Wastewater Treatment and Recycling
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Lecture – 41
Wastewater Sludge Processing and Treatment : Sludge Stabilization and Conditioning

Hello friends and welcome back. So, we have been talking about Sludge Processing and Treatment this week. And in the previous lecture we did talk about the first major step which is taken in the sludge processing which is sludge thickening. In this particular lecture we are going to discuss the Sludge Stabilization and its Conditioning.

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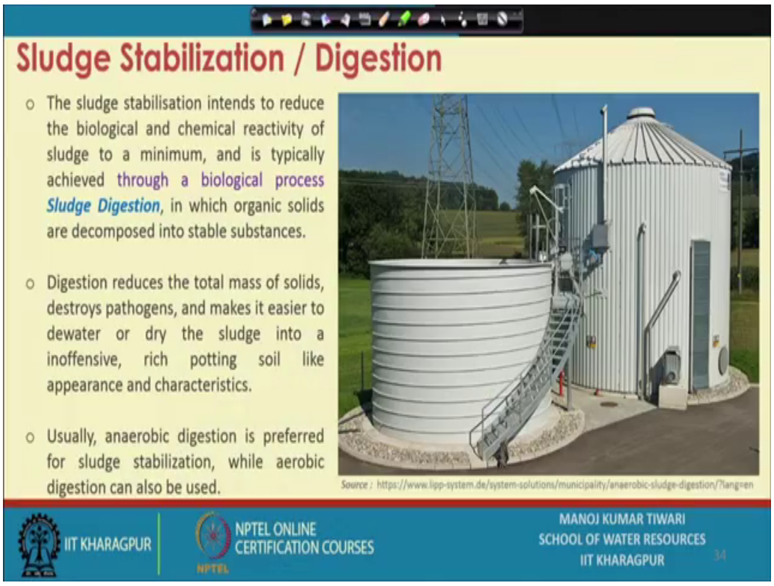

So, we will begin with the sludge stabilization. Stabilization essentially the digestion process slow sludge is stabilized intent which is kind of idea is to reduce the biological and chemical reactivity of the sludge. Then what we call it to be like a stabilized sludge, when there is not of not much of biological or chemical reactions taking place within the sludge zone, or within the sludge medium. And this is typically achieved through biological processes which is called Sludge Digestion.

So, essentially sludge stabilization we are talking about sludge digestion, there are thermal digestion processes as well, but biological digestion processes predominate the thermal digestion processes. So, that way we have the sludge stabilization through either thermal means or through biochemical means. Now essentially in the biological sludge stabilization the organic solids that are decomposed to stable substances. Because those are the one we who are reactive who basically gets react who can convert to the newer cell mass or other things within the sludge zone. So, they are digested to form stable substances, or stable components.

The digestion reduces the kind of total mass of the solid that is one thing it does, it destroys the pathogens typically. So, that way digestion can be considered as a disinfectant process as well. However, it is not that effective in destroying pathogens always; if we go for thermal digestion then it will, but typical biological digestion may will have some effect on the like removal of killing of pathogens as well. But it cannot put a guaranteed disinfectant sludge ok.

So, then and other thing it will do it will make easier for dewatering. So, it will make easier to dewater, or dry the sludge into kind of inoffensive, rich potting soil like appearance. Now usually the anaerobic digestion is preferred for sludge stabilization, while aerobic digestion can also be used. But it is the anaerobic digestion which is more popular.

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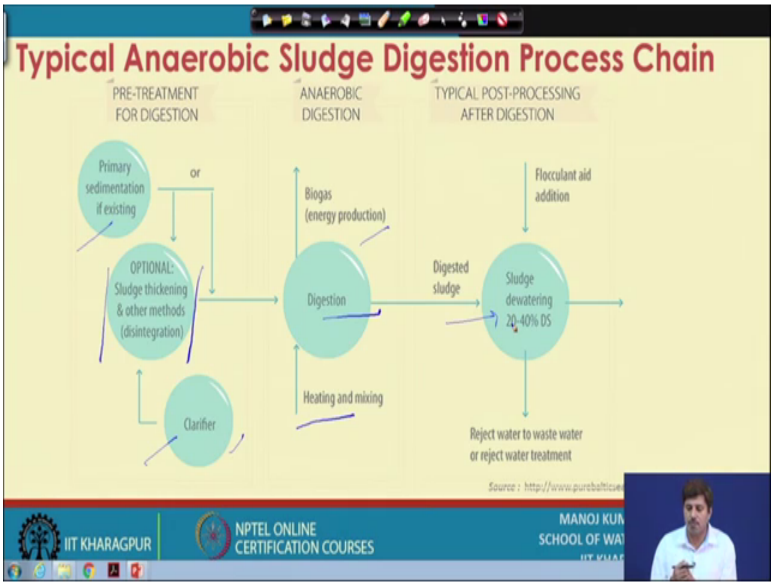

So, if we see the kind of pretreatment that is needed for digestion. So, we get sludge from either primary sludge from sedimentation, or secondary sludge from secondary clarifier. The first thing we do is sludge thickening which we discussed in the previous class. So, that is kind of preliminary requirement for digestion because otherwise the water content is very high particularly with the secondary sludge when it is high more than 99 percent water content. So, then the stabilization process becomes relate really difficult and we have to basically handle a large volume of sludge as well.

So, that is why idea is to first thicken the sludge, reduce the water content, increase the solid content, and reduce the volume largely. Because as you are discussing through just thickening process we can reduce the volume by almost 90 percent, if we effectively kind of thicken the sludge. So, that way instead of having like handling a much much larger volume; if we are able to handle just 10 percent of the volume it be makes our process far more economical and far more effective.

So, anaerobic digestion typically will then like the thickened sludge is bought to the digester and there this anaerobic digestion takes place. So, there would be some amount of heating and mixing may be provided. And then there would be energy generation or in the form of biogas which will come out of the digester ok.

And after that the digested sludge is further taken for dewatering purpose in the different setups or equipment where we may need to add flocculent or. So, we will consider dewatering processes later on, but for typical digestion perspective, so thickening is needed which we have already discussed and then it is bought to the anaerobic digestion.

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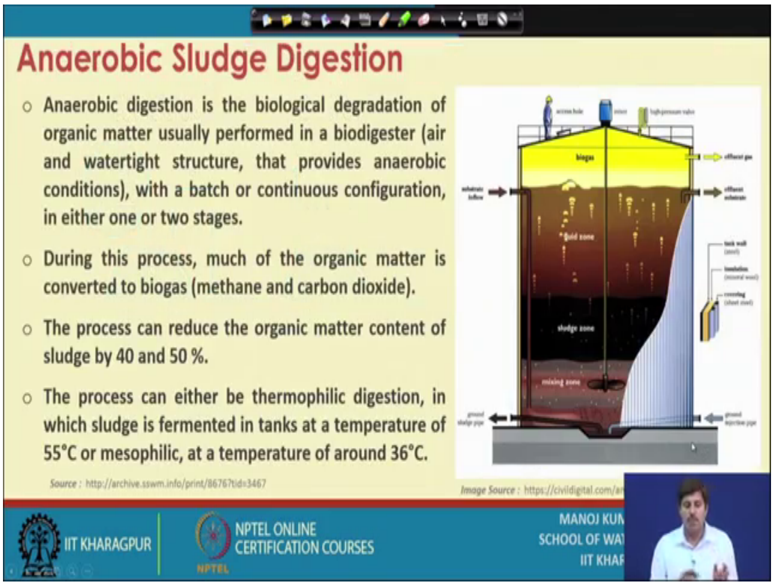

So, anaerobic digestion is typically a biological degradation of organic matter which are present in the sludge ok. And it is usually performed in a bio digester what typically we call and this bio digester is kind of an air, and water tight structure which provides the anoxic conditions within ok.

And these bio digesters can be operated in a batch or continuous configuration and can be either single stage or dual stage digesters ok. So, during this process majority of the organic matter is converted into biogas which is methane and carbon dioxide. So, essentially we are having or lot of organic matter coming in the sludge and as like we discussed that the v s to t s content the volatile solids to total solids contained in the particularly the secondary sludge if we talk about our primary sludge.

So, in the primary sludge it is of the kind of 70 to 75 percent that range and in secondary sludge also it will be more than 60 percent typically. So, there is a lot of organic matter, there is lot of volatile solids present in the sludge and that can be kind of processed for the digestion and then the organic matter or organic sludge which is present in there eventually converts to the biogas in the form of methane and carbon dioxide.

These processes can reduce the organic matter content by 40 to 50 percents almost half of the organic matter can be digested that way. And this process can either be like thermophilic digestion, in which the sludge is fermented and takes at a temperature ranges of around 55 degree Celsius or in a mesophilic range, where temperature is 36, 37 degree Celsius. So, it can be done that way in either setups.

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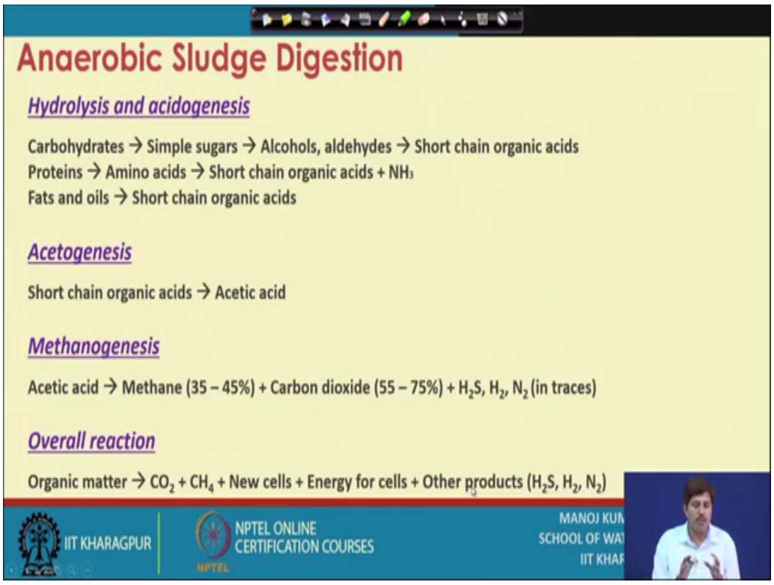

A typical digester will basically have a mixing zone, a sludge zone, then fluid zone that way. So, if you essentially see it is a prototype of any typical anaerobic processes will be of the anaerobic typical reactions which we discussed earlier. So, there will be hydrolysis and acidogenesis taking place, there is acidogenesis taking place, there is methanogenesis and then there is overall reaction which can take place.

So, the idea of like the anaerobic digestion of the sludge is to first break down the again the larger chain compound carbohydrate protein to this like a short chain organic acids. And then convert these two acidic acid through acidogenesis process, then methanogenesis will convert these to methane and carbon dioxide ok. And then there are some other trace elements that is how the digestion takes place.

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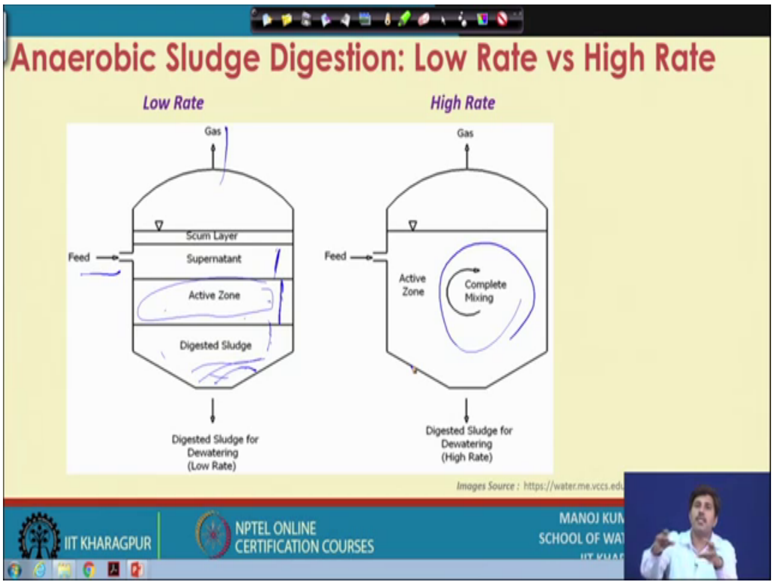

So, as we said that this digestion could be low rate, or high rate digestion process. So, what happens in a low rate digestion? If we see the feed that we get in the feed that we get in eventually comes to a closed chamber because it is anaerobic digestion. So, there will be like there will be active zone where this sludge gets digested and that once it gets digested it will try to settle it will come to the lower zone.

So, then digested sludge settles in here, the supernatant water will come here and then is scum layer could be formed and the gas can be collected here. So, this is a typically low rate digestion where processes are taking place in this way itself. Then we have a high rate digestion process where we do complete mixing. Here since digestion is taking place in a selective zone the processes are slow it is not well mixed system.

So, the rate is slow and that is why we call it low rate digestion, but if we actually make this entire digester volume as an active zone through complete mixing. So, then the micro then kind of like entire mass is entire mass of the sludge is interactive zone and then digestion takes place not only in the selected zone or selected patch, but in this entire reactor. And that leads to basically higher rate of digestion and that is why we call it high rate processes ok. And then again the digested sludge can be taken down for dewatering purpose and gas can be collected from the top that way.

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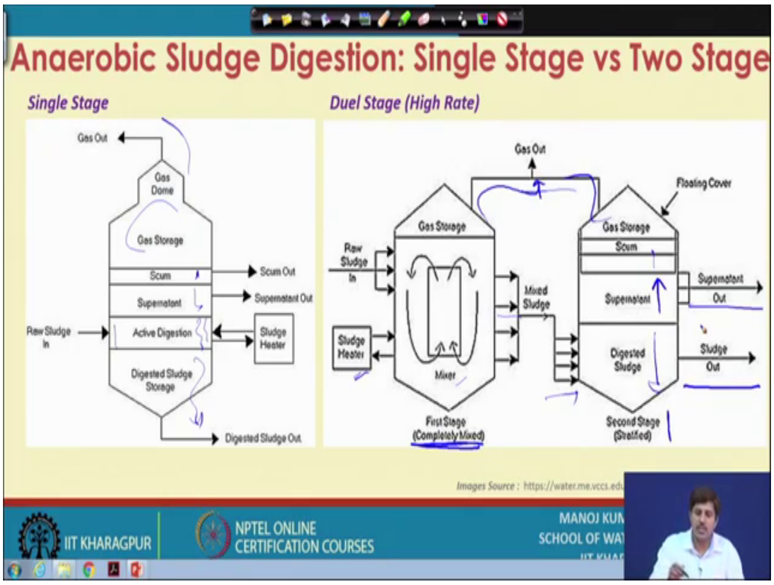

So, that will be basically a high rate digestion high rate digestion and low rate digestion. We have single stage and two stage or what we call as duel stage digestion as well. So, in a single stage digestion again it is typical process as we were just looking at. So, we will get raw sludging, there will be active digestion, there will be supernatant, there will be scum formation, then gas storage, and gas can be taken digested sludge will come at the bottom.

So, that kind of typical slow rate digestion the duel stage digestions are which is done in two stages and are much faster. So, they are like usually high rate digestion and which is typically done in a two stage. So, what happens here that we get the raw sludge in and through a kind of motor we ensure this mixing over here. So, this and then we have intermittent sludge holder if needed.

Here the sludge is well mixed and this there is a gas generated which takes place and this first stage is kind of completely mixed ok. So, there is like since completely mixed; obviously, the digestion rate will be faster ok. So, that takes place here and then mixed sludge is taken out to the second stage ok.

So, second stage we allow this to settle. So, digested sludge settles over here supernatant goes here. Then scum formation and there will be some gas formation in this one as well. So, that can also be taken out and collectively gas can be taken out ok. So, then supernatant goes out from here and your sludge goes out from the lower part so, that way we can actually done these things in a two stage. So, this active digestion thing is done in a separate stage where this complete mixing is in a in short in order to get the faster rate of digestion, or high rate of digestion. Whereas, the subsequent processes will be slower that way, so that is what is essentially two stage digestion process ok.

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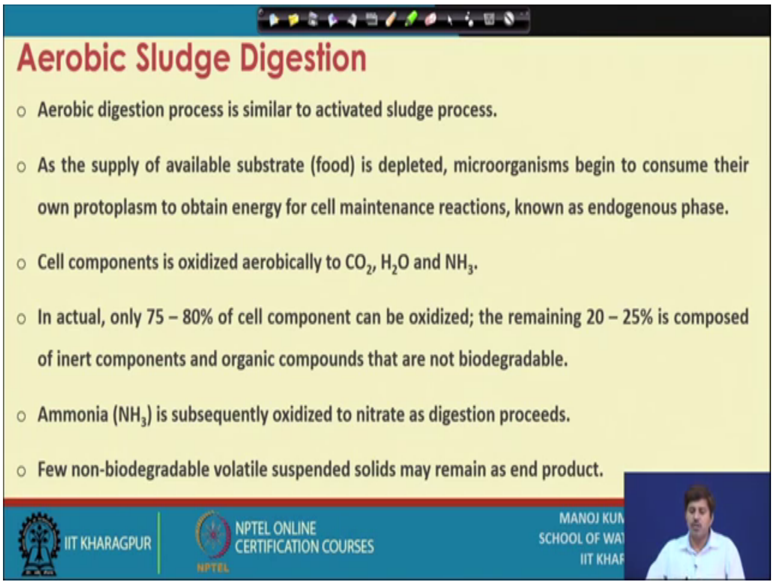

Now, if we see the that is about anaerobic sludge digestion the aerobic sludge digestion is also done, but it is not that popular because of the it is energy footprints. So, in aerobic digestion this process is similar to activated sludge process it is the like sludge is taken to a chamber where there is a kind of like available substrate, or food is depleted.

So, there is because it is not the what there is no like water coming in with BOD where their food is available for microorganism. So, when the sludge is taken in a chamber and it is actually kind of aerated or kind of like air supply is maintained, but there is no food supply there is no substrate present in there. So, microorganisms begin to consume their own protoplasm which is kind of like it go in the endogenous phase ok. And then from consuming their own protoplasm they obtain energy for the cell maintenance and the reactions and that way the digestion takes place.

So, cell components of the various microorganisms are oxidized into CO 2, H 2 O and ammonia. Actually around 75 to 80 percent of the cell components can be oxidized and the remaining 20 to 25 percent components is composed of inert components, and organic compounds that are not biodegradable.

Ammonia is sick like subsequently oxidized to nitrate as the digestion proceeds because the age like in typical activated sludge process we get we keep it for lesser retention time. But for sludge digestion the retention time is much larger. So, the nitrification also takes place over there and ammonia can subsequently be oxidized to nitrate ok. And even the non biodegradable volatile suspended solids may remain as may come as a end product because they are not getting degraded or decomposed in there.

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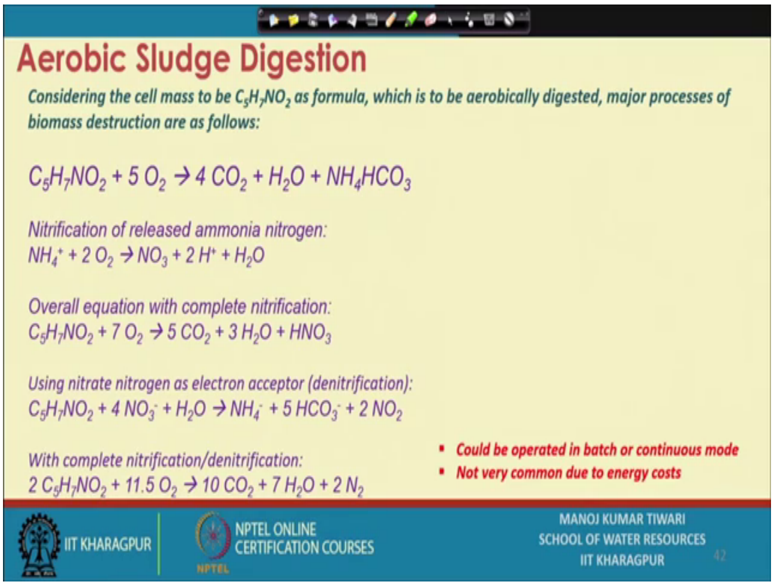

So, if we typically consider this cell mass as C 5 H 7 N O 2 which is typical composition of a cell mass it is taken. Of course, there are various formulas for cell mass we have a much larger formula where there is phosphorous and those kind of things are also involved. But conventional or the more common formula with nitrogen hydrogen carbon and oxygen is considered at C 5 H 7 N O 2 for biomass.

So, if we take this as a kind of biomass or cell mass which is aerobically digested, so major processes that will happen. So, this will get oxidized first and we will convert to CO 2 and this particular compound ammonium bicarbonate that way. And then the nitrification will convert this ammonia to nitrate then this overall equation with complete nitrification will be this reacting with the O 2 we can join this. So, we get C O 2, we get H 2 O, and we get HNO 3.

Now, causing nitrate nitrogen as an electron acceptor because denitrification can also take place particularly in the lower part of the digester, where there is not enough oxygen is reaching. So, in those cases if it happens it is not necessarily that it will happen. But if it happens then this nitrate can be converted to the back to ammonia that way ok. So, denitrification can also takes place and with complete nitrification and denitrification we get like if we say that nitrification and denitrification both is occurring. So, eventually your cell mass will be converted to C O 2 H 2 O and N 2 and that way this will escape the system this will escape the system. So, that is how the stabilization takes place ok

Now, this could be operated in batch, or continuous mode they aerobic sludge digestion as well. However, it is not very common due to this energy cost because there is high degree of energy cost associated with the anaerobic sludge digestion processes and that makes it kind of difficult to bear the cost of the aerobic digestion by the various wastewater treatment facilities. Particularly in the like developing word nations, so that is why this is not that popular ok.

And anaerobic decomposition is far more popular as the typical anaerobic processes can actually lead to the production of biogas as well which can make the digestion process self sustainable, or can be used for. Like if you are able to produce biogas or energy in the form of that, so you can utilize that energy at the plant site itself ok.

So, those kind of benefits can be obtained by anaerobic digestion where the processes are similar we go for hydrolysis, or fermentation, acido acidogenesis acetogenesis, and methanogenesis. As we discussed while aerobic as we discussed in the presence of oxygen the cell mass, or the is kind of oxidized.

And eventually if it go undergoes complete oxidation, and complete nitrification denitrification cycle. So, it can produce the C O 2 N 2 all those kind of elements and then your organic mass there the cell mass they are gets stabilized. So, that is why that is how the aerobic stabilization or aerobic sludge digestion takes place.

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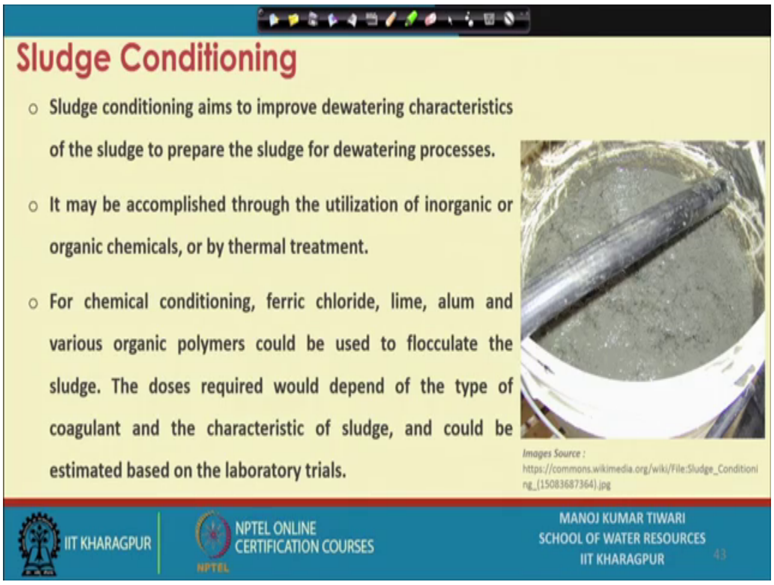

So, a post stabilization what we see is the sludge conditioning ok. The sludge conditioning aims to improve the dewatering characteristic. So, what happens? If you recall the process that we saw in the earlier class, so sludge is first thickened and then it is stabilized.

Then it needs to be like for the after the stabilization also we need to because if you are going doing this aerobic stabilization or anaerobic stabilization there is still lot of water present in the sludge and then that water has to be withdrawn for further processing of the sludge. So, for the withdrawal of water the dewatering step is taken place

But in order to improve the efficiency of dewatering in order to make the dewatering more efficient a preliminary step may be adopted which is sludge conditioning ok. Now sludge conditioning just aims to improve the dewatering characteristic of the sludge and the that way we prepare this sludge for this substantial dewatering processes.

Now it may be accomplished through utilization of inorganic, or organic chemicals or by thermal treatment as well. So, there are thermal ways to sludge conditioning and there are chemical ways to sludge conditioning. Now what happens? That in the like this dewatering this sludge conditioning step in usually kept after this sludge has been stabilized. But many times many places this sludge conditioning is done before sludge is sent for the first thickening stage ok.

So, even because it will if you stabilize if you would kind of condition the sludge. So, it is thickening characteristic may also be improved. Since thickening and dewatering are more more or less have a similar objective and you have too much of water you thicken it to say 1 percent or 2 percent to say up to 10 percent. Whereas, sub see substantial dewatering aims to increase the solid content up to say 30 percent or so.

So that is the basic difference and in between like with the thickened sludge, with the dewatered sludge completely like dry sludge we cannot go for these aerobic, or anaerobic digestion steps. So, since these steps are to be done in a slurry form, or in a moi in with the sludge having significant amount of water content. So, that is why be because as we were just discussing the anaerobic digestion.

So, what happens in the anaerobic digestion? That or for that matter anaerobic digestion also the hydrolysis is a step where these things has to be hydrolyzed. So, there has to be significant water present in the system. So, we do not try this sludge before these processes, but again we can put some con conditioning kind of treatment before thickening as well in terms of adding some flocculent, or those kind of thing. But otherwise traditionally thickening is traditionally the sludge conditioning is done after the sludge stabilization, or sludge digestion has taken place.

So, in conditioning as we are saying that there are approaches we can accomplish it with the utilization of the inorganic or organic chemicals or by thermal treatments; so, for conditioning chemical conditioning purpose the ferric hydroxide, lime, alum which is kind of like traditional flock coagulants. So, they can be used the salts of iron and alum can be used as a coagulant, lime can also be used basically for generation for stabilizing this thing because there might be lot of alkalinity depending on which process it is coming in.

So, then there is like various organic polymers can also be used which could be like cationic, ionic, or non ionic polymers. They can also be used to flocculate the sludge and the doses that are needed for these chemicals when we go for chemical conditioning. So, let us say we want to figure out how much dose is to be given of ferric chloride, or for alum, or for the organic polymer that we have, we will depend on several factors and prime of them is the characteristic of this sludge ok.

So, what is the characteristic of the sludge? What is the type of coagulant? What are its properties? So, that will eventually govern how much dosage of sludge would be needed? And this could typically be estimated based on the simple laboratory trials ok.

So, we have a kind of like a traditional jar test is used where we have multiple jars in there and we add these different flocculants, or the like the different doses of the selected coagulant we add and then we do this processes and see which one is giving the best degree of flocculation. So, that can that those can be used for the purpose of sludge conditioning, the chemical conditioning.

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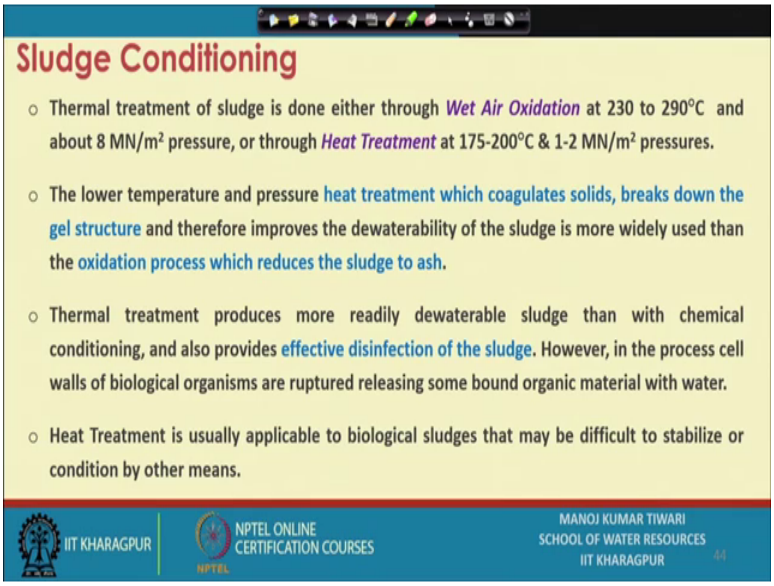

Then we have thermal conditioning of this sludge this thermal conditioning of sludge is done either in wet air oxidation, or what we typically call as through heat treatment. So, there are two approaches out of which heat treatment is far more popular as opposed to the wet air oxidation.

So, wet air oxidation is typically done at much higher temperature the temperature ranges some 230 to 290 degree Celsius, and at much elevated pressure also so up to 8 like mega Newton per meter square pressure. So, this range of the pressure and temperature is needed for wet air oxidation. And what essentially happens that in this oxidation process the solids, or the whatsoever organics are present in there. They are reduced to kind of as so it is a wet incineration kind of thing because we are doing at much elevated temperature and much higher pressure as well.

The traditional heat treatment is done at 170 to 200 degree Celsius range typically at times even lower. So, at times we can do it at around 150 degree Celsius. So, it is done at a lower temperature and 1 to 2 mega Newton per meter square pressure. And what this does? This traditional heat treatment will actually coagulate the solids breakdown the gel structure and that way it kind of let the water settle out or squeeze out of the solids and that way improves the dewaterability of this sludge ok.

And it is more widely used more commonly used as opposed to the wet ox wet air oxidation which is a quite energy intensive process. Because we have to do it at a much elevated temperature and much higher pressure also. So, this thermal treatment kind of produces more readily dewaterable sludge than chemical conditioning it is far more effective than chemical conditioning methods, but at the same time the cost is also much higher.

In addition it provides effective disinfection of the sludge, because when we do it when we try to sort of condition the sludge at higher temperature at elevated temperature. So, bacteria, or microorganisms, or pathogens cannot sustain those high temperature cannot sustain like that high temperature when it is the sludge is under stabilization process. So, they will also get killed and that way we get quite effective disinfection of this sludge through this process ok.

This heat treatment can also be used not only for conditioning, but as we are suggesting for stabilization also because it like as we are saying that it breakdowns the organic matter as well. So, that way it can actually kind of stabilizes the sludge also and can be con like the conditioning and stabilization can be achieved in a same setup um that case. However, when we like are trying to kind of stabilize through heat treatment the disinfection is obtained that is fine, but for this disinfection the cell walls of the biological organisms are ruptured, and that releases some of the bound organic materials with the water.

So, that the water we are getting will may have some more organic matters which have already been say precipitated, or converted they may again come back into the water. So, that is one of the aspect with the thermal heat thermal conditioning particularly with the heat treatment which needs to be seen. And it is usually applicable to biological sludge that may be difficult to stabilize, or condition by typical chemical measures or chemical means and that is why it is preferred for biological sludge even after it is higher cost.

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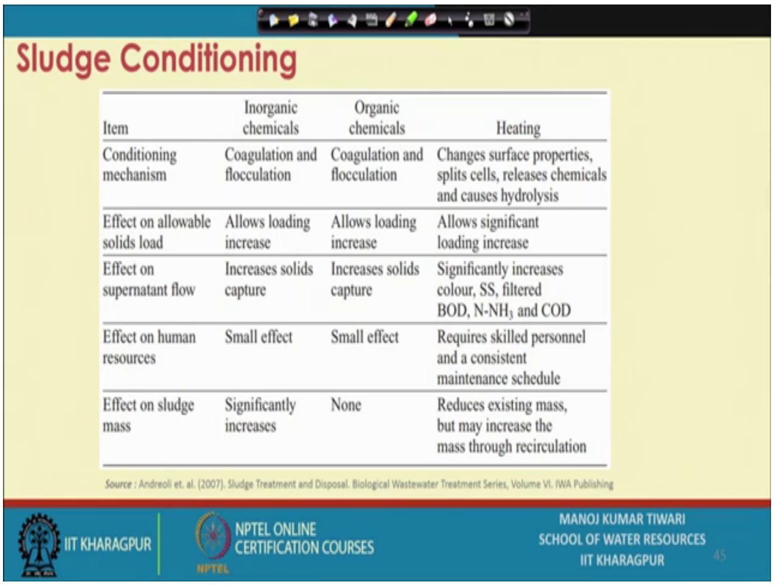

Item	Inorganic chemicals	Organic chemicals	Heating
Conditioning mechanism	Coagulation and flocculation	Coagulation and flocculation	Changes surface properties, splits cells, releases chemicals and causes hydrolysis
Effect on allowable solids load	Allows loading increase	Allows loading increase	Allows significant loading increase
Effect on supernatant flow	Increases solids capture	Increases solids capture	Significantly increases colour, SS, filtered BOD, N-NH_3 and COD
Effect on human resources	Small effect	Small effect	Requires skilled personnel and a consistent maintenance schedule
Effect on sludge mass	Significantly increases	None	Reduces existing mass, but may increase the mass through recirculation

Whereas chemical sludge can a chemical stabilization can take place at a much lower cost that way. So, if we see the like if we try to compare these various conditioning methods ok. So, as we discussed we can have like depending on the conditioning mechanism if we see for if we are using inorganic chemicals. So, conditioning mechanism is coagulation and flocculation. For organic chemicals or various organic polymers again the conditioning mechanism is traditional coagulation and flocculation process ok.

While when we do the thermal treatment heating so the conditioning mechanism becomes changed in the surface properties. We are not adding any chemical which can coagulate the sludge that way. So, what happens that? It is surface properties change, the cells are displayed, the chemicals are released and the hydrolysis is done at elevated temperature. So, that is what leads to the conditioning of the sludge.

If we see the effect of the allowable solid loads so, this allows loading increase, this also allows loading increase and this significant loading increase is allowed a supernatant flow if we see. So, the increased solid capture there will be also increased solid capture. Here there is significant increases in the color suspended solids filtered BOD means soluble BOD. Because we are causing hydrolysis of various recalcitrant or the cell system, so that can be there ammonia cod those kind of thing can come actually in the supernatant.

If we see the effect on human resources small effect where as this required skilled personnel and a cons like consistent maintenance schedule for the heat treatment, or thermal stabilization thermal conditioning. And if we see the sludge mass, so here there is kind of like significant increase in the sludge mass not much effect. And here the reduced existing mass and maybe increases the mass through the recirculation. So, that is what happens within the reactor. When we are within the system when we are trying to condition the when we are trying to do the sludge conditioning.

So, that way the sludge is conditioned and once this sludge is conditioned then after that what as a next step we go. So, we have first thickened the sludge, then the we did the stabilization of sludge through digestion traditionally anaerobic digestion. Then the sludge is conditioned the digested sludge is conditioned and once the sludge is conditioned.

Then we take it for the next step which is dewatering the sludge where we try to remove majority of the water from the sludge and make it as kind of a dry sludge cake which is produced through the dewatering mechanism. And after that we can think of the next subsequent option in the form of disposal or reuse or incineration those options. So, we will discuss the rest of the processes in the next and the last lecture of this week. And for the time being then we call this lecture off. So, thank you for joining and see you in the next lecture.

Thank you.