Wastewater Treatment and Recycling
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Lecture – 40
Wastewater Sludge Processing and Treatment Sludge Thickening

Hello friends so, we have been discussing about sludge management this week, which is produced from the wastewater treatment at different stages in the last couple of lectures of this week, we did talk about the generation aspect of the sludge and it is characteristics. So, what it contains and what different stages it is generated, how do we what we call as a primary sludge or secondary sludge, those kind of things we discussed in the earlier lectures of this week.

This lecture we are going to talk about in fact, we are going to start the discussions about the sludge processing and it is treatment, which we will continue to the next week as well, next lecture sorry. So, we will begin with the basics of how this sludge is processed and what are the various options for the treatment. And, then we will can take various treatment steps or various processing steps rather, we can say because not much of the treatment is provided, there is just digestion or a stabilization thing which you can call as a treatment, but majority of thing is in the form of certain processing that way.

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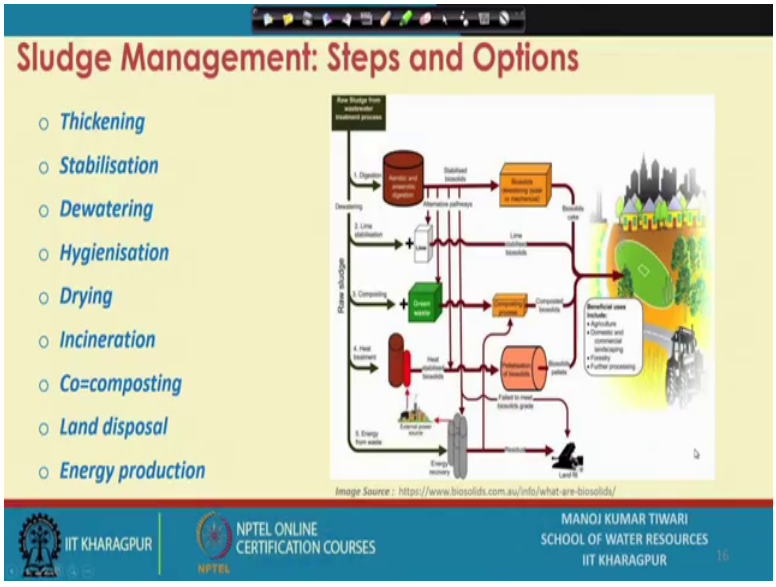

So, if we see these sludge management various steps and options. So, we have a variety of like quite a few of the processes or steps, which we can take for the processing of the sludge, this can involved the basic thickening it can involve stabilization, where we stabilized sludge it can have dewatering. Then ionization then we need drying incineration, we can go for composting or co composting then land disposal energy production. So, there are variety of these options.

And if we see typically the raw sludge which is produced from wastewater can undergo digestion, where is aerobic or anaerobic digestion take place and then the bio solids, we generate can be dewatered and then can be processed, we can go for stabilization, chemical stabilization like we can go for lime stabilization, where we add lime let it thicken then the kind of stabilized solids. We generate can be processed we can go for composting of the sludge, where we can take the sludge directly or we can take the digested sludge that way we are like green waste is generated and we can produce compost out of that.

We can go for heat treatment where this sludge is heated up and then the heat actually stabilizes variety of the bio solids. And then we can kind of take it to the next step or there is option of generating energy from the sludge, where basically we can do energy recovery in several means. We can do energy recovery by incinerating or those kind of thing, or we can recover energy from the digestion process as well particularly the anaerobic digestion process. So, that way there are various processes, various steps which can be taken for management of the sludge or for handling the sludge which is being generated.

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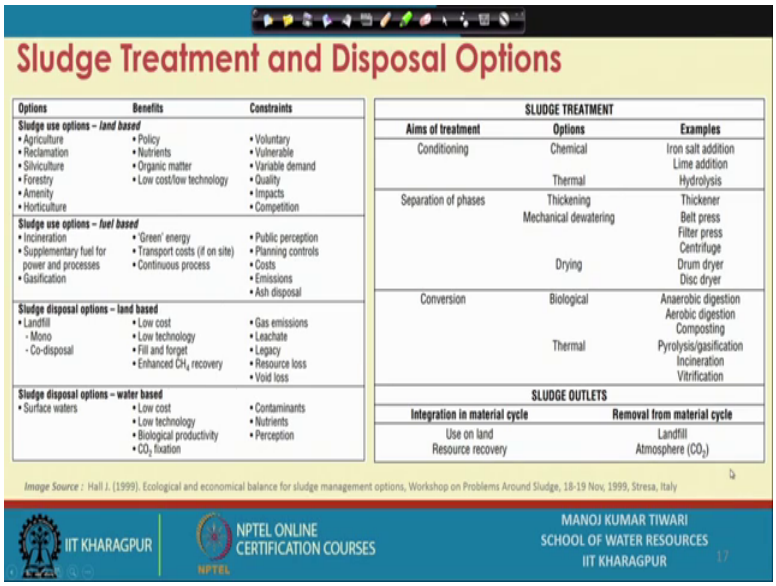

If we see these treatment and disposal option so, there are as we were discussing the various options, there are options of sludge use which are land based. So, when we are basically seeing the land based options sludge can be used in agricultural activities, it can be undergo reclamation.

It can be go in forestry horticulture, then variety of these things sludge can be used. The major benefits are that, there are policies exist for such reuse options sludge use options, we can use nutrients we can use organic matter and it is a low cost low technology criteria.

There are several constraints as well it is quite a few like, it is a vulnerable process can actually affect the soil quality adversely, there is a quantity issues there are impact issues. And, there are like competition from the other sectors as well, then we can go for sludge use options which are fuel based. So, we can go for incineration gasification, or we can use sludge as a supplementary fuel for powers and various processes. The benefits are that it is a form of green energy because we are using waste material.

We are using sludge for generating energy, there is like if it is generating on site. So, like the plant where we are generating sludge, if we can produce power and run the same plant itself. So, there is not much of transportation cost involved. And it can be a continuous process, because sludge generation is more or less continuous, we keep on getting sewage water and then as we treating the sludge generation is a continuous

process. So, we get a continuous supply of this sludge which can be used for the generation of the fuel.

There are several constraints the public perception, whether we are using sludge for energy generation. So, how good this system is going to be what are the pollution aspect related to that, there are planning controls there is a cost aspect, these are generally a costly process because incinerating requires huge amount of energy.

So, we are generating energy, but there is a like inflow of energy is also needed and many times what is seen that if it is not on a favorable scale, we may end up actually supplying more energy than we produce. So, that way it eventually becomes an energy negative proposition. So, that has to be seen, there are various issues with the emissions, because when we are incinerating when we are kind of gasifying this sludge.

So, the sludge may contain various pollutant in solid state, but when we end up incinerating it or gasifying it we may release actually in the form we can emit in the form of air pollutants to the atmosphere. So, that becomes an issue and then we generate ash which is again a kind of issue related to the disposal of the generated ash.

Now, there are, these are the kind of use option when we use sludge either on land or as a fuel based, this sludge can be disposed off. So, there are disposal options for the sludge, the disposal option is the sludge being a solid material will not be disposed to the water resources typically so, it goes to the land and it can go to the landfills as mono. So, where only sludge is being land filled, or it can go for co disposal where sludge along with some other solid waste materials like municipal solid waste, or those kind of thing is kind is subjected to land filling together.

So, these are the options. Now, again there are benefits that these are also low cost and low technology approaches, you just fill it into the landfill and then forget. So, not much kind of a maintenance or observation or monitoring is needed and from such landfills there is a chances of methane recovery if we set up a system like that, but again very rare though.

There are constraints in the form of gas emission which can be generated there is a leachate possibility of leachate production, when we have made sludge to the landfills and if let us say rainfall or precipitation occurs. So, there is like the water is going to pass

through or mix through the sludge and, it can potentially generate leachate which can contaminate the groundwater and may have variety of metals or those kind of things.

But, again the leachate can also be controlled by properly designing the landfill. So, if we put a leachate collection system to the landfill. So, whatever leaches is generated can actually be con collected as a liquid waste form and then can further be processed, there is a legacy issues legacy pollutants or those kind of thing there is a loss of resource, because we are using land resources for waste disposal. So, the land which is kind of a very precious resource gets lost in this management of this sludge only.

And ways when it gets dried so, there is a wide loss those kind of issues are there are disposal options which are water based so, we dump this to surface water very very rarely used not recommended generally though it can be dumped to the sea. So, instead of like surface normal surface water ponds like those kind of thing the sludge can be dumped to see that way that is another option.

So, this is a low cost low technology there is biological productivity and it can act as a for CO 2 fixation, there are constraints in the form of contaminants being released nutrients being released to the water or then like perception basis that we are dumping a solid waste or waste material to surface water body. So, those kind of issues are also there.

Now, if we see the treatment options these are the kind of a use options and disposal options. Among treatment options there is conditioning of the large which could be chemical conditioning or thermal conditioning. So, for this we can use iron salts or lime addition or hydrolysis, there is a separation of phases. So, through thickening and dewatering we can do the phase separation. And through drying again we can actually let the water evaporate and sludge becomes a dry case.

So, we have thickeners belt press filter press centrifuge, drum dryer, disk dryer rotating disc, thickener those kind of things we have. So, there are variety of option in here which some of these we will discuss in the later slide. Then conversion options is there, where we can go for biological conversion which in includes aerobic composting and anaerobic composting, or like anaerobic digestion aerobic digestion and standard composting. And then there are thermal conversions where we can go for pyrolysis or gasification

incineration and vitrification kind of processes for the conversion of the or we can call that stabilization in fact, the stabilization of the solids present in the sludge.

So, sludge outlets if we see there it is possibility of integrated in material cycle. So, if those kind of things are there. So, we use on land resource recovery and if we kind of remove it from material cycle so, it goes to the landfill or goes to the atmosphere. So, these are the kind of options that we typically get.

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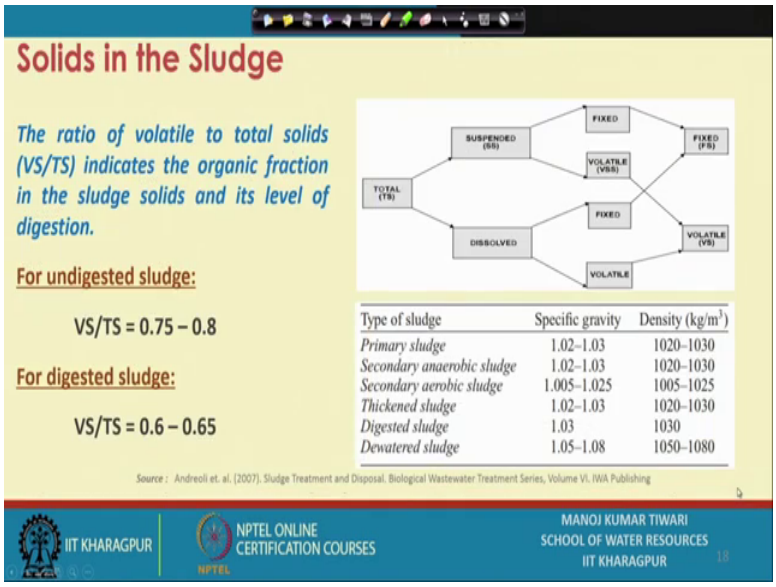

So, this are various treatment and disposal options kind of now, for the treatment of sludge the first and foremost thing we understand that what we are going to treat or what we are going to process.

So, as we discussed essentially sludge processing needs to the be there like processing of these solids. So, it is essentially the solids which we are planning to process, now there are different forms and different types of solids. So, the total solids present in the sludge can be basically as categorized as suspended solids or dissolved solids, then as the criteria says fixed solids, volatile solids which will both be in the form of suspended solids.

So, this will be actually FSS fixed suspended solid volatile suspended solids and similarly fixed dissolved solids and volatile dissolved solids. And then we have total

volatile solids and total fixed solids and here we have total suspended solids and total dissolved solids.

So, that way we have all these various options, now for the sludge purpose its actually the ratio of volatile solids to the total solids, which is VS by TS this indicates kind of the organic fraction present in the sludge, because TS is your total solids all the solids which are present and VS or TDS we you said is actually the total volatile solids which are present in the system.

So, volatile solids is a symbolic of organic solids, because organic solids can vaporize, inorganic mineral metal salts sand silt clay those kind of things will not get vaporized. So, since this is the organic fraction and this is the total fraction so, ratio of the organic fraction to the total fraction is indicates the basically organic fraction of this sludge present in the total solids and this tells the possibility or effectiveness of the level of digestion.

So, if we have an undigested sludge where digestion has not taken place, we get volatile solids to total solids ratio of the order of 0.75 to 0.8; that means, majority of this thing is already intact organic matter, but for digested sludge we get a lesser ratio, because some of the organic matter through digestion has been mineralized has been converted to mineral. So, there is a loss of volatile solids from the total solids and as a result the ratio of volatile solids to total solids decreases for digested sludge.

Now, if we see the different type of sludge the primary sludge, secondary anaerobic sludge or secondary aerobic sludge, thickened sludge, digested sludge, dewatering sludge this is their specific ranges or specific gravity and density. So, what we see that primary sludge is typically having density of the order of say 1020 to 1030 slightly higher than that of water.

Your secondary anaerobic sludge has similar density, secondary aerobic sludge will have a slightly lesser density than the primary sludge. And then thickened sludge will again have similar density of that digested sludge and when you dewater sludge, you end up getting relate a little higher density as compared to the other forms of the sludge. So, that specific gravity and density is quite useful for the analysis, when we end up kind of quantifying the sludge or measure the sludge.

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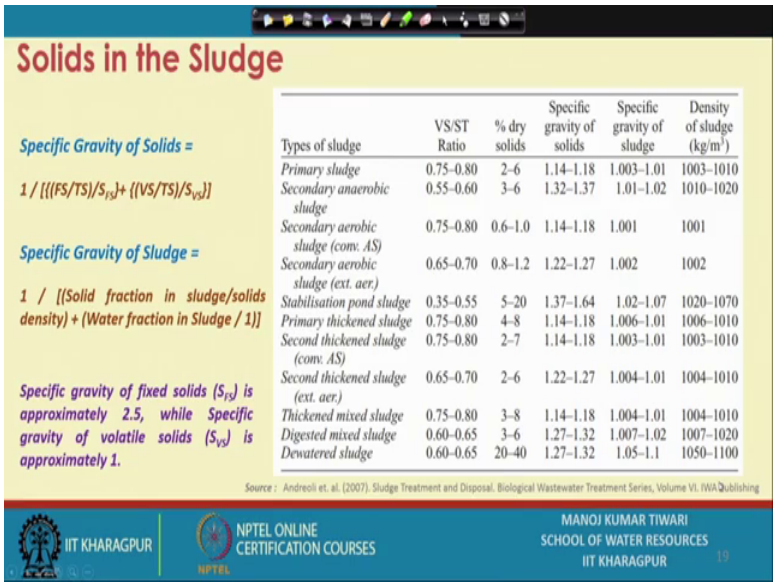

So, how we get the volume or those fractions in a sludge or the quantification of solids in the sludge so, the specific gravity of solids if we say in the sludge, will actually be equal to the like fixed solid to total solids, which gives us the ratio of the fixed component of solids and a specific gravity of fixed solid.

So, that is one constituent and then similarly the fraction of the volatile solids to the specific gravity of volatile solids. So, if we take this and all this divide one with this number, we get the specific gravity of solids. And similarly we can get the specific gravity of sludge, when we divide one with the solid fraction, in the sludge divided by solid density and water fraction in the sludge divided by the density of water. Density of water is typically 1 so, we can use 1 here.

The typical specific gravity of fixed solids here, S FS is approximately 2.5 though various sources differ on this some take it as around 2.65 some say 2.5 so, but average can be approximately taken as 2.5 whereas, specific gravity of volatile solids is approximately equal to 1. So, as you are seeing that when the sludge is having larger constituents larger component the specific gravity was all particularly in that range.

Again depending on the type of sludge it is primary secondary sludge or what this is we get the volatile solids to total solids ratio. So, for primary sludge it is higher, the percentage of dry solids remains from 2 to 6 percent the specific gravity is from 1.14 to

1.18. The specific gravity of this sludge is very close to the that of water and that way the density also converts to can be estimated from the specific gravity.

Secondary sludge which is formed from the anaerobic processes has relatively lesser because anaerobic digestion all already takes care lot of this thing. So, we will get lesser VS to TS ratio the percentage of solids is 3 to 6 little higher percentage and this is the specific gravity, this is the specific gravity of solids and the specific gravity of the sludge.

Then secondary aerobic sludge coming from the activated sludge process, coming from the extended aeration process. So, that way we can have the different this thing then when we stabilize it. So, stabilization pond primary thickening, secondary thickening through activated sludge secondary thickening through extended aeration thickened mixed sludge, then digested mixed large and dewatered sludge.

So, for all these are the kind of useful information in the form of their the specific gravity of the dry solids the specific gravity of the sludge and density of the sludge and percentage of dry solids. So, that way we can estimate the kind of come extent volume or weight of the solids present in the sludge. Now, these solids are the one which are processed and as we discussed, there are variety of processing, there are variety of processing steps.

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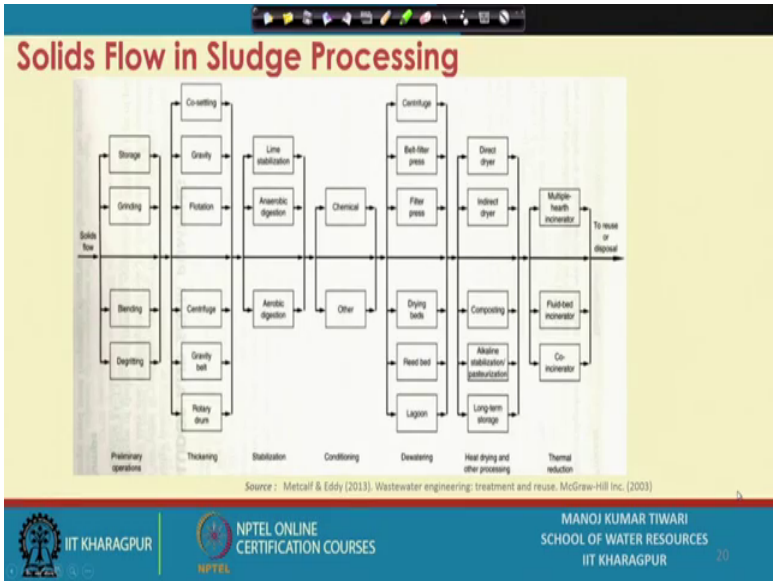

So, the first like if we see the solid flow, how the solids flows in a sludge processing system a typical sludge processing system. So, the solids that we get over here is first go to the preliminary operations, where we store maybe grind maybe blend or kind of like we go for degritting. So, removal of the grit and those things, then the general step or the general starting step basic starting step is sludge thickening.

So, sludge is thickened, how it is thickened it can be thickened by co settling by gravity, by flotation, by centrifuge by gravity belt by rotary drum. So, there are variety of options for thickening. And then it goes to the stabilization where it is stabilized. So, stabilization can be through aerobic digestion anaerobic digestion, or through lime stabilization which is chemical form of stabilization, then it goes for conditioning.

So, stabilized sludge can be conditioned using various chemicals. So, there are organic chemicals for sludge conditioning, there are inorganic chemicals for sludge conditioning. So, those can be used or there are other processes thermal processes for sludge conditioning as well. So, it can be conditioned using providing temperature or providing heat.

Again these are kind of optional steps we may actually condition sludge at the beforehand also. So, many times what we see that sludge is first chemically conditioned and then it was taken to thickening. So, there is a flexibility of kind of let moving here and there based on the volume based on the characteristic based on the quantity and based on the design of the sludge processing system. Towards the later part it is the sludge goes for dewatering purpose again majority of this thing like centrifuge gravity belt filter press, belt filter drying beds read beds and various lagoons can be used for the dewatering purpose.

And after that there is heat trying another processing which could be basically composting indirect dryer direct drying, alkalinite, alkalinity stabilization or long term storage of the sludge. And then it can go for thermal reduction so, multiple health incinerator, we can it can actually go to the incinerator if we tend to kind of incinerate or final process that or from here, also it can actually go to direct disposal purpose. But if you want to incinerate it, then it will be incinerate the dried sludge will be incinerated and then the kind of residues or ash which is formed can go for the disposal purpose.

So, that is the typical solid flow how this sludge is processed over there. Now, as we were discussing that when the this process takes place. So, the preliminary operations are simple we need to blend different sludge, or we need to de grit the store and or grinding those kind of things are pretty simple, many times not done actually at the sewage treatment facilities. The first step usually taken is the thickening, a many places the conditioning is the first step, but otherwise the thickening is generally which is first provided.

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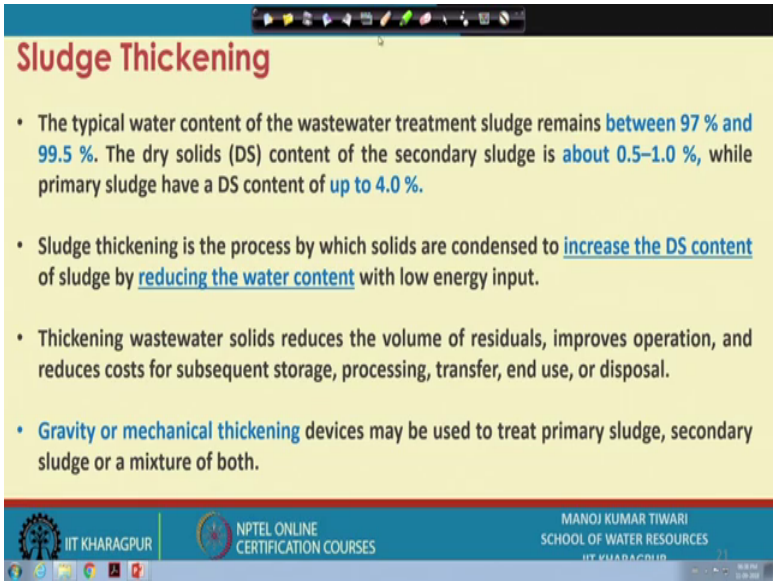

So, if we talk about thickening which is traditionally the first step of the treatment for the sludge that way. So, the typical water content of the wastewater treatment sludge remains between 97 percent to 99.5 percent a large amount of a large volume or large mass of the total sludge is actually in the form of water, the dry solid contents that way will be typically about 0.5 to 1 percent in the second sludge, whereas in primary sludge it could be up to four percent. So, that is the kind of dry solids, we can get in the sludge. And secondary sludge particularly is more has much more water content, where dry solids could go could be somewhere between 0.5 to 1 percent and then more than 99 percent is actually the water.

So, in order to reduce the volume, because what is ever process we take on further the first thing we want to the kind of huge volume, we are getting we reduce the volume and a very simple step for volume reduction is take out water from the sludge. There is a lot

of water content in the sludge and if we can reduce that water content, we will be able to kind of save a lot.

So, that way if you see the sludge so for say you have just dry solids let us say 1 kg dry solids I have. Now, if there is 99 percent water content so; that means, there is 99 kg or 99 there be 99 kgs of water and total weight of the sludge is going to be 100 kg, this will give me typically 1 percent sludge, 1 percent solid content.

Now, if I am able to change this 1 percent to say 10 percent. If I am able to change this 1 percent to 10 percent, then what happens that this 1 kg solid is still remaining because there was a 1 kg solid so, the solid mass is still intact, but now since my water content is 10 percent. So, I will have just 9 kg of water and my total weight is just going to be 10 kg.

So, I have saved 90 percent of the weight or that way, if you say the specific gravity more or less similar. So, 90 percent of the volume I have reduced by increasing water content of the sludge from 1 percent to 10 percent. So, that is how we can save in the front in the form of space or in the form of weight of the sludge.

Sludge thickening is the process by which solids are kind of condensed. So, their dissolved solid content is increased and, their water content is reduced. And this is done with a low energy input, traditionally with the low energy input. Nowadays, we have some mechanical systems which need significant amount of energy for thickening process as well, but still the concept is to achieve this reduction in the water content or increase in the dyes dry solid content with the minimal amount of energy.

So, thickening wastewater solid reduces the volume of residuals, it improves the operation and reduces the cost of the subsequent storage processing transfer end use or disposal systems. Because we have reduced the volume so that way all subsequent processing cost reduces. And typically this thickening can be achieved by the gravity or mechanical thickening devices, which may be used to treat primary sludge, secondary sludge or kind of a mixture of both.

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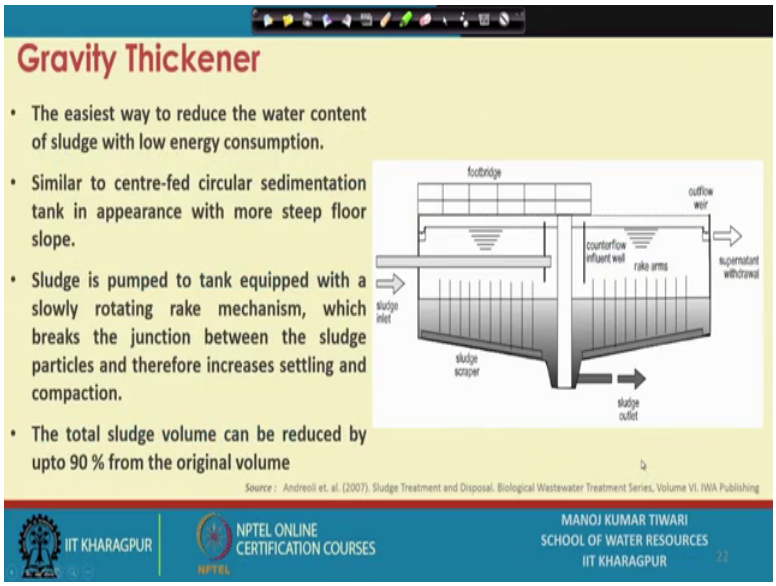

So, what are these thickening devices if you see, there is gravity thickener, which is kind of the easiest way to reduce the water content of the sludge, with the low energy consumption. So, it is a simple process we have kind of a like circular sedimentation tank kind of thing we will get. So, it is as good as a circular sedimentation tank in appearance with more steep floor soap. So, the slope is much steeper and through this mechanical arm we allow this thing. So, sludge is pumped to the tank from the generally bottom. So, we will actually pump the sludge from here.

And then or we can actually let the sludge enter from here also. So, both kind of systems are there, this breaks the junction between sludge and particles this mix mixing and, allows the particles to settle the total sludge volume can be reduced by up to 90 percent from the original volume in these gravity thickeners with very low energy input.

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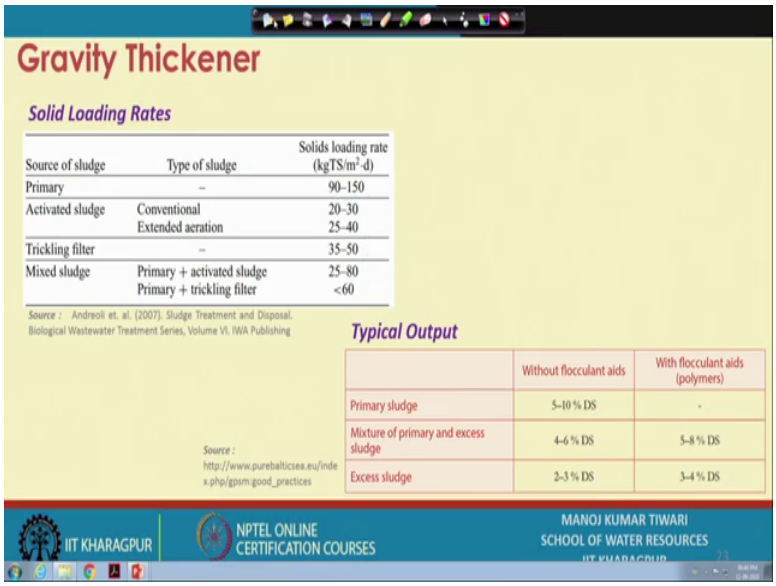

So, the solid loading rate in these gravity thickness for if source of sludge is primary the permissible or the range of solid loading is typically 90 to 150 kg tons of sludge per meter square per day. For activated sludge it is lower for extended aeration similar range for trickling filters, as it is this range and if you have mixed sludge it works in this range the typical output that we get.

So, if we do some flocculent addition, we can get primary sludge of the order of 5 to 10 percent dry solids. The mixed sludge 4 to 6 percent and excess sludge means which is kind of activated sludge secondary sludge so, of 2 to 3 percent dry solid contains, when we add polymers we can further like increase this a little more.

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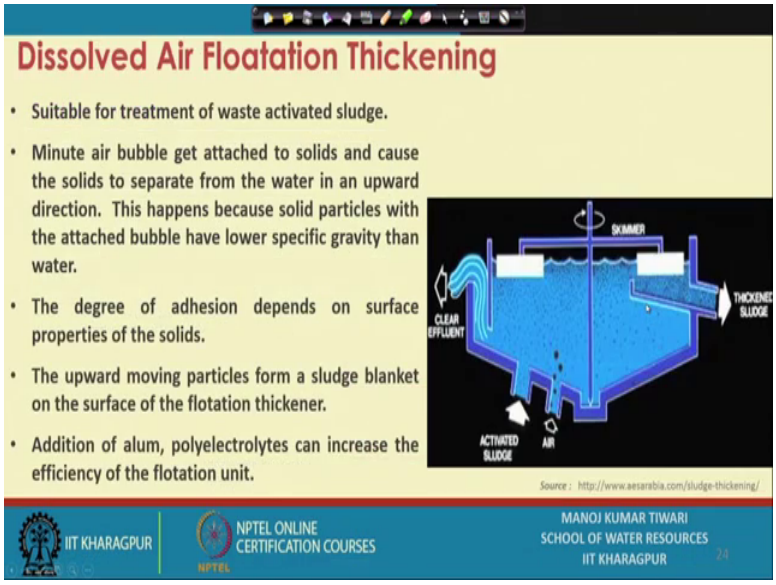

So, that is the performance that we get from this thing, then we have dissolved air flotation thickness. So, here what happens that we provide the activated sludge and then we provide air, now what happens that this is this method is primarily suitable for the waste activated sludge, or secondary sludge what we typically call because there is specific gravities even lower as opposed to the primary sludge.

So, they are lighter and then when you supply air to this. So, these air bubbles attached to those sludge particles. And this minute air bubbles when is it is attached to this sludge or attached to the solid is caught, it basically let us the solids to flow on to basically float on the top bring it bring them on the top with the bubbles. And then from the top through a skimmer those solids can be removed and the thickened sludge can be taken out and the clear effluent can be taken out from the other side.

The degree through which this gets adheres depends on the surface properties of the solids, the upward moving particles from a sludge blanket on the surface of the this kind of floatation thickness, we can add alum or polyelectrolyte that can increase the efficiency of these systems.

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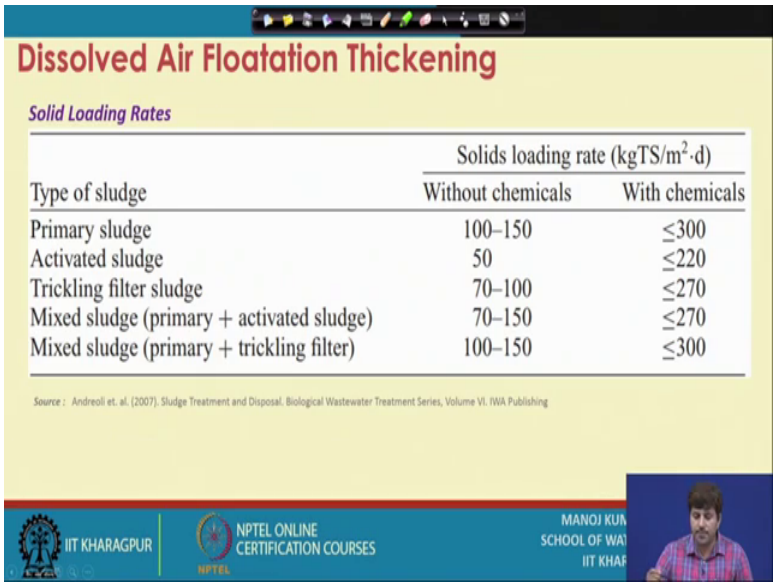

The loading rate in the dissolved air flotation thickness is of this range. So, without chemical addition for different type of sludge, it would be like for primary sludge 100 to 150 for activated sludge, it is 50 or for this thing it is, but it is more suited for the activated sludge with chemicals, we can increase the loading rates substantially. So, the flocculent or these chemical add additions makes the process much more effective.

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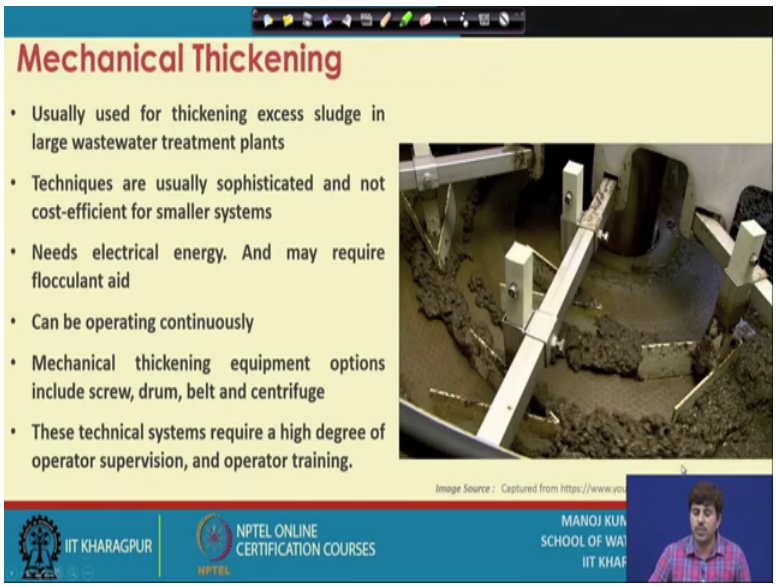

Then we have mechanical thickening which is usually used for thickening of access sludge in a large wastewater treatment plant, these are like techniques used usually

sophisticated and are not very cost efficient, because when we go for mechanical thickening we have to supply energy.

So, the energy demand increases of the sludge thickening step. This needs electrical energy and may require kind of flocculent add as well, it can be operated continuously those for the performance wise it is better. The mechanical thickening equipment can include screw, drum, belt and centrifuge those kind of thing. And this kind of technical systems requires a high degree of supervision and operators training for the process.

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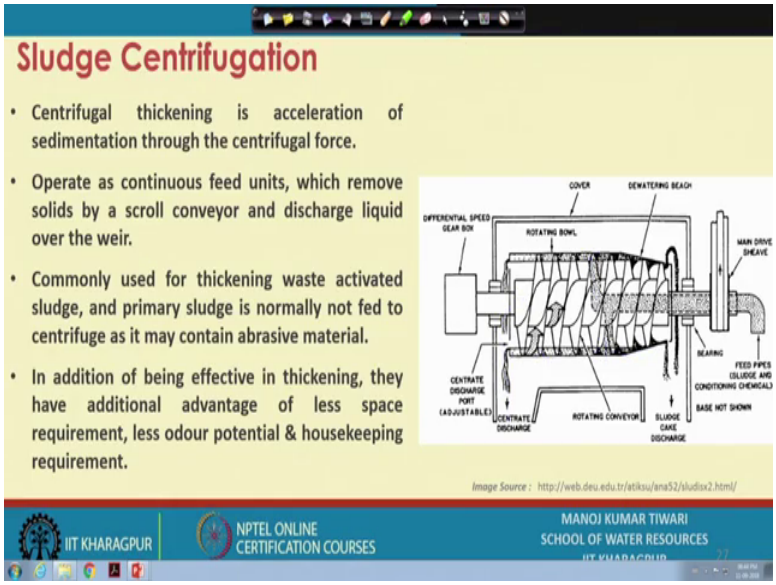

So, there are variety of mechanical thickeners, there is centrifuge which is nowadays getting more and more popular and more and more common for the sludge thickening process, it is not just only for thickening, but for dewatering as well. So, centrifugal thickening is basically it operates on a continuous feed basis and the sludge is entered into the centric into this chamber and through centrifugal forces, it is pushed down towards the wall of this that way.

So, it get is settle in this centrifuge, water is taken the supernatant water is taken out separately and this sludge is collected basically from the other place. So, this is commonly used for thickening waste activated sludge and primary sludge is normally not fed to the centrifuge, because it may contain abrasive materials.

So, waste the or your secondary sludge is primarily the microorganism. So, they do not cause much harm to this, but in primary sludge you may have some those kind of materials which could be of abrasive nature and can harm the centrifuge. So, in addition of being effective in thickness, they have additional advantages of less space requirement, because these are a compact unit there is no order generation and there is not much of a housekeeping requirements. So, that way this process is actually a more effective, but of course costly.

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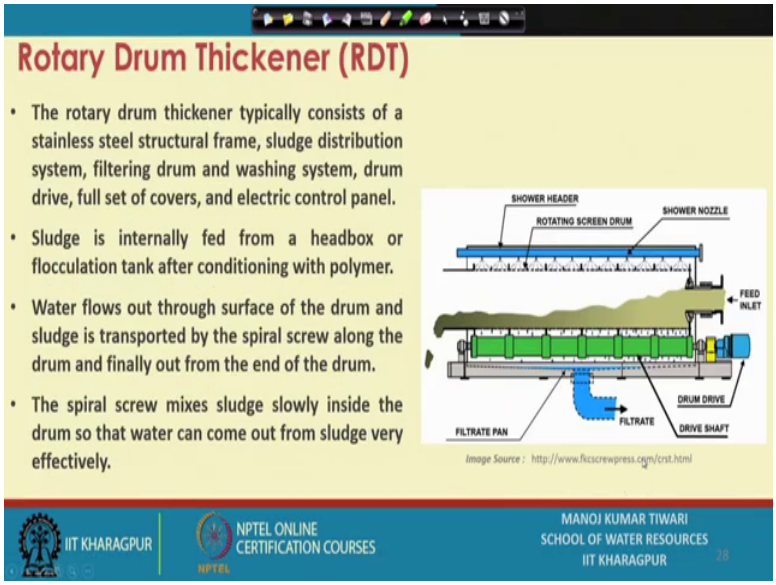

There are rotary drum thickeners, which typically consists of stainless steel structure frame. So, in this structure frame the sludge will be fed in here and it keeps on rotating. So, the water in sludge will actually be falling in here and they will be collect the filtrate will be collected separately and the sludge which keeps on getting dried and collected on the other end. So, there are spiral screw mixes, the spiral screw which are there, they mixes sludge slowly inside this drum so, that the water can come out from sludge very effectively.

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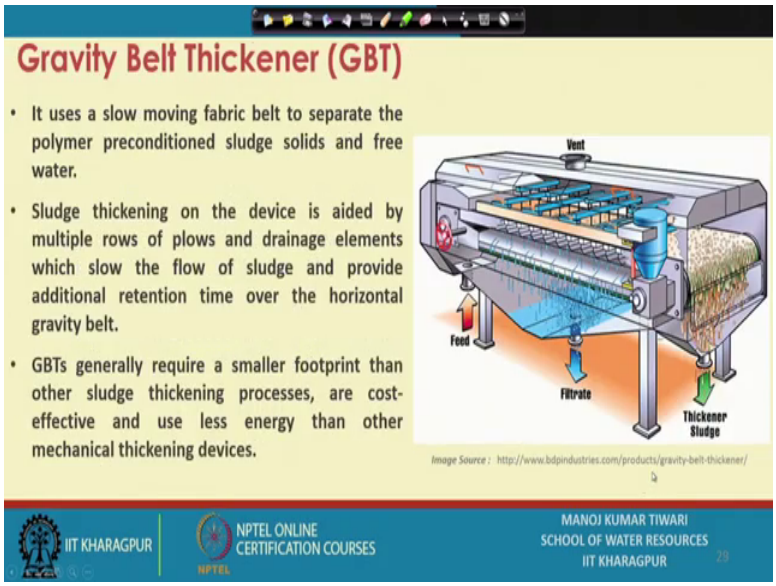

So, this is one of the kind of mechanical units, which are again used for the sludge thickening purpose there are gravity belt thickener GBT which typically we call. So, again there would be kind of belt kind of system will be there and feed is given from here and then through mechanical system that feed rotates over these things and through went basically we put this water. So, what happens that it is added by multiple rows of flows and drainage element and which kind of slow the flow of the sludge and provide additional retention time over this horizontal gravity belt. And from there water spills out and then sludge is collected separately.

So, this GBT is generally require a smaller footprint than other sludge thickening processes and are cost effective and use lesser energy than the various other mechanical thickening devices.

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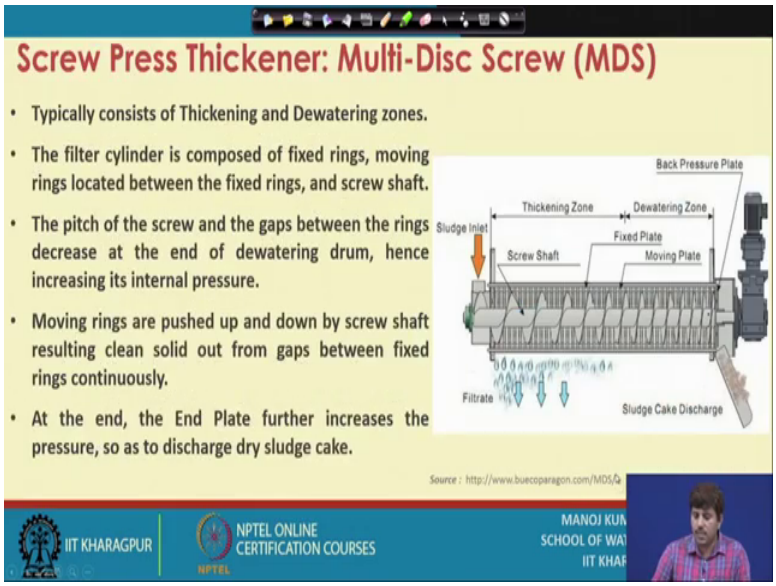

But of course still because mechanized process so used more energy than the traditional gravity thickeners. There are screw press thickeners like the multi disc thickener, which is an example of a screw press thickener. So, sludge is a put in the system and then through this thing like a screw it is pressed in there. So, this filter cylinder is composed of fixing ring, which moves located near the fixed ring and a screw shafts. And then the pitch of this screw gaps which kind of the pitch of this screw and the gaps between the ring decreases towards the end of the dewatering system.

So, here you see that the space is larger and here it kind of decreases that way. So, this increases the internal pressure over there and these moving rings pushed up and down by your screw shaft which is there, this is your this is your screw shaft over here. And then this screw shaft is moved that way and at the end the end plate further increases the pressure. So, that discharge of dies such takes place from this side and the water filtrate comes from primarily predominantly from this side.

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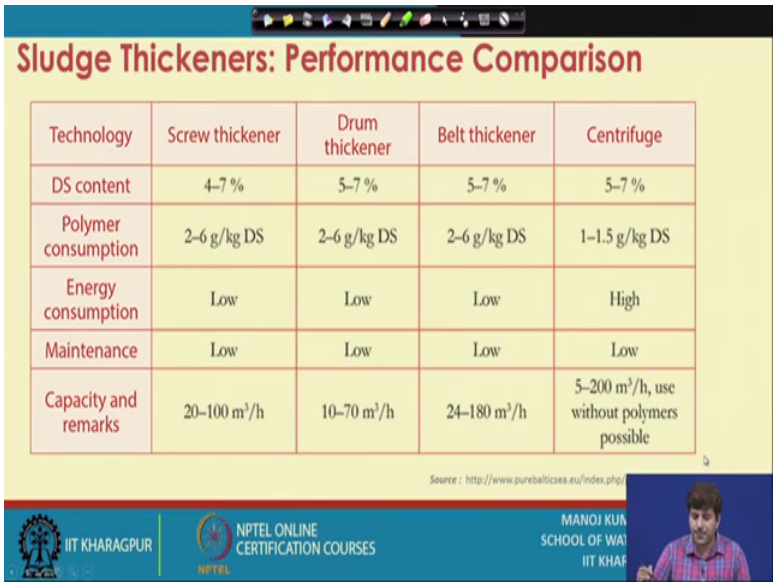

So, if we see the performance of these different type of sludge thickeners, or particularly the mechanical sludge thickeners. So, we have screw thickener, drum thickener, belt thickener centrifuge there are dry solids contents ranges from 4 to 7 percent 5 to 7 percent 5 to 7 percent, the polymer consumption, if you are adding will be ranging this centrifuge has less polymer consumption or we know may not need polymer consumption at all, but needs the high energy as opposed to the other processes.

The maintenance is low for all of these and the capacity is some 20 to 100 meter cube per hour, this has 70, 10 to 70 meter cube per hour smaller capacity, this has centrifuge are of various sizes so, can be used of the much larger capacity as well.

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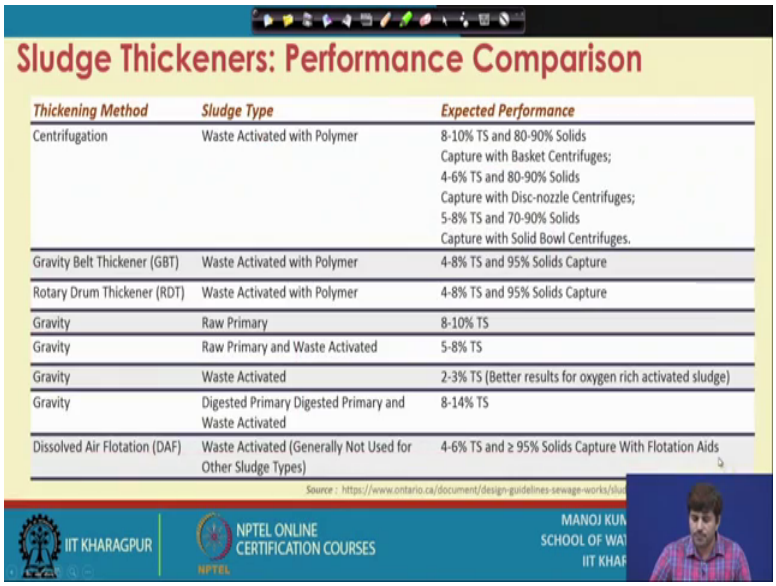

So, if we see the performance comparison of these different sludge thickeners a kind of summary. So, the centrifugation which is good for waste activated sludge with polymer, this is the expected performance 8 to 10 percent of total solids and 80 to 90 percent will be that way. So, the gravity belt thickener, the rotary drum thickener is also good for waste activated, this thing gravity thickeners are good for raw primary and waste activated both.

In the raw primary it can actually turn solids from 8 to 10 percent this is from 5 to 8 percent for the waste activated only, it will result in 2 to 3 percent total solids. If we use like oxygen rich activated sludge, there will be better results and the dissolved air flotation thickness if we see. So, this is good for waste activated sludge only it is generally not used for other type of sludge and, it can result in 4 to 6 percent of the total solids concentrations.

So, that way kind of like this thickening takes place, which is which is the basic or the primary or the first step in the process of the sludge treatment or sludge performances, later processes like the stabilization of sludge or this thing is followed after thickening. So, we end this session here and in the next class we will talk about the subsequent sludge processing and treatment steps, we will start with the digestion first and then we take on the other aspects of the sludge management and sludge treatment.

Thank you.