degritting what we are doing is if you don't have a grit chamber or if the grit chamber is not functioning properly then definitely this inorganic material will be coming along with the biosolids so the sludge will be containing both organic and inorganic solids.

So if the grit or the inorganic solids are present along with the sludge then the pumps whatever we are using for the sludge will be getting affected by this grit so it is very very essential to remove the grit or the heavy inorganic material whatever is present in the biosolids. So it is necessary when no grit chambers are provided before the primary settling. The purpose is to remove the grit whatever is present in the biosolids.

Blending is the process in which the mixing takes place so that finally we get a uniform characteristics sludge. We are grinding it then we are screening to remove the nuisance material then we are going for degritting. Degritting will be removing all the grit material. Once these three operations are done we will be blending the sludge because we have seen the characteristics of the sludge coming from different operations are entirely different. So if you send them one by one so the treatment system the treatment system will be getting the feel of so much varying characteristics so it will be affecting the efficiency of the treatment system further whatever we are going to adopt for stabilization and other processes. So it is essential to send some what homogeneous sludge to further treatment units so that is the purpose of this blending.

Storage: to smooth out fluctuations in the rate of solids production. we know that the solids whatever is coming from different treatment units will not be continuous in nature because the screens or the screening whatever we are getting and whenever the screens get clogged and when the pressure drop is more than the permissible limit then only we go for cleaning of the screen. Once the screen is clean we are getting the solids from the screen so definitely it is not a continuous one.

Similarly it is for the activated sludge process also. in most of the cases the sludge wastage is not on continuous basis, it is daily once or twice or three or four times we will be wasting the sludge. Similarly in other biological process and chemical process the sludge wastage will not be a continuous one. So in such cases if we allow the sludge whatever is coming from the treatment units as such to the biosolids handling units then the efficiency of the system will not be proper. In such cases what we have to do is we have to blend the sludge and store it in a storage tank which will be utilizing the flow of the sludge and from the storage tank we can supply a specified quantity or a uniform quantity to further treatment units. So the sludge storage tank will be functioning exactly in the same way as that of an equalization tank in a wastewater treatment system. This storage is also very very essential which smoothes the fluctuations in the rate of solids production.

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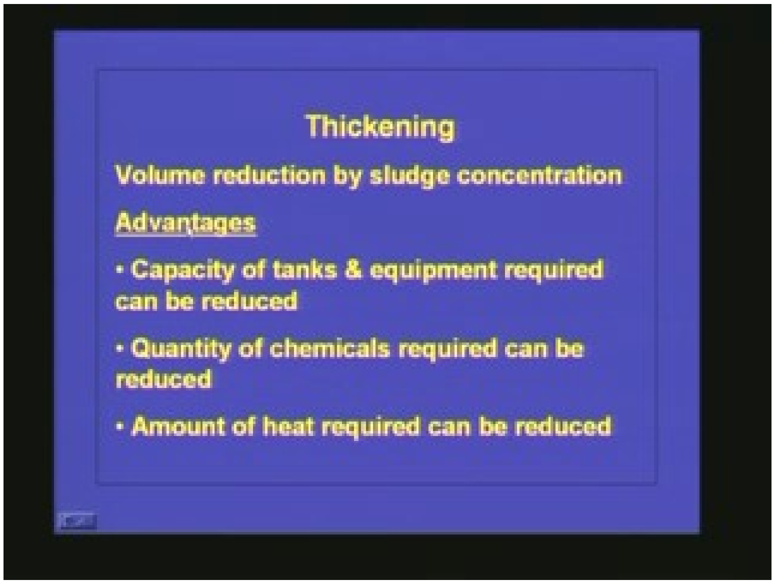

Now we will talk about thickening. The preliminary process is over and we know that the solids whatever is coming will be having less than 5% of solids. So if the solids concentration is less than 5% we can imagine that the remaining 95% is water because of this water content the volume of the treatment unit whatever we are going to provide will be increasing considerably. Definitely the treatment cost or the capital cost for the treatment unit will be increasing drastically. So if you can reduce the water content considerably then definitely your further treatment unit volume will be reducing significantly, that is the very purpose of this thickening.

The main function is volume reduction by sludge concentration and the advantage of this thickening is the capacity of tanks and equipment required can be reduced because we know that the solids is only less than 5% and the remaining capacity is only to handle the water whatever is present in the solids. So if you can remove that one we are only interested in handling the solids so the capacity of the tanks and equipment required can be reduced considerably then definitely the quantity of chemicals required can be reduced.

The reason is if you go for chemical conditioning or chemical stabilization if you want to add the chemicals definitely we have to add the chemicals to take care of the water whatever is present in the sludge because if the water content is small the chemical whatever we are adding it will be getting diluted and the effect will be less. Hence, we add more amount of chemical to take care of the dilution aspect. So if you can remove the water content from the sludge considerably definitely the quantity of the chemical to be added can be reduced significantly.

If you talk about the heat treatment the amount of heat required can be reduced because if the moisture content or the water content is very high definitely the heat required will be very high. So if you can remove that one the energy involved or the heat that we have to supply to achieve the same degree of treatment can be reduced considerably.

What are the methods commonly used for thickening?
They are;

- Co - settling thickening
- Gravity thickening
- Floatation thickening
- Centrifugal thickening
- Gravity belt thickening and
- Rotary term thickening

These are the most commonly used methods for thickening.

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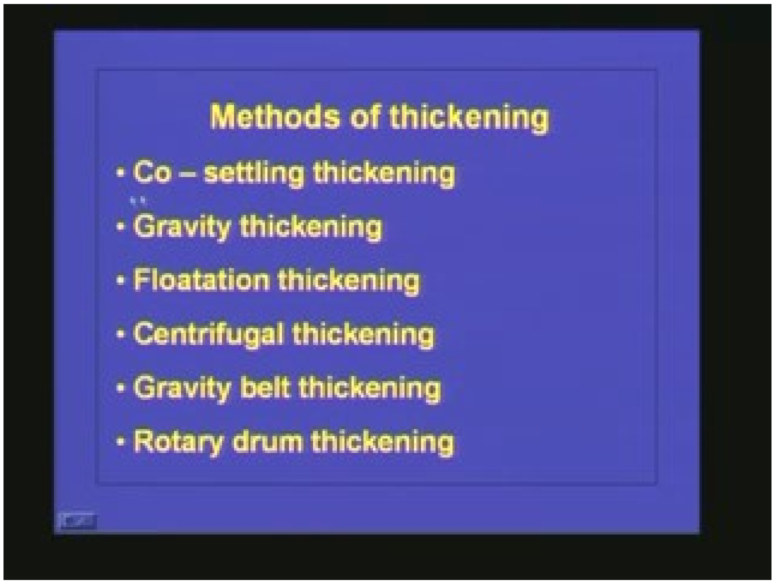

In co-settling we will be having various clarifiers and the sludge from the clarifiers will be coming to the thickener. Similarly the overflow from the clarifiers also will be coming to the thickener. So because of this one a proper thickening will be taking place in the thickening tank and it will be considerably reducing the sludge volume.

Gravity thickening we have already discussed in detail when we were discussing about the secondary sedimentation tank design. In activated sludge process whenever we design the secondary sedimentation tank it has to satisfy two criteria, one is the clarification and another one is sludge thickening. So we have to find out the area of the secondary sedimentation tank based upon these two criteria and we have to provide the area whichever is coming, mark either area corresponding to the clarification or the thickening.

The thickening area we can find out using the solid flux theory and we have seen in detail how to find out the area and how to design a gravity thickening unit. This shows the picture of a gravity settler. It is nothing but a sedimentation tank but the only thing is when we design the overflow rate, loading rate and cross sectional area it should be provided based upon the sludge thickening characteristics.

This is a circular type sedimentation tank, this is the entrance of the sludge (Refer Slide Time: 53:27) it will be getting distributed like this, this is the pressurized wastewater entrance it is coming here and here it is getting distributed like this and here it is getting settle and clear liquid will be going out like this and sludge can be collected through this one this is the sludge collector and here we have a retention baffle this will help the solids to enter into the liquids so what will happen is more and more clear liquids will be getting remote from this system so definitely whatever solids we are getting here will be having a high density compared to whatever we are supplying.

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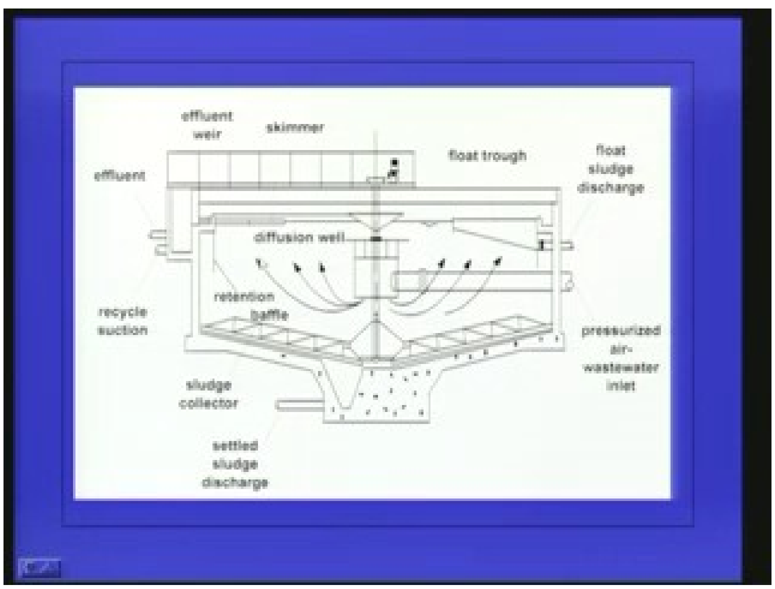

So this is a thickener floatation unit we all know. if the solid's density is less then instead of going for gravity settling or settling we can concentrate it by floatation. So floatation also we have discussed in detail when we were discussing about the solid removal.
Centrifugal thickening: Here we use the centrifugal force for the thickening. And in gravity belt thickening the sludge will be placed on a belt and the belt will be moving and with respect to time what will happen is whatever water is present in the sludge will be gradually oozing out and we will be getting a relatively concentrated sludge towards the end of the belt thickener.

In rotary drum thickening the drum will be rotating and because of the rotation the liquid will be getting remote from the sludge and we will be getting a concentrated sludge.

I will show few photographs of this centrifugal thickening gravity belt and rotary drum thickening. This is the centrifugal thickener.

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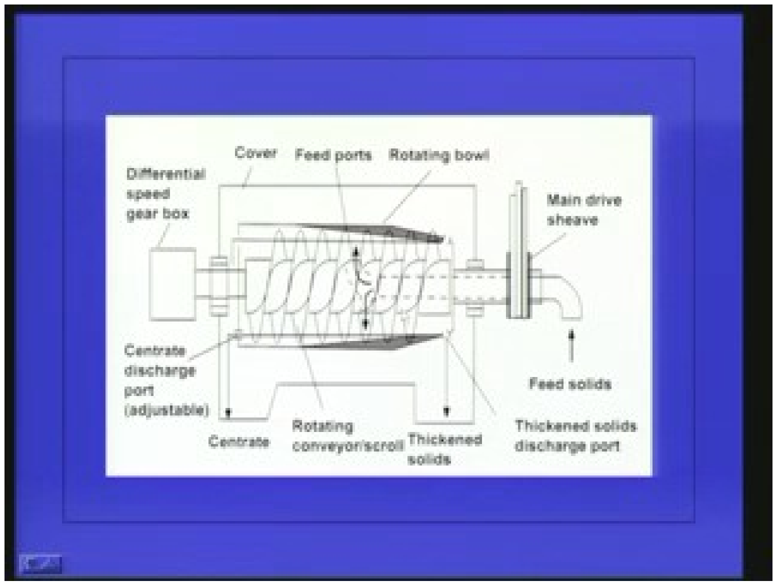

Here we can see that the free solids are entering and it is getting out in the system here, it is coming through the central shaft and it is getting out here and as we all know this is the gear box and this gear box will be rotating at a differential speed so with respect to time the solids will be getting pushed to the periphery of this drum, this is the rotating drum and we can see that this is having a tapering section. So as the solids move towards this side more and more compression will be taking place and the water will be getting discharged from the sludge and here we will be getting somewhat concentrated sludge. This we can remove (Refer Slide Time: 56:10) using this part here and here so the drum will be rotating and the feed is coming from the center and because of this one it is getting thickened.

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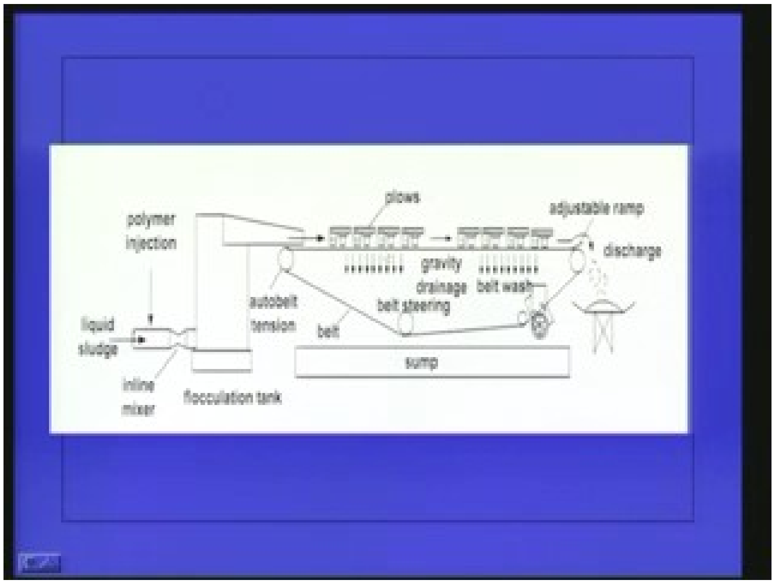

So this is the centrifugal thickener and this is the belt thickener. Here we can see that the liquid sludge is coming, we are adding some polymers and that is coming here, it is moving through the belt and because of this one gravity drainage is taking place so water is getting removed and this portion is meant for belt washing (Refer Slide Time: 56:40). So as it moves the sludge will be getting dewatered and here we get more concentrated sludge.

We have seen in detail the different process we have to adopt for the solid stabilization. we have seen the flow diagram so preliminary treatment is required then we have to go for dewatering the reason is the water content in the sludge will be very very high and solid concentration will be less so definitely it will be increasing the volume of further treatment. So once the dewatering is done then we can go for stabilization. The purpose of stabilization is to remove the pathogens and to distract the organic matter so that there will not be any further futrification.

Once the stabilization is over we can go for conditioning and again dewatering then drying then disposal. but in usual wastewater treatment plants especially when we go for the biological treatment systems we have seen that either in the activated sludge or the sludge coming from trickling filter usually we go for dewatering then anaerobic digestion then if you are going for belt thickener or centrifuge we have to go for chemical conditioning.0

But if you are going for sludge drying beds this conditioning is not required because in the sludge drying bed itself we are giving lot of time for the water to get removed from the sludge so that we can get a dry sludge which poses less volume and whatever is coming out by this we can use it as a manure because it is almost degraded and it will be having high nutrient value or if you want to further reduce the volume of the sludge we can go for heat treatment like incineration etc.

Once the volume reduction is taken place we can dispose it into land like and filling or something like that. So in the next class what we will do is we will be discussing in detail what all are the stabilization process that are most commonly used because that is very very important. We have to design the stabilization process based upon the sludge nature and the sludge quantity. So we will see the sludge stabilization and other processes in detail.