Biological Process Design for Wastewater Treatment
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Lecture 35
Sludge Management - V

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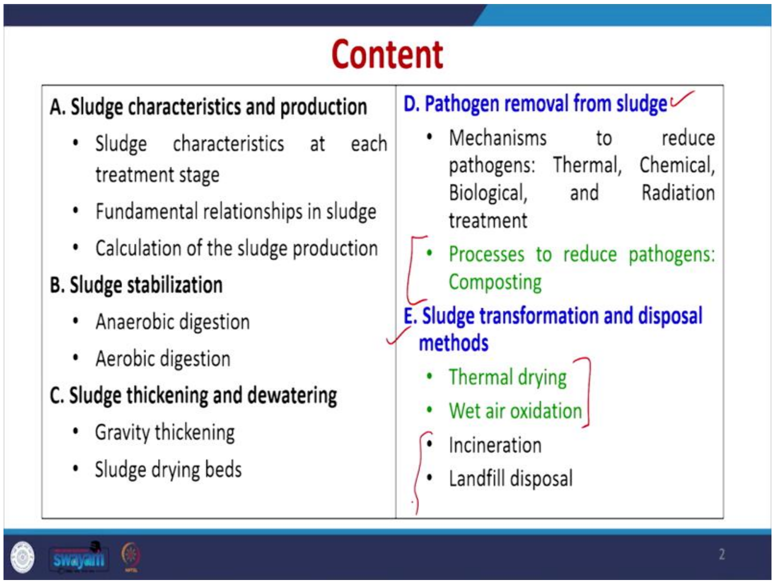

Welcome everyone, in this NPTEL online certification course on Biological Process Design for Wastewater Treatment. So today we will continue with the sludge management section and we are going to learn regarding the pathogen removal from sludge that we started in the last lecture. So today we will be discussing more of the processes to reduce pathogens via composting which is one of the common most method which is used for the pathogen removal from sludge and also will start the section on sludge transformation and disposal methods.

So we will be studying regarding the thermal drying and the wet air oxidation. So this is how we transform and dispose of the sludge. Later on we will study the incineration and landfill most probably in the next lecture.

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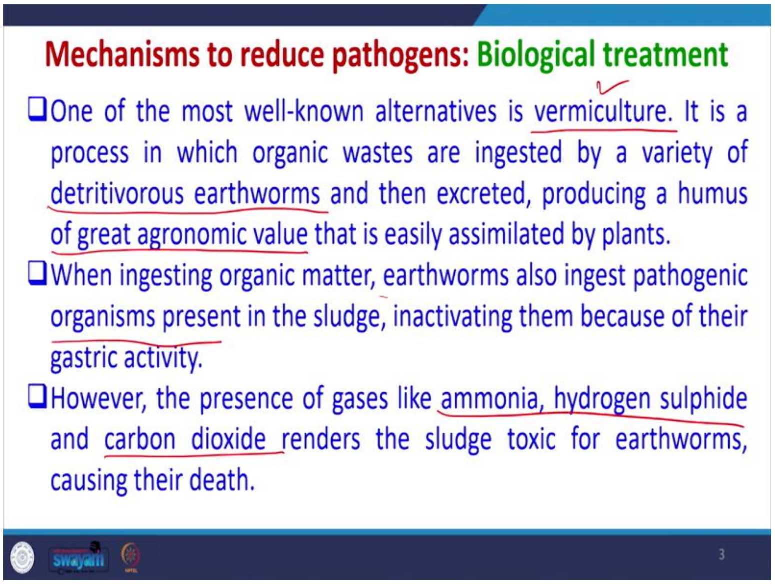

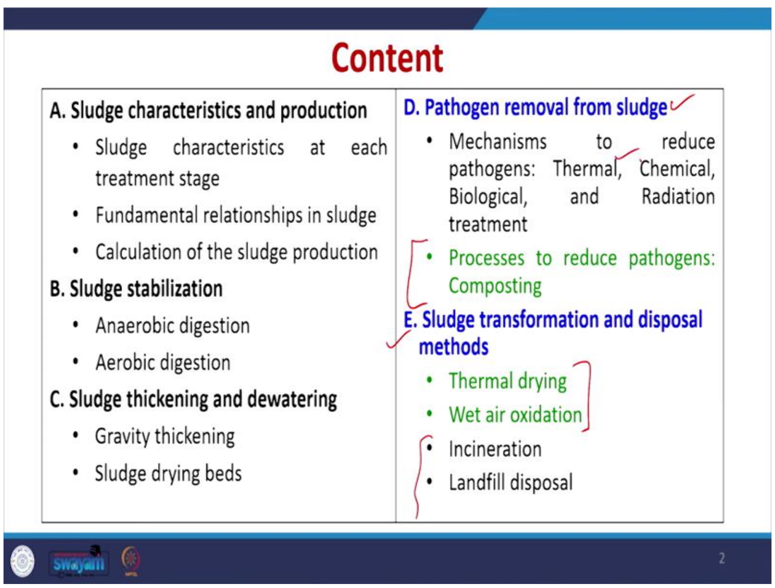

So mechanisms to reduce the pathogens. So we studied regarding the mechanisms via thermal method, via chemical method, via radiation method, then biological method can also be used for the pathogen removal and one of the most common well known alternative is vermiculture. So it is the process in which the organic wastes are ingested by a variety of detritivorous earthworms and then excreted producing a humus of great agronomic value and that is very well practiced in many places and that is easily assimilated by plants.

So when ingesting organic matter earthworms also ingest pathogenic organisms present in the sludge and inactivating them because of their gastric activity. So vermiculture is one of the method. However the presence of gases like ammonia, hydrogen sulphide, carbon dioxide can render the sludge toxic for earthworms and causing their death. So if we can remove the ammonia, hydrogen sulphide, carbon dioxide, etcetera beforehand by exposing the sludge to natural environment.

So that these gases are diffused off then we can use the vermiculture very well for pathogen removal because the earthworms will naturally ingest the pathogenic organisms present in the sludge.

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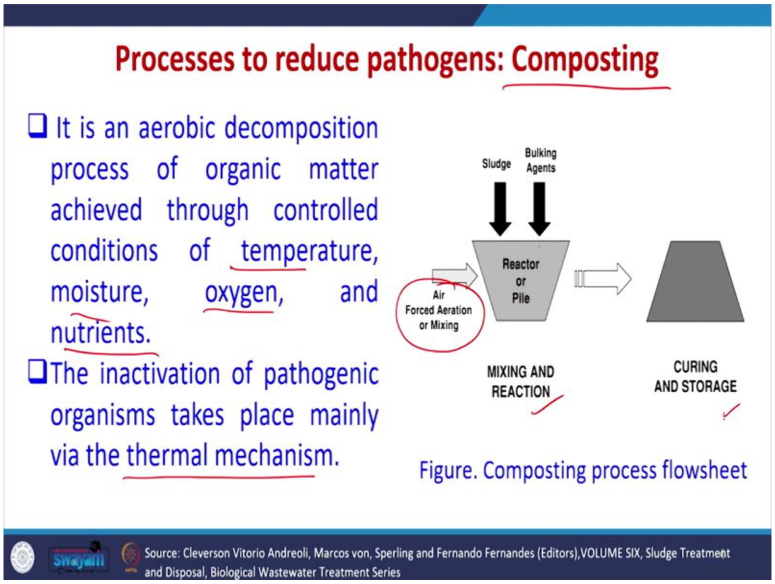

Now we can use the composting. So also, so composting is one of the method which is most commonly used. So it is an aerobic decomposition process of organic matter achieved through control conditions of temperature moisture oxygen and nutrients.

So if we can take control of these things we can take care of aerobic decomposition process and which is basically the composting. The inactivation of pathogenic organisms takes place mainly via thermal mechanism. So we can see the reactor or pile in which the sludge will be there then the bulking agents will be there. So that it is there. The sludge size is little bit higher. The air is forced aeration or mixing is done and then the mixing and reaction will take place after time we can get the cured sludge which can be stored or taken care.

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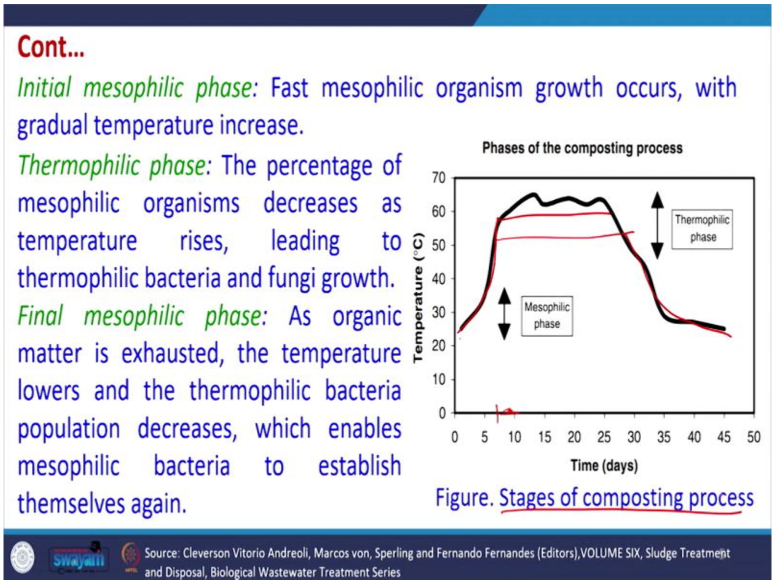

So there are certain stages in the treatment the there is initial mesophilic phase the fast mesophilic organisms growth occurs with gradual temperature increase. So you can see the mesophilic phase in which the temperature is increasing and it occurs between 7 to 10 days. So in this range the mesophilic phase will be there.

Then thermophilic phase the when the temperature goes beyond 45-50, the 10 percentage of mesophilic algorithms decrease as the temperature rises leading to thermophilic bacteria and fungal growth. So this is the phase in which this is happening. So this is the thermophilic phase roughly where this is happening.

Then again we have final mesophilic phase, as the organic matter is exhausted, the temperature lowers and the thermophilic bacteria population decreases, which enables the mesophilic bacteria to establish themselves again. So these are the three stages of composting processes the initial mesophilic phase, the thermophilic phase, and the final mesophilic phase.

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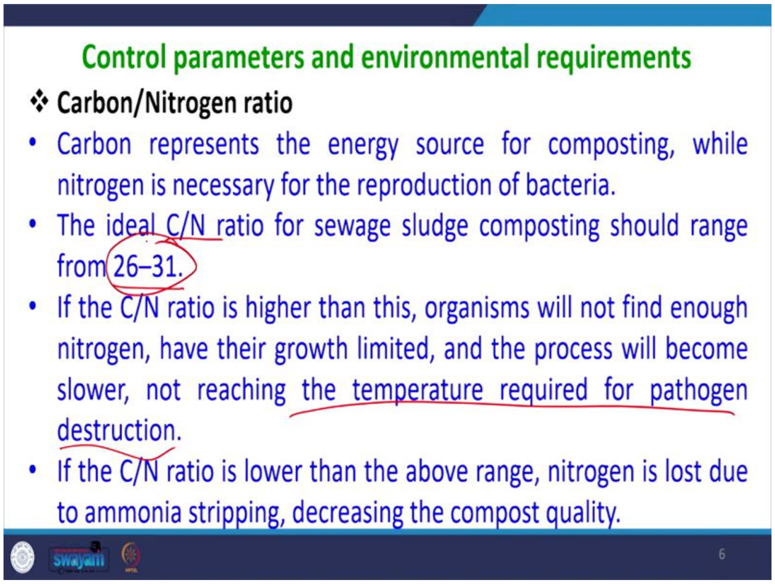

Now there are certain control parameters and environmental requirement. So one of the first important parameter is the carbon to nitrogen ratio. The carbon represents the energy source for composting, while nitrogen is necessary for reproduction of bacteria itself. So ideal C to N ratio for sewage sludge composting should range of 26 to 31.

If the C/N ratio is higher than this, organisms will not find enough nitrogen, and their growth will be limited, and thus the process will become slower, not reaching the temperature nature required for pathogenic destruction. If the C/N ratio is lower that means nitrogen is lost due to ammonia stripping and decreases the composed quality. So both ways it is not good and we should have the C/N ratio in this range.

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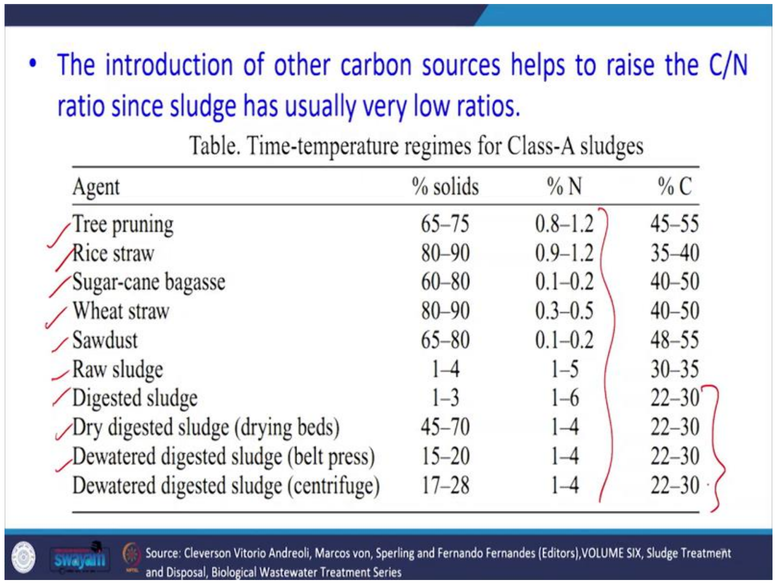

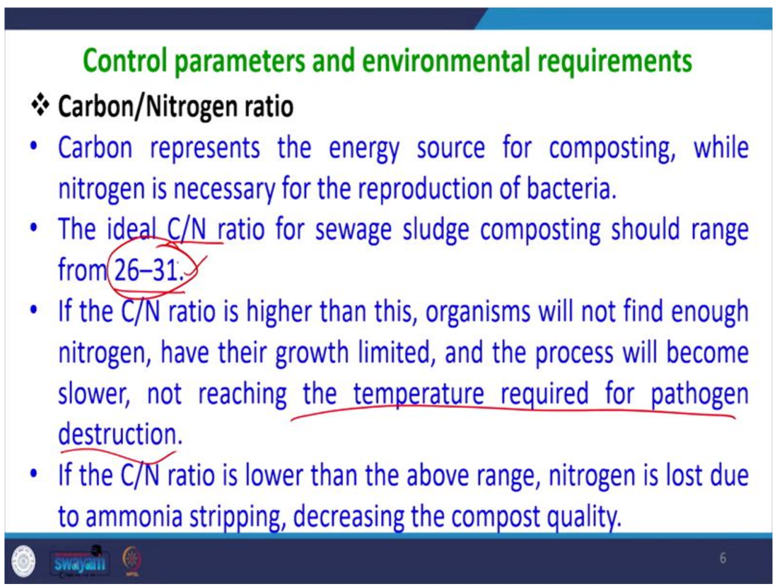

Then the introduction of other carbon sources helps to raise the C/N ratio and since the sludge has usually lower ratio. So we can use tree pruning, rice straw, sugar-cane bagasse, wheat straw, sawdust, raw sludge, digested sludge, or the dry digestive sludge, dewaters sludge, etcetera. So any of these have different types of solid percentage and the nitrogen content. So the ratio which is there.

So if the ratio suppose it is the ratio is less than 26. So in this case we can use these, the sludge has which have lower values. If the ratio is less we have to use the content which is having more nitrogen. So that means can increase similarly if the ratio is already higher we can use something where the ratio can be decreased. So we can use different types of sludges for mixing. So that the ratio which is required for composting is maintained.

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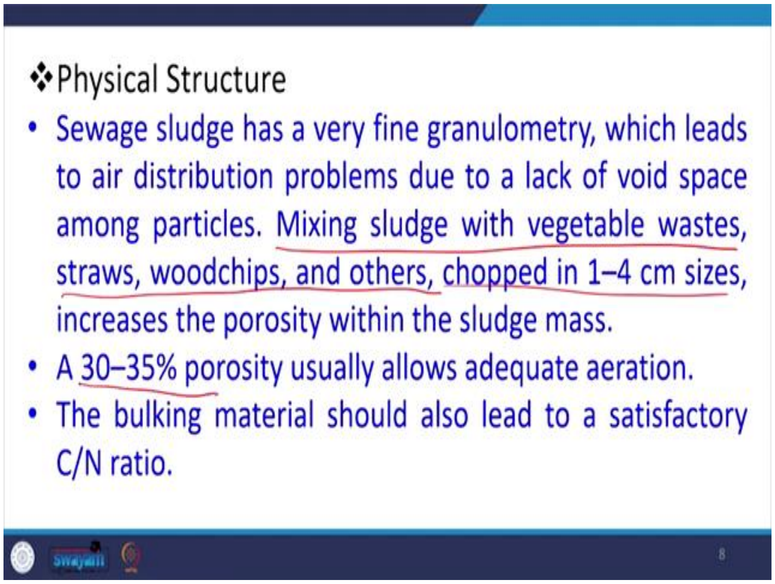

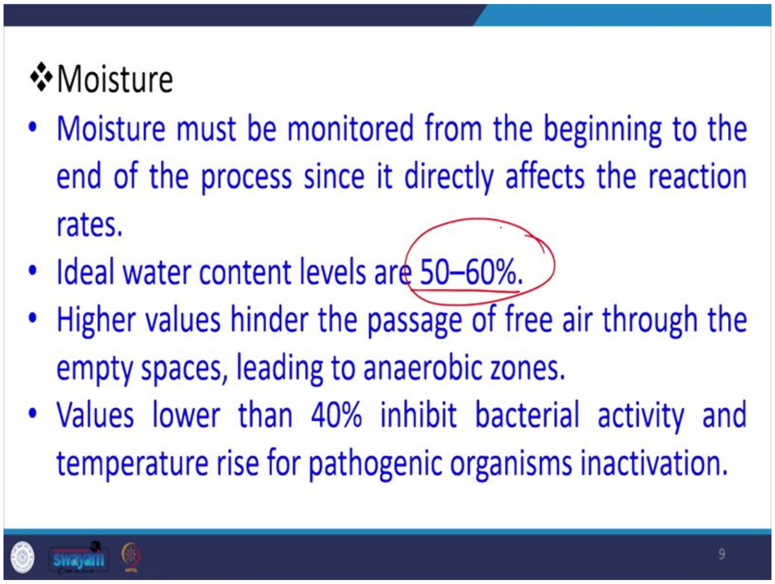

Then the physical structure of the sludge is also important. Sewage sludge has very fine granules which leads to air distribution problems due to the lack of void spaces among particles. So mixing sludge with vegetable waste, straws, wood chips, and others, chopped in 1 to 4 millimeter sizes increases the porosity within the sludge mass. And a 30 to 35 percent porosity is adequate for proper aeration. So that is required.

So the bulking material should also lead to a satisfactory C/N ratio. So what material we are using that has two major uses, one is that it should be able to maintain a particular C/N ratio. Then the second it should be added in such a manner the porosity at least become 30 percent or more, then the aeration is also easy.

Now the moisture must also be monitored from the beginning to the end of the process since it directly affects the reaction rate. Ideal water content levels are 50 to 60 percent. So this should be the water content level, higher values hinder the passage of free air through the empty spaces and leading to anaerobic zones.

So this condition we have to avoid values lower than 40 percent inhibit bacterial activity and temperature rise for pathogenic organism inactivation. So we have to maintain the ideal water content at this level, otherwise the operation will not be smooth, it will be hindered.

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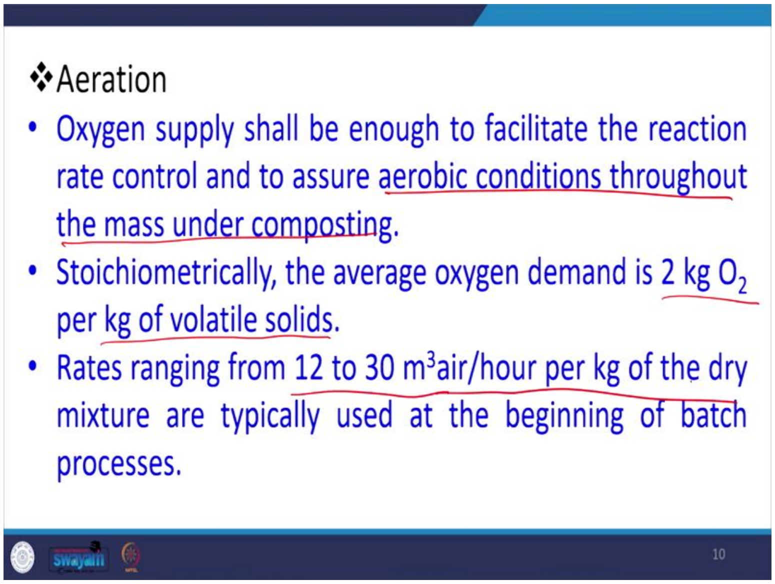

Now aeration because we this process is like aerobic process. So oxygen supply shall be enough to facilitate the reaction rate control and to assure the aerobic conditions throughout the mass under composting. So we have to see that oxygen is available for the aeration reaction, otherwise if oxygen is not available, we will not be able to properly do the composting.

The stoichiometrically the average oxygen demand is 2 kg oxygen per kg of volatile solid. So rates ranging from 12 to 30 meter cube of air per hour per kg of the dried mixture are typically used at the beginning of each batch process and this is the amount of air that has to be obtained.

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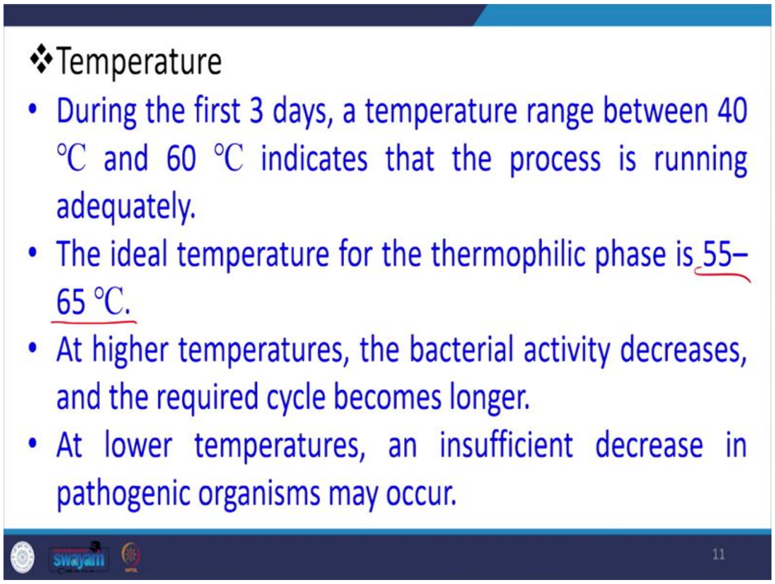

The temperature, during the first 3 days, a temperature range usually is between 40 to 60 degree indicates that the process is running adequately. The ideal temperature for the thermophilic phase should be between 55 to 65 degree centigrade. At higher temperatures, the bacterial activity decreases and the required cycles becomes longer. At lower temperature insufficient decrease in the pathogenic organisms may occur. So we have to see that the temperature also is roughly in this range 55 to 65 degree centigrade.

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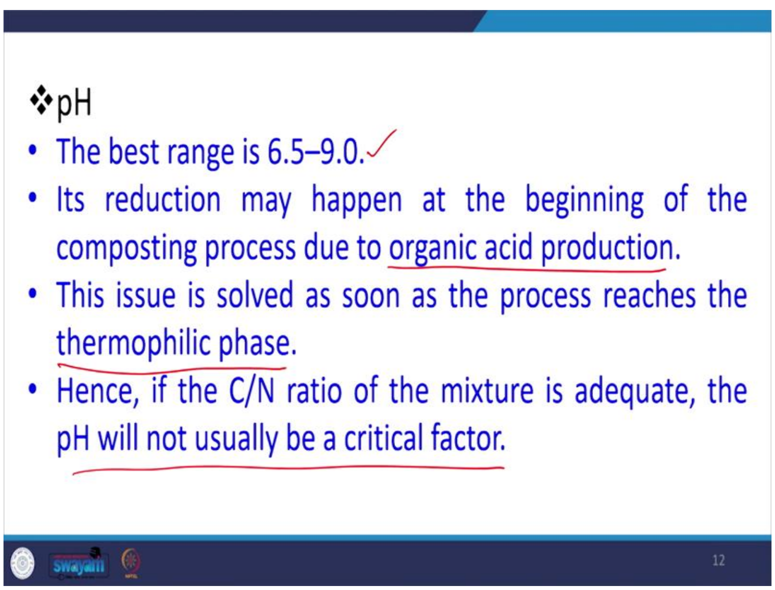

pH is also one of the important parameters for composting. So in this case the best pH range is 6.5 to 9. So if the pH is in between then the system works the composting occurs very well. If the pH reduces, its reduction may happen at the beginning of the composting process due to organic acid production which happens during the composting.

This issue is solved as soon as the process reaches the thermophilic range. So this will not happen when the process reaches thermophilic range the pH will increase and be in this range. Hence, if the C/N ratio of the mixture is adequate the pH will not be usually a critical factor, otherwise it will become a critical factor and we have to take care of the pH via composting.

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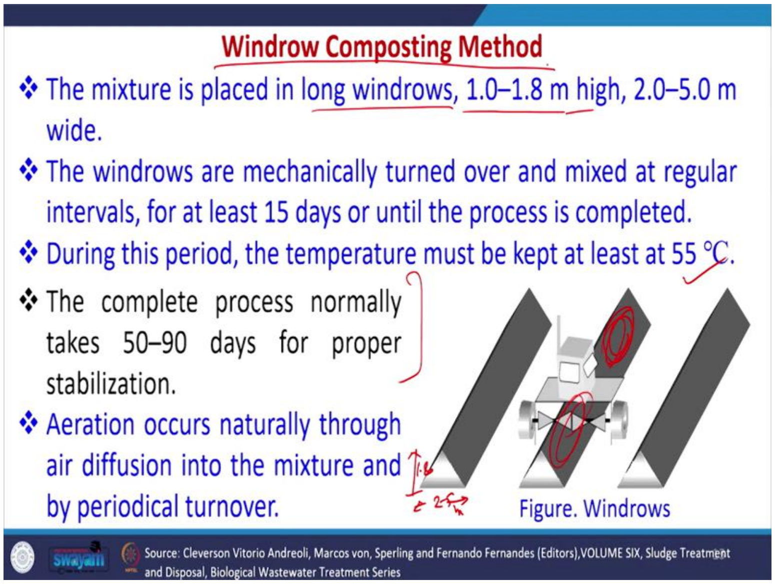

Now windrow composting method is one of the common most method which is used for composting, the in this case the mixture is placed in long windrows. So you can see the windrows which are there around 1.0 to 1.8 meter high, and then this is 1.8, and this is 2 to 5 meter wide. So it may vary from 2 to 5 meter. The windrows are mechanically turned over and mixed at regular intervals for at least 15 days.

So we have mechanical device, it will keep mixing this every day until the process is completed. During this period, the temperature must be kept at least 55 degree centigrade which is the requirement. The complete forces normally takes place 50 to 90 days of proper stabilization. Aeration occurs naturally through the air diffusion into the mixture and because of the periodic turnover which is happening.

So this windrow composting method is used in lot of industries including sugar distillery etcetera. So this is a common method by which we can do the pathogen removal as well as the great other organic compounds and convert that into usable byproducts. So this is there.

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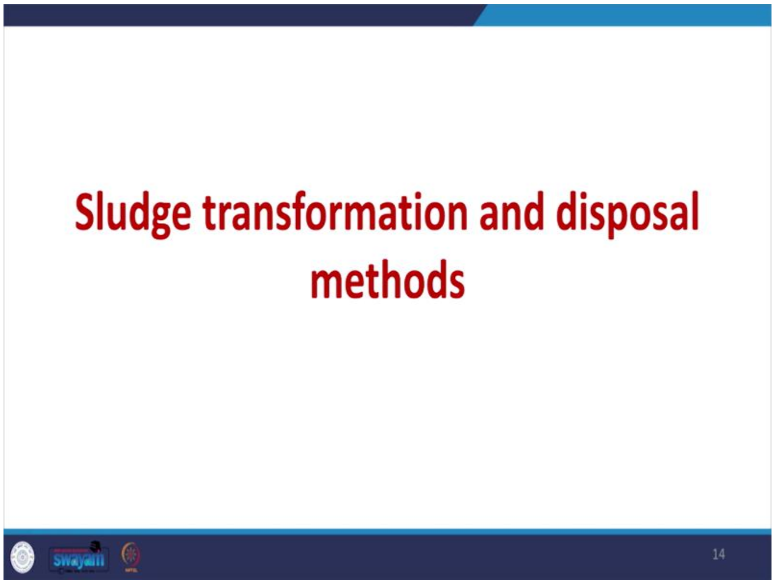

Now we will study the sludge transformation and the disposal methods. So this last section we are going to start today. So we will try to learn the sludge transformation only today, the disposal method will be studying in the next lecture.

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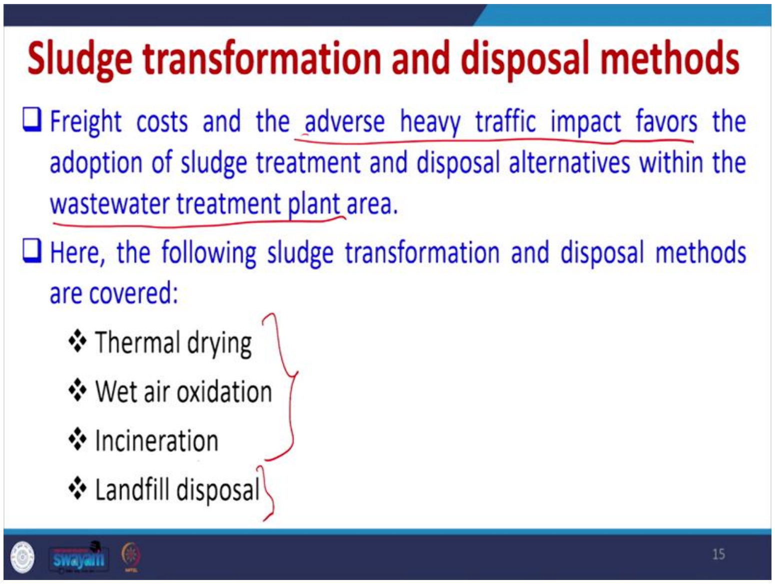

So the sludge transformation and disposal methods are very important, because we have to finally transform the sludge and dispose it off. So Freight cost the adverse heavy traffic impacts favor the adoption of sludge treatment and disposal alternatives within the wastewater treatment plant area. So we want to do this everything from sludge drying to thickening to digestion to everything, within the wastewater treatment plant area itself. However generates the area requirement is high, so we may have to do it other place.

So the following sludge transformation and disposal methods will be discussing. So there are three transformation methods that thermal drying, the wet air oxidation, the incineration, there are other possibilities also, and finally if it works well. So we can go for land fill disposal as well. So these are the methods and will be studying them one by one.

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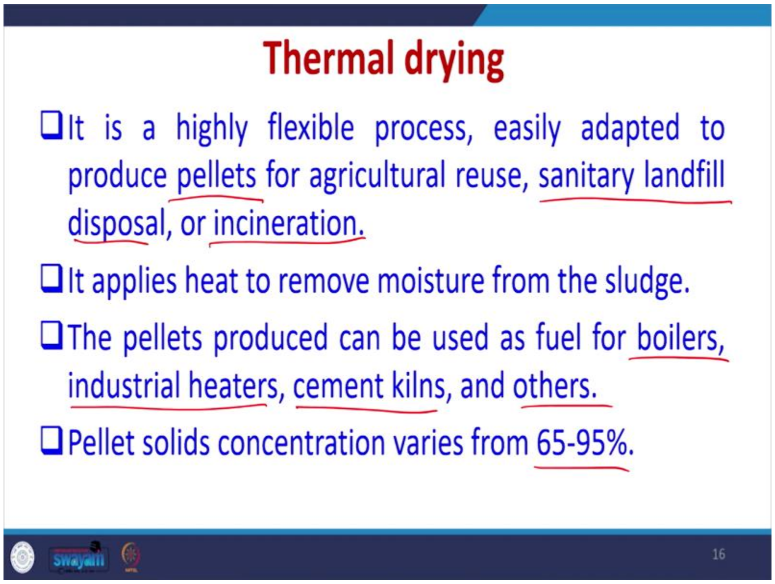

So let us start with thermal drying today. So thermal drying is a highly flexible process easily adapted to produce pellets of agricultural reuse, and sanitary landfill disposal, or incineration. So in this case it can be adopted to produce pellets. So we can produce pellets, we can finally dispose them off in the sanitary landfill or for incineration via thermal drying. So it applies heat to remove moisture from the sludge. So it is like sludge drying bed also.

The pellets produced can be used as fuel for boilers, industrial heaters, cement kilns, and others. The pellet solid concentration varies from 65 to 95 percent. So it is much higher than the what we obtained from the sludge drying bed. So thermal drying it is done.

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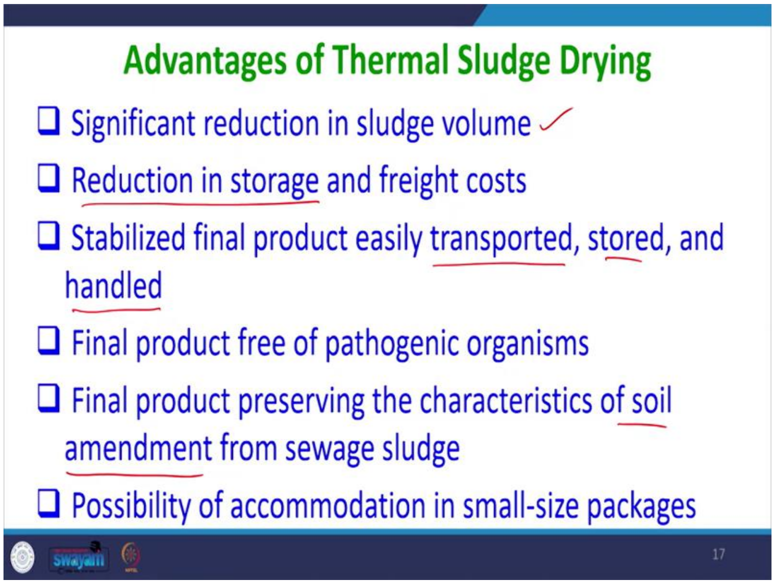

Now, advantages of thermal sludge drying. Significant reduction in the sludge volume, this is the first and foremost benefit that we get. Then the reduction in the storage and freight cost, because we are able to reduce the sludge volume, then that means we have to transport smaller volume, and since we are transporting smaller volume, that means the freight cost will be reduced, similarly before transporting we have to store them, now since volume has been reduced, so reduction in the storage cost will also happen.

Now the stabilized final product can easily be transported stored or handled. So this is possible. Final product is free from pathogen organisms because we are using thermal sludge drying. So because we are using thermal methods the pathogens are also getting removed. The final product preserves the characteristic of soil amendment material from sewage sludge and it can be used as a soil amendment material. The possibility of accommodation in small size packages is also possible, because we have reduced the size.

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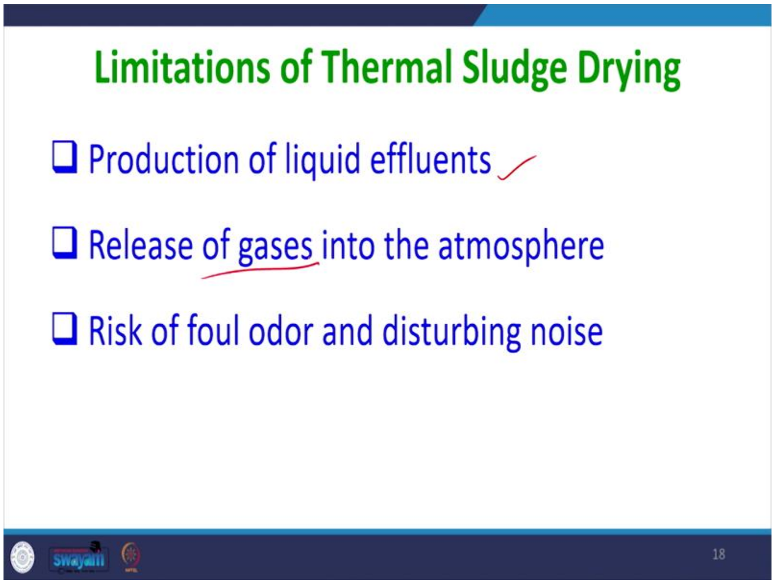

Now certainly there must be some limitations also of thermal sludge drying and these limitations are production of liquid effluence during the thermal sludge drying, release of gases also into the atmosphere depending upon the type of material which it contains, risk of foul odor and disturbing noise also occurring during thermal sludge drying.

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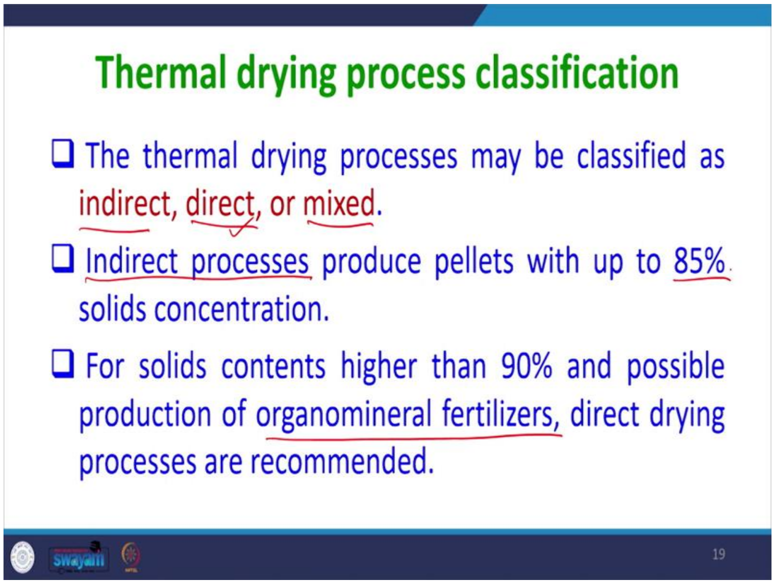

Now a thermal drying processes can be classified also. So there are three classifications of thermal drying processes, they are indirect, direct, or mixed. Now the indirect processes they produce pellets with up to 85 percent solid concentration. For solid contents higher than 90 percent and possible production of organo-mineral fertilizers, direct drying is recommended. So if you have go for much higher we have to go for direct drying, otherwise we can get up to 85 percent solid concentration via indirect method and in between we can get via mixed method.

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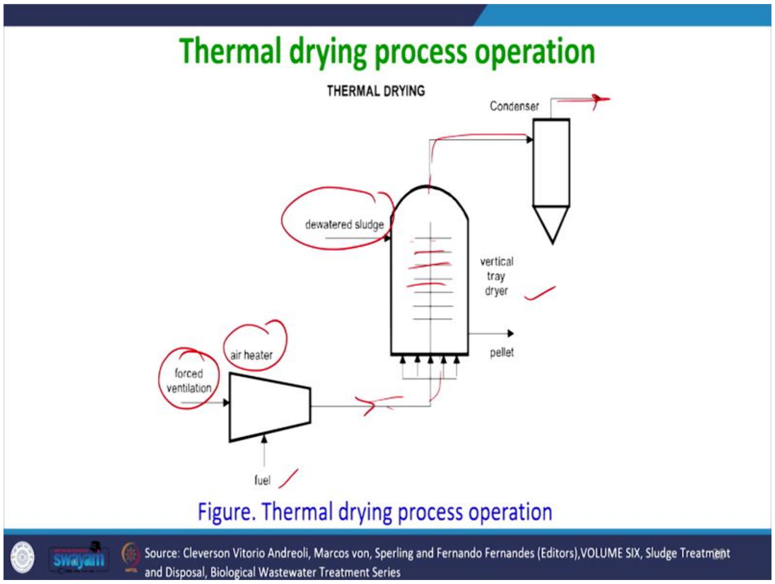

Figure. Thermal drying process operation

So thermal drying process operations we will try to understand the process here. So this is the main section. So dewatered sludge goes here. So we have vertical tray dryers which are there. Now for drying them we have to use the air and that air has to be heated also. So forced ventilation via air heater in which the some fuel supply may be there. So heated air is going here and in the vertical tray we have the sludge which is already dewatered but it we are going for further drying and the air it will be coming out. So we have the condenser from which the water will be taken out air can be recycled back. So this is the thermal drying process operation.

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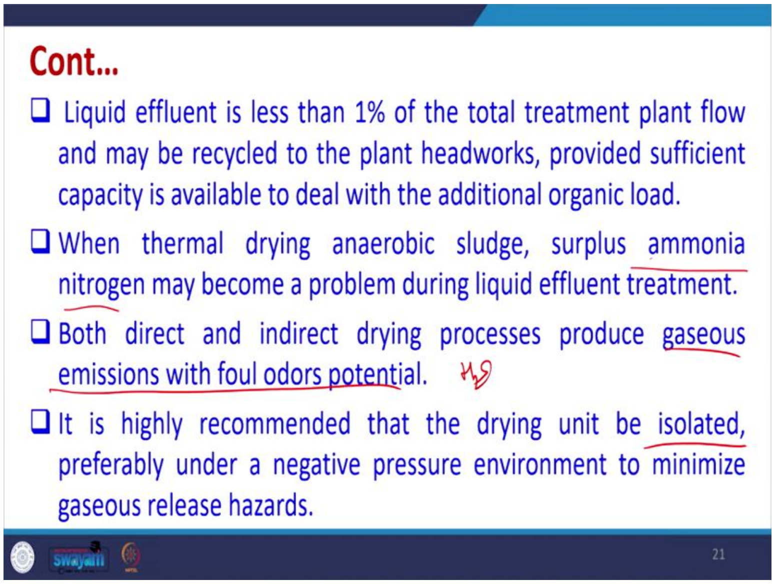

Liquid effluent is less than 1 percent of the total treatment plant flow and may be recycled to the plant head works and provided sufficient capacity is available to deal with the additional organic load. So we will get some liquid effluent is also possible during the process. When the thermal drying anaerobic sludge is there, surplus ammonia nitrogen may become a problem during liquid effluent treatment. So this is there.

Both direct and indirect drying processes they produce gaseous emissions with foul odor like if suppose H_2S is coming, then there is a problem, because odor will be generated and that has to be taken care. It is highly recommended that the drying unit be isolated preferably under a negative pressure environment to minimize the gaseous release. So this can be taken care of.

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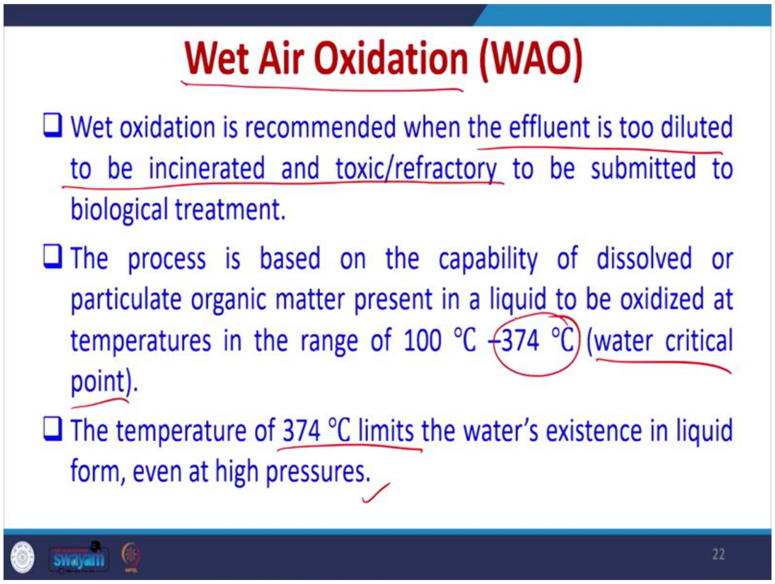

After thermal drying process there is another process which is called as wet air oxidation. So we can use the wet air oxidation technique also as one of the sludge transformation method. So wet air oxidation is recommended when the effluent is too diluted to be incinerated and toxic refracted to be submitted to the biological treatment.

So with this type of method is used in the sludge case also in the normal water case also. So the process is based on the capability of dissolved and particular organic matter present in a liquid to be oxidized at temperature in the range of 100 degree centigrade to 374 degree centigrade which is the water critical point.

The temperature of 374 degree centigrade limits the water existence in the liquid form and even at higher pressure. So this is there. So we use this technique with respect to this temperature in the wet air oxidation.

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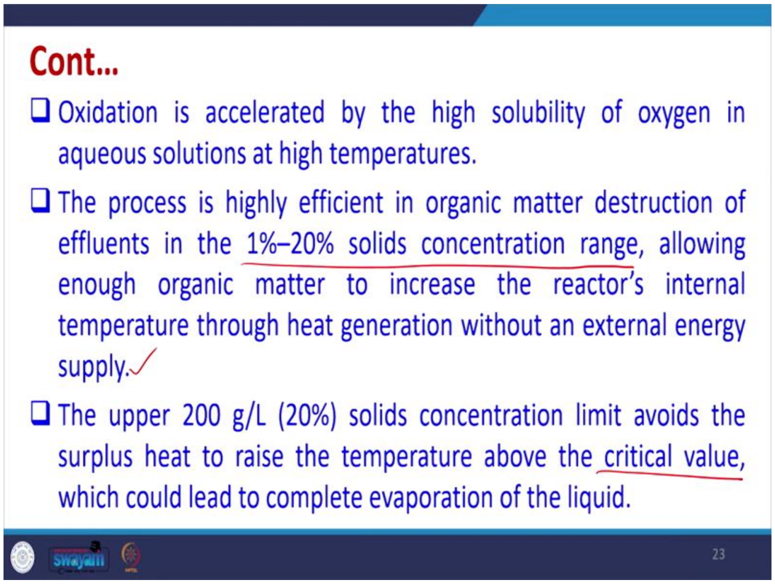

So wet air oxidation is though it is used more for water critical water treatment but it can be extended to sludge also. So in this wet air oxidation, the oxidation is accelerated by the high solubility of water in aqueous solutions or in sludge at high temperature. The process is highly efficient in organic matter destruction, if the solid concentration is in this range, 1 to 20 percent allowing enough organic matter to increase the reactors internal temperature through heat generation without any external energy supply.

The upper 200 gram per liter that means 20 percent solid concentration limit avoids the surplus heat to raise the temperature above the critical value and which can lead to complete evaporation of the liquid also. So this is also possible in the case of wet air oxidation.

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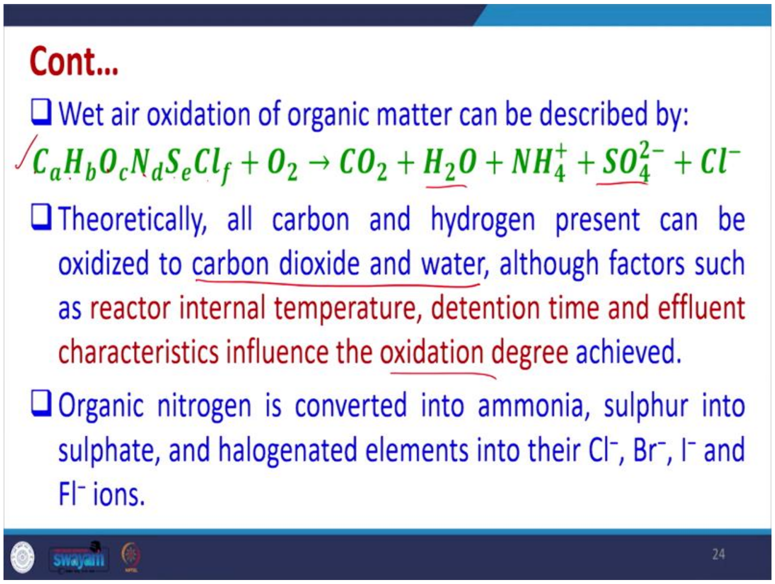

Wet air oxidation of organic matter can be described by:

$$C_aH_bO_cN_dS_eCl_f + O_2 \rightarrow CO_2 + H_2O + NH_4^+ + SO_4^{2-} + Cl^-$$

The wet air oxidation of organic matter can simply be represented by this equation where the carbon, hydrogen, oxygen, nitrogen, sulfur, chlorine, everything we are assuming to be present in the organic matter and it will convert the carbon into CO_2, hydrogen into H_2O, then NH_4 also form SO_4^{-2}, then chloride.

So theoretically all carbon, hydrogen present can be oxidized to carbon dioxide in water, although factors such as what is the reactor internal temperature, what is the detention time, the characteristics of the influent or the sludge influence the oxidation degree achieved. Organic nitrogen is converted into ammonia, sulfur into sulfate, and halogenated elements into chloride, bromide, iodide, fluoride, ions, etc. So this is there.

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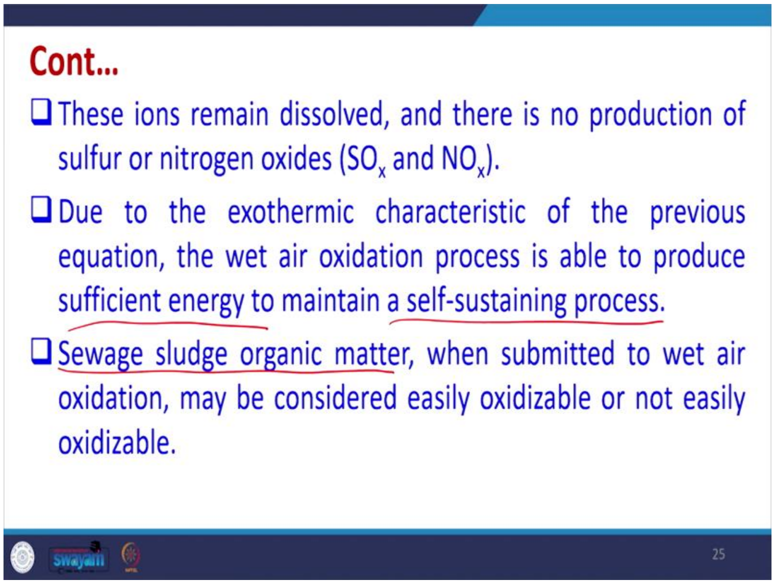

These ions may remain dissolved and there is no production of sulfur or nitrogen oxide. This is good thing with respect to wet air oxidation. Due to exothermic characteristics of the previous equation the wet air oxidation process is able to produce sufficient energy to maintain a self-sustaining process. Then the sewage sludge organic matter, the sewage sludge when submitted to wet air oxidation may be considered easily oxidizable or not easily oxidizable depending upon the various characteristics of the sludge.

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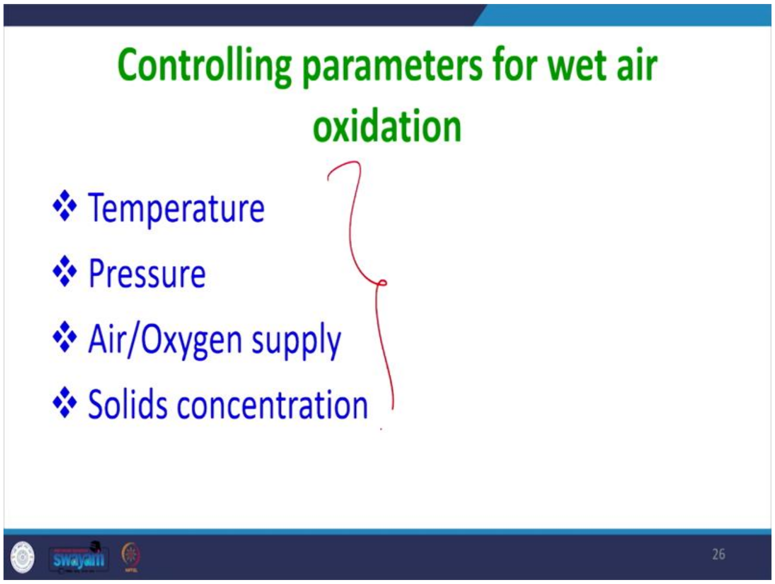

The parameters which may affect the wet air oxidation are temperature, pressure, air oblique oxygen supply, and the solid concentration which is there. So any all these four parameters may affect the wet air oxidation process in greater details.

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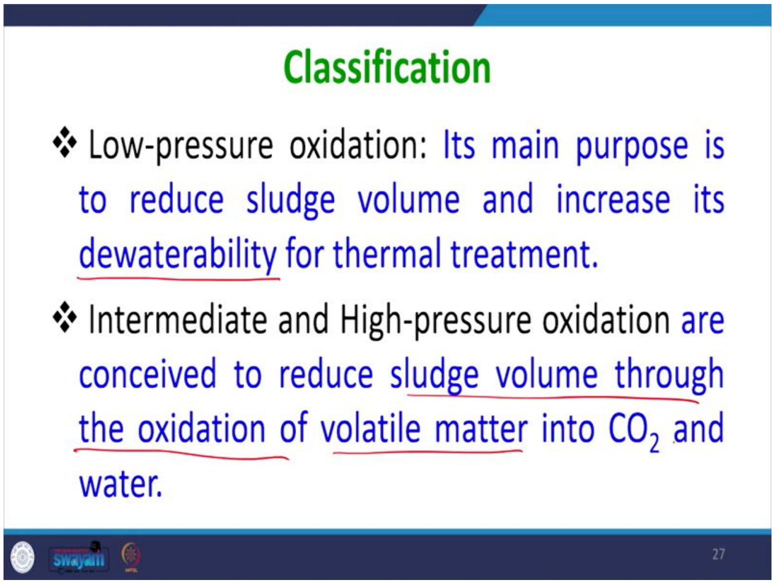

Now let us we will try to understand each of the parameters in greater detail now. So low pressure oxidation. So this wet air oxidation may be classified as low pressure, intermediate, and high pressure oxidation. So in the case of low pressure oxidation its main purpose is to reduce the sludge volume and increase it's dewater ability for thermal treatment. So for low pressure conditions these are the major objectives. For intermediate and high pressure oxidations are conceived to reduce the sludge volume through the oxidation of volatile matter into CO_2 and water. So this way also reduction will happen.

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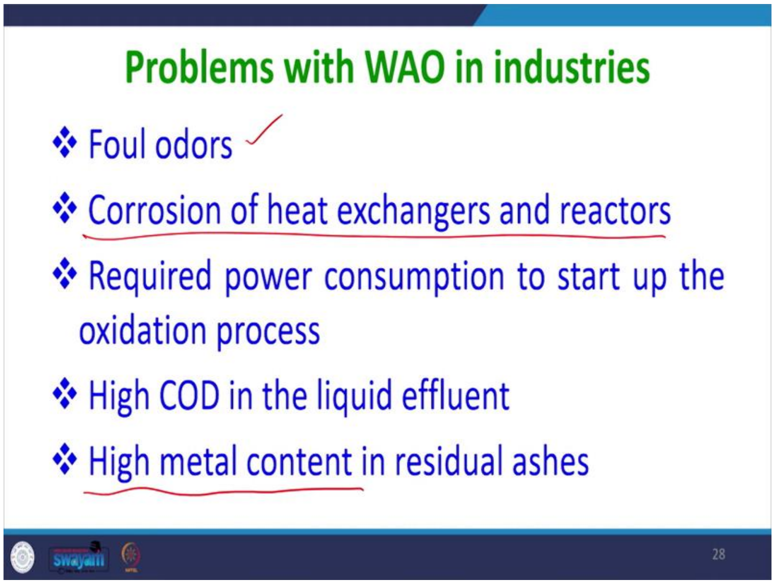

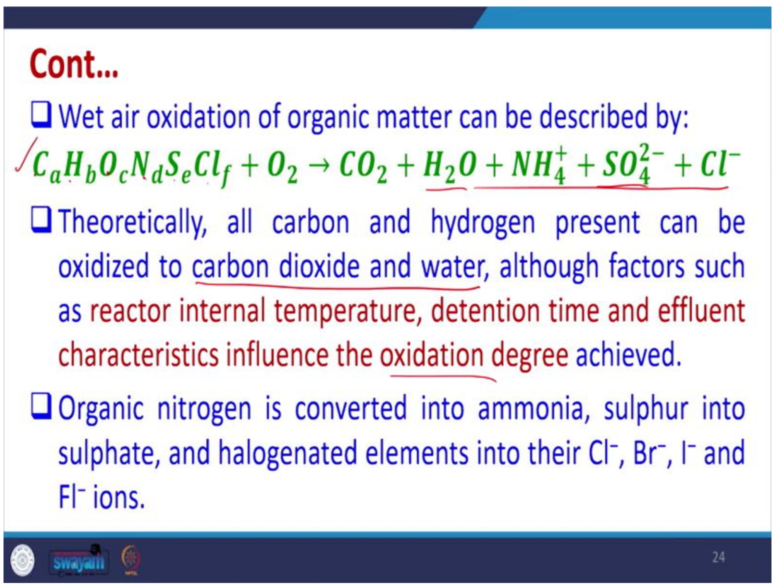

The problems with wet air oxidation in industries is, that we may have foul order. The corrosion of heat exchangers and reactors, because we have gases which are coming out as well as the halogenated materials which are coming out. So along with ammonia etcetera. So that may cause the problem. So this corrosion of heat exchangers and other reactors is the issue when we are using wet air oxidation and also of the wet air oxidation reactor itself the corrosion may happen.

It requires lot of power consumption to start up the oxidation process. Then a very high COD is there or very high organic matter is there, then also issues may happen. Also it has very high metal content in the residual ashes which are obtained. So these are the various problems which are faced when we are using the wet air oxidation in the industries.

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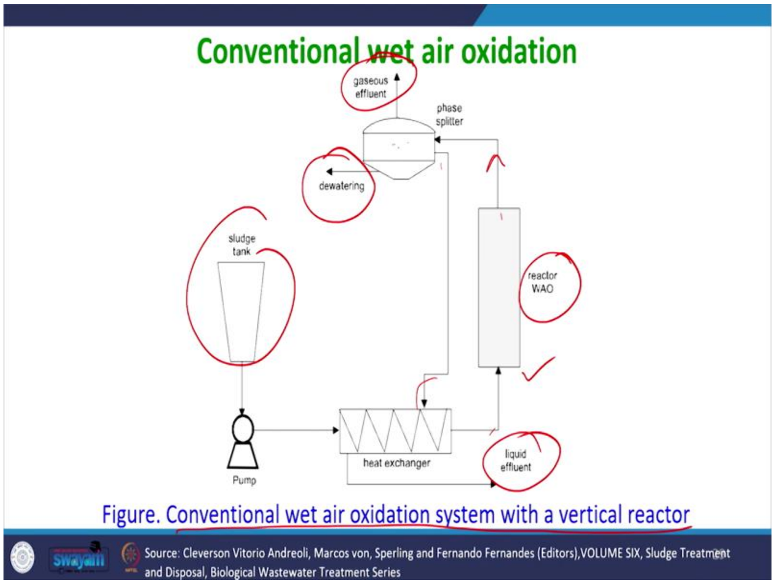

Now the conventional wet air oxidation with a vertical reactor is shown here. So we can see here the wet air oxidation reactor which is shown here. So we have the sludge tank which is pumped through a heat exchanger. So that it is heated and it is goes into the wet air oxidation where certain temperature will be maintained. After that we have the gases which are coming out, these gases are further may be taken care the temperature will be now lowered and I, under that condition we will getting dewater, this water may also be recycled back and used in the heat exchanger because the temperature will be higher.

We have gaseous effluent will be coming out and that we have to take care and also from the heat exchanger we have liquid effluents which are coming out and these also we have to take care they may be required to be further be treated in the user wastewater treatment plant. So this is the conventional wet air oxidation method.

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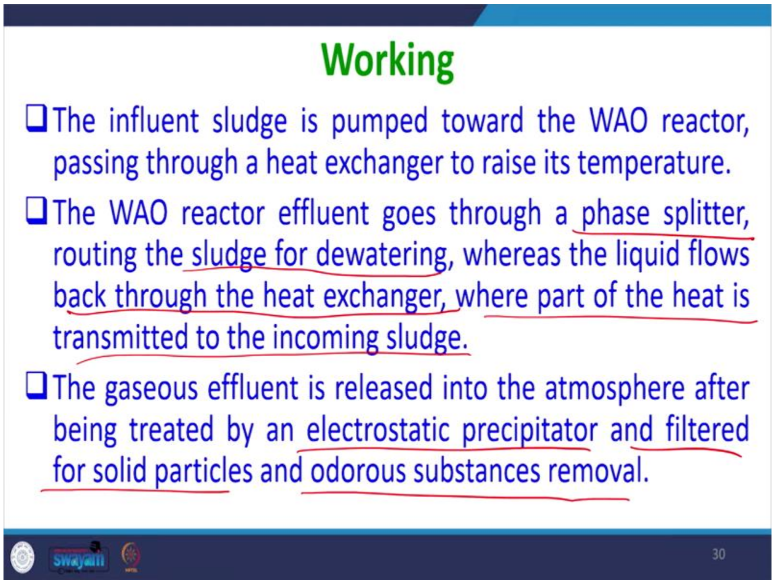

Now this is the working. The influent sludge is pumped towards the wet air oxidation reactor passing through the heat exchanger to raise its temperature. The wet air oxidation reactor effluent goes through a phase splitter, routing the sludge for dewatering, whereas the liquid flows back through the heat exchanger, where part of the heat is transmitted to the incoming sludge.

The gaseous effluent which are released into the atmosphere after being treated by the electrostatic precipitator and filtered for solid particles and address substances are also removed. So this is how the wet air oxidation reactor works. So this is the working of a wet air oxidation reactor.

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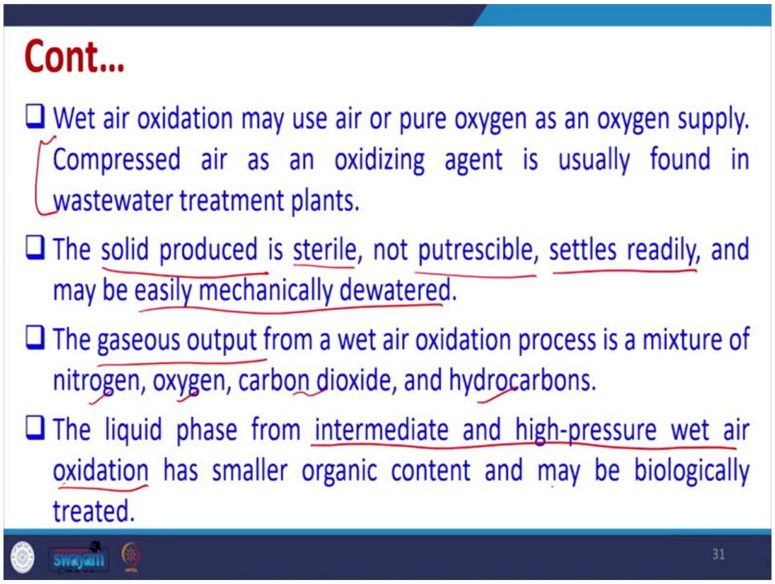

Now the wet air oxidation may use air or pure oxygen as an oxygen supply. The compressed air as an oxidizing agent is usually found in the wastewater treatment plants. The solids produced are sterile, not putrescible that means they do not produce odor, they settle readily, and may be easily mechanically dewatered. So this is with respect to the solid which is produced. The gaseous output from a wet air oxidation process is a mixture of nitrogen, oxygen, carbon dioxide, and hydrocarbons. So we have to take care of this.

Then the liquid phase from intermediate and high pressure wet air oxidation system has smaller organic content and may be biologically treated in the wastewater treatment plant. So this is how we can take care of the wet air oxidation. So today we have learned regarding the composting process in detail. After that we started studying the sludge transformation methods which include like the drying bed, thermal drying beds, we have studied in a vertical system. And similarly we have studied the wet air oxidation method.

So wet air oxidation is more commonly used for treatment of liquid effluents but it can be extended for sludge is also is up to a certain concentration of solid content. So these are the two method that we have studied. We will further study the sludge transformation methods and thereafter incineration is one of the common method that will be studying in the next lecture and after that we will finally be studying, the how the sludge can be disposed off. So this will be continuing in the next lecture. So today will end our lecture with this particular section and will continue further. Thank you very much.