Water and Wastewater Engineering
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Sludge Treatment (continued)
Lecture # 31

Last few classes we were discussing about sludge treatment. We have what is the process or what are the steps involved in sludge treatment starting from the pretreatment, dewatering, stabilization etc. We were discussing in detail about stabilization and we have seen that there are various methods which are commonly practiced for sludge stabilization and we have also seen the objective of sludge stabilization. The main objective is to inhibit the material growth so that it will not be further putrefaction of the sludge and because if putrefaction takes place it will be creating or generating malodors and other nuisances.

We discussed in detail alkaline sludge stabilization, anthropic sludge stabilization, aerobic process as well as composting in detail. Today we will discuss the remaining steps of sludge treatment. Those are conditioning, dewatering, incineration and finally hand disposal. We will see one by one in detail. What is the purpose of this conditioning?

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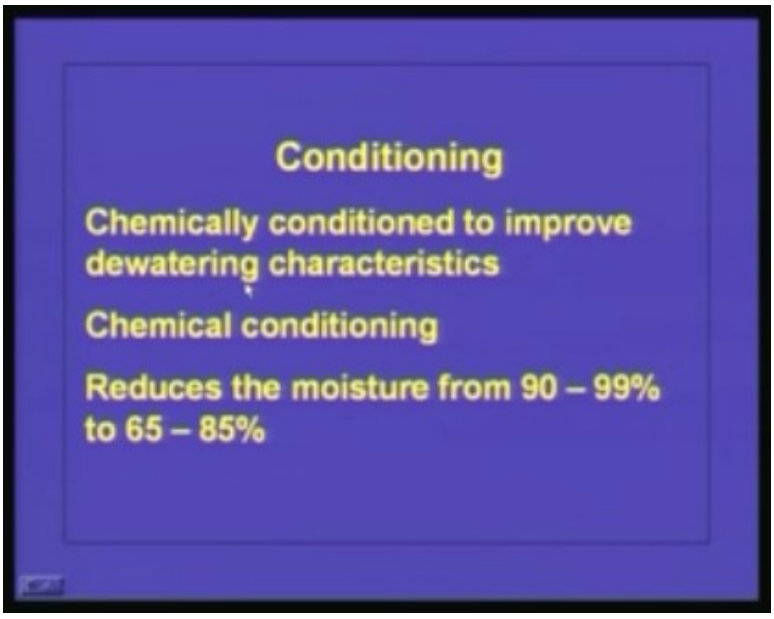

Conditioning is basically used to improve the dewatering characteristics of the sludge. What we are doing here is after the stabilization of the sludge in some cases the stabilized

sludge will be having lot of water content or moisture content so in such cases what we do is we add some chemicals to improve the dewatering characteristics. The most commonly used conditioning is chemical conditioning and sometimes we can go for heat conditioning also. In chemical conditioning if you add chemicals to the stabilized sludge it reduces the moisture from 90 to 99 percentage to 65 to 85 percentage so we can see that here considerable reduction in moisture is occurring because of this conditioning so that will be reducing the cost of treatment tremendously.

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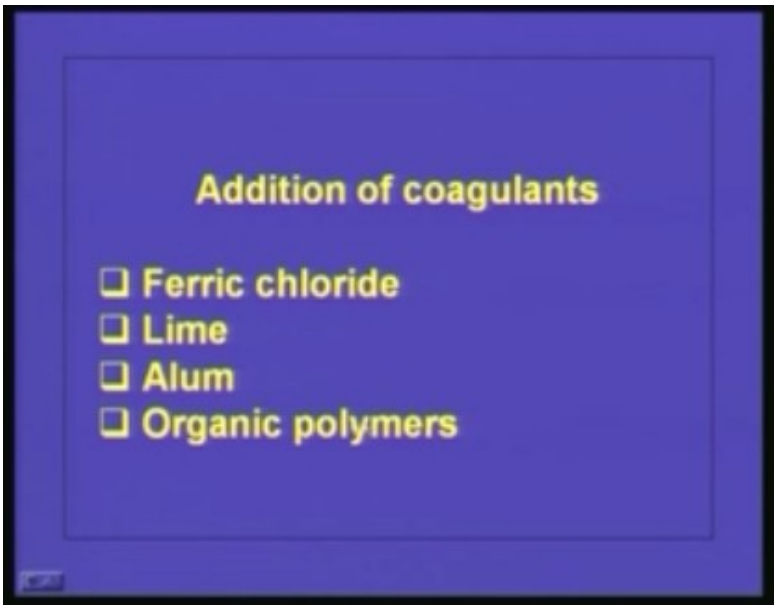

So the most commonly used chemicals for this conditioning are ferric chloride, lime, alum and organic polymers. In this if you add organic polymers it is not going to increase the solid contents of the sludge but if you add ferric chloride lime or alum the organic content or the solid content of the sludge can be increased.

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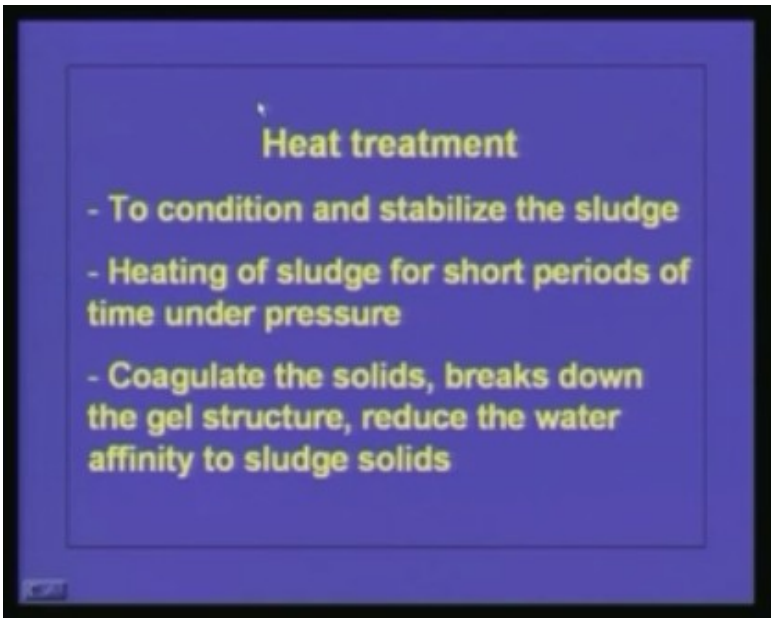

Now, coming to the heat treatment this is also used to condition and stabilize the sludge, heating of the sludge for short periods of time under pressure is practiced in heat treatment. So what will happen in heat treatment is it coagulates the solids and breaks down the gel structure and reduces the water affinity to sludge solids. So because of this process the water whatever is hold in the sludge will be coming down so definitely the sludge will be having more solids compared to the water content so the volume of the sludge will be reducing considerably.

Once again, in heat treatment what we do is, give heat treatment for a short period under pressure so it will coagulate the solids, break down the gel structure and reduce the water affinity to sludge and it reduces the volume of the sludge as a whole. What are the advantages of this process?
Heat treatment is having many advantages. One is the solid content is increased to 30 to 50 percentage because the raw sludge will be having the solid content of around 4 to 6 percentage and after stabilization it will be increasing and this conditioning will increase the solid concentration to 30 to 50 percentage and no additional chemical conditioning is required because the heat treatment itself will be coagulating and breaking the gel structure of the sludge so no chemical addition is required. The process stabilizes the sludge and destroys pathogenic organisms. Even if some pathogenic organisms are left over stabilization this heat treatment will be stabilizing the sludge further and destroying the pathogenic organisms.

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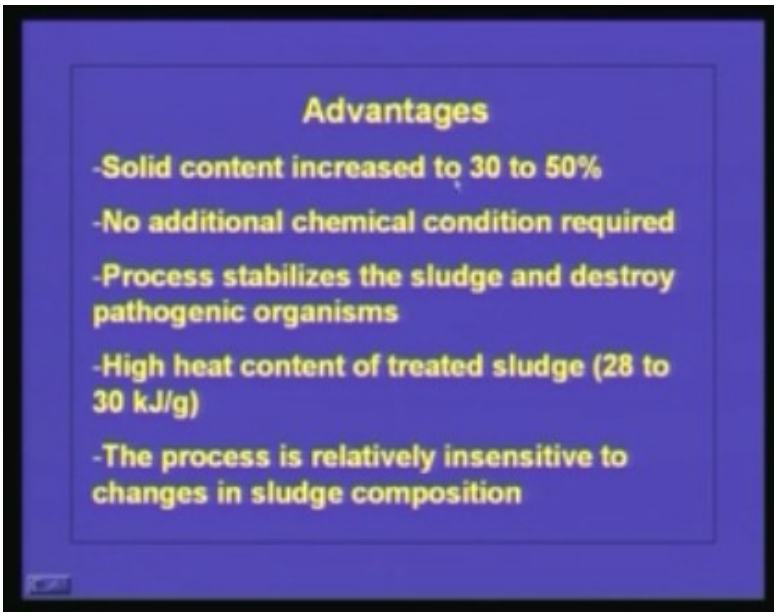

As the heat treatment because it reduces the water content it improves the heat content of the treated sludge. Usually the heat content will be increased up to 28 to 30 kilo joules per gram and this process is relatively insensitive to the changes in sludge composition. We know that the sources of sludge are different.

Now we take a treatment plant, we have seen that the sludge can come from screening, screens, grid chamber, primary sedimentation tank, secondary sedimentation tank or chemical processors. So each and every processors whatever the sludge generates the characteristics of sludge will be different as well as the quantity generated also will be different. So if you go for heat conditioning the sludge characteristics will not be affecting the process much. Now we will see what all are the disadvantages of this heat treatment.

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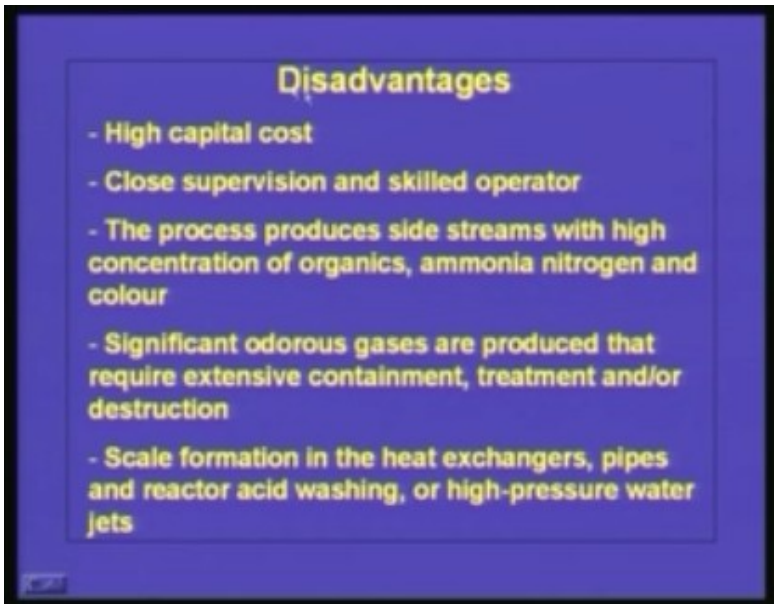

The first one is high capital cost because we have to heat the entire sludge whatever is stabilized so the capital cost for that treatment system of heating unit will be very very high. And it requires close supervision and skilled operator. The process produces side streams with high concentration of organics, ammonia nitrogen and color because the heat treatment will be coagulating the solid content or solid particles present in the sludge and it will be breaking the gel structure so the entire amount of water holding in the sludge will be coming out so the liquid whatever is coming out will be containing lot of organic matter and organic nitrogen as well as color so we cannot just discharge this liquid somewhere but that requires further treatment. That is another disadvantage of this heat treatment.

The third one is significant odorous gases are produced that require extensive containment, treatment and/or destruction. Because when we go for heat treatment whatever volatile organic matter present in the treated sludge or the raw sludge will be volatilizing and it will be coming out along with the gas stream when we apply temperature. So if you let it out it will be creating air pollution so we are not supposed to let it out without treatment.

Therefore, if you want to treat the gases whatever is generated in the heat conditioning unit we have to put up other air pollution control devices so naturally it will be increasing the capital cost and operational and maintenance cost. Moreover air pollution control equipment needs other skilled labors so all these things are the major disadvantages of heat stabilization.

The last one is because of heat stabilizations scale formation in the heat exchanges can happen, pipes and reactor. So, scale formation happens or it requires acid washing or high

pressure water washing is required. We know that the sludge will be containing lot of inorganic substances and most of the time it will be having alkalinity or carbonate and bicarbonate concentration so what will happen is as we increase the temperature the solubility of calcium carbonate will be decreasing and it will be precipitating and since other solids are present there in the waste sludge the precipitation potential will be much higher so it will be getting precipitated on the reactor so if you want to remove the sludge then either we have to go for acid washing or high pressure jet water washing.

Now we have seen what conditioning is. Conditioning is done to remove the entire water present in the stabilized sludge. Now we will see what are the different processes we can use for dewatering. We have already discussed this before stabilization because before stabilization we do dewatering. Dewatering is a physical unit operation used to reduce the moisture content of sludge and bio solids.

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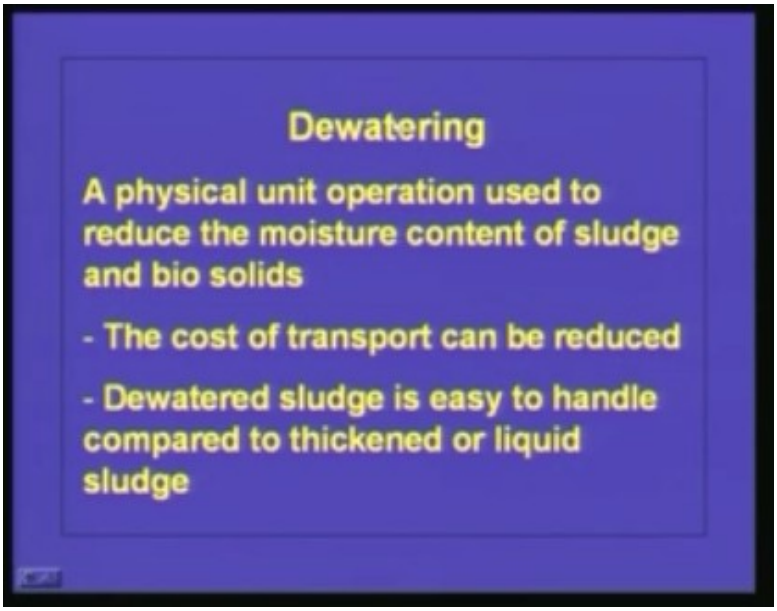

Why we want to dewater the stabilized sludge?
After the stabilization process we have to take the sludge and dispose it in some other place. We are not supposed to put everything in the place where it is originated. So if you want to transport it and if the volume of the sludge is too high then the transportation cost will be so high. So it is always advisable to reduce the volume of the treated sludge as much as possible. That is the advantages of dewatering.

The cost of transport can be reduced, dewatered sludge is easy to handle compared to thickened or liquid sludge. And if you want to further reduce volume of the treated sludge by thermal means dewatering is required because if the water content or the moisture content is very high incinerators and other treatment units will not be functioning properly so dewatering is necessary and dewatering is essential for composting also.

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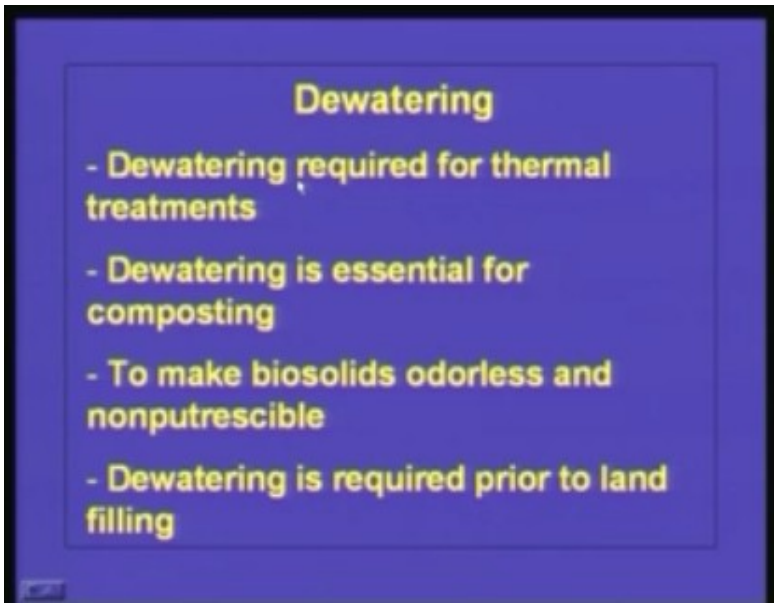

We have seen that in composting dewatering is one of the pre-treatment and to make biosolids odorless and nonputrescible this dewatering is required. If the moisture content is more then it will conducible for the microorganisms to grow in the sludge. Definitely if microorganism grows in the sludge then it will be biodegrading the organic matter present there and as a byproduct different types of gases will be generated and that will be creating odour. So dewatering can avoid the microbial activity in the treated sludge and dewatering is required prior to land filling also. If lot of water content is there then everything will be oozing out once we put the treated sludge in the land filling side. Therefore the entire amount of water coming out of treated sludge will be percolating through the soil and it will be reaching the groundwater and this lechate will be containing lot of organic matter, organic nitrogen, other inorganic salts etc so definitely it will be contaminating the ground water. So, if you can reduce the water content then the lechate whatever is coming form the treated sludge will be very very less and it is easy to contain them and take it and treat it.

Even if you want to dispose the sludge in land fills dewatering is essential. Now we will discuss what are the different methods we can use for dewatering. This also we have seen earlier. The methods usually used are as follows:

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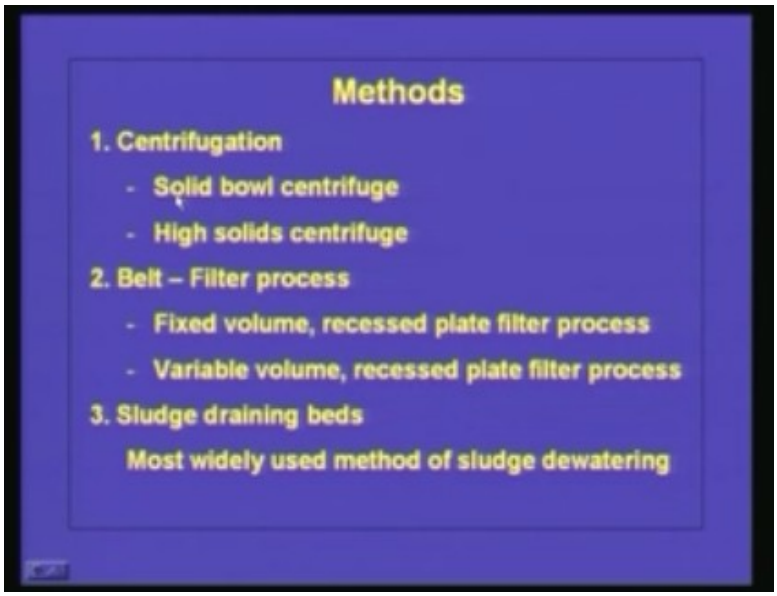

One is centrifugation. Either we can go for solid bowl centrifuge or high solids centrifuge. The second one is belt - filter process. It can be either fixed volume, recessed plate filter process or variable volume, recessed plate filter process. The third one is sludge draining beds. This is the one most widely used sludge dewatering especially whenever we talk about domestic waste water treatment plants and others. In some industries they use this centrifugation and belt - filter process dewatering the sludge. But whenever we talk about the municipalities where there is domestic waste water treatment plants so most of the time they go for sludge draining beds for the sludge dewatering. We will see the advantages of this sludge draining beds for other dewatering processes. The cost involved is very very low for the sludge draining beds and infrequent attention is required because we can just go and dump the sludge on the sludge draining beds and it will automatically get dried because of evaporation and leaching of water from the sludge.

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Infrequent attention is required in such cases. Anybody can take care of sludge draining bed. The third one is presence of high solid content in dried products. Almost all the water content will be getting escaped from the sludge so we will be getting a dried solid content in the dried sludge. But there are certain disadvantages if you go for the sludge drying beds. The first one is it requires large space requirement. the reason is we cannot put lot of sludge in one bed, the reason is it has to get exposed to the solar radiation and because of the solar radiation evaporation will take place and the water content will be removed from the treated sludge.

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Another one is whatever water content is present in the sludge will be coming down percolating through sand which is put in the sludge draining bed so that way we can remove the water. Most of the water is getting removed from the treated sludge because of this leaching out and the lechate we have to collect. So, for this one the height of the sludge bed is limited to say 10 to 20 centimeters. So if you have huge quantity of treated sludge coming out so and the maximum permissible height or depth of the sludge bed is only 10 to 20 cm then we need a huge area to distribute the entire sludge. That is the major disadvantage of this sludge drying bed and it is having effects of climatic changes.

If it is summer time definitely the dewatering or the drying of the sludge will be very very fast. But during winter and rainy seasons the sludge strain will not be effective at all. During rainy season more and more water will be getting added to the sludge so the retention time required in that sludge drying bed will be much higher compared to the summer.

It is labour intensive as far as sludge process and sludge removal is concerned because we are pumping the liquid sludge to the sludge drying beds. Once the sludge is dried we have to remove the sludge from the sludge drying bed manually so it is a labour intensive process. There is odor and insect potential. Because if the sludge is lying there for more time and it is taking lot of time to dry up then definitely it acts as the site for insects and odor generation.

There are different types of sludge drying beds;

- Conventional sand bed
- Paved sludge drying bed
- Artificial media
- Vacuum assisted drying beds and
- Solar drying beds

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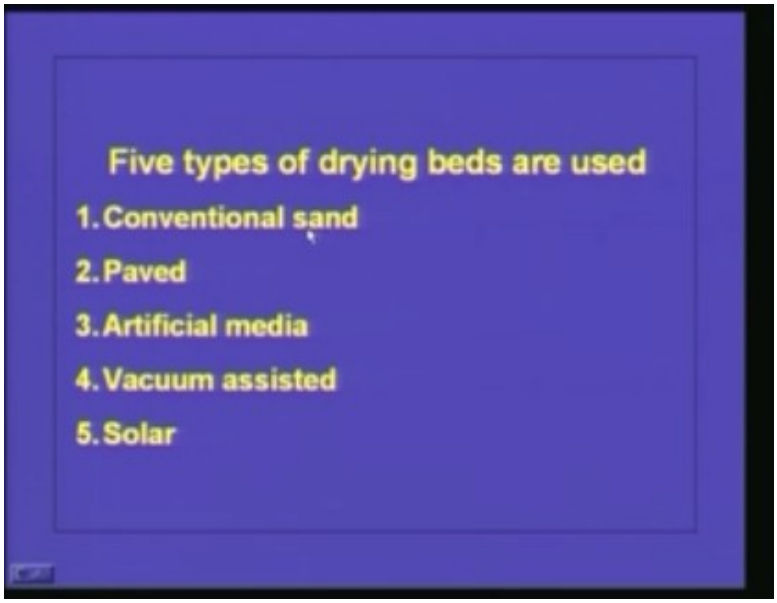

The conventional sand drying bed is the one which is most commonly used. It's a long rectangular bed filled with sand having high permeability and it will be having under drainage system which can collect water coming out of the sludge and the collected water can be sent back for further treatment. As the sludge is lying on the sand bed what will happen is whatever water is present in the sludge can ooze out and come through the sand and get collected in the under drainage system and sludge will be put on the sand bed only for some 10 to 20 centimeters so what will happen is within 7 to 15 days depending upon the climatic conditions and solar radiations whatever water content is present in the sludge will get escaped. Once the sludge is dried the dried sludge cakes can be removed and can be used as a manure or soil conditioner. This is the conventional method.

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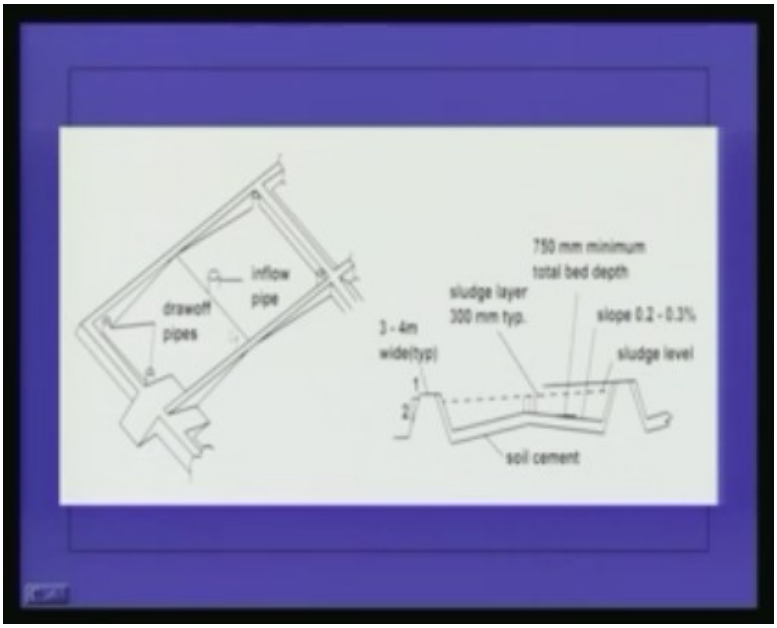

Paved sludge drying beds: This is the sludge layer, it is around 300 mm thick and this is the total bed depth so it will be having a paved surface and this is vacuum assisted one. Here we have the medium and gravel and we are putting the sludge here and with the help of vacuum the water present in the sludge can be removed.

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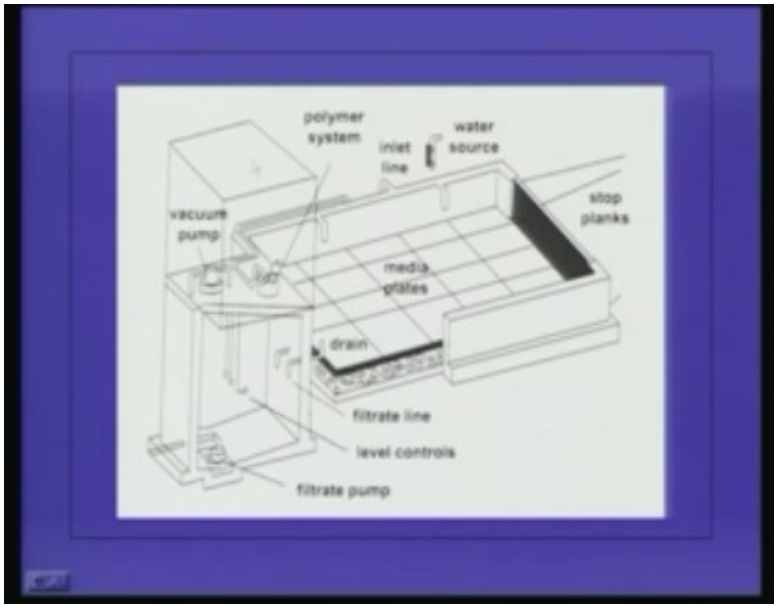

This is the vacuum pump and the filtrate is coming here and filtrate is pumping back. This is a very costly affair so most of the time we are not going for this type of sludge

drying bed. Another method of water removal is reed beds.

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Reed beds can be used and the capacity of the reed beds is around 0.02 meter cube per second and it is constructed using river-run gravel.

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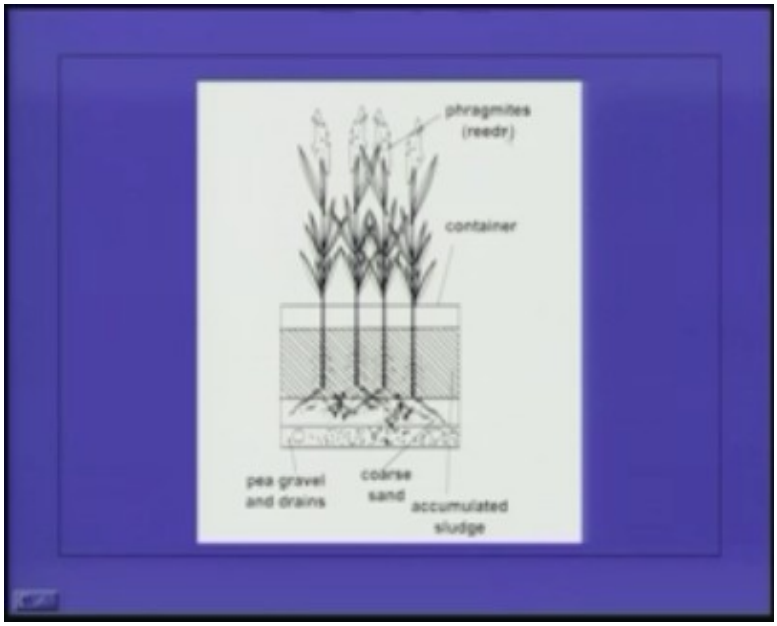

This is a reed bed. Here this is the river gravel and reeds are growing over this one and the sludge will be applied in the top of the reed bed. It is something similar to subsurface

flow wetlands but the difference here is in subsurface wetland the wastewater will be flowing through the subsurface it will never come in the surface. But here the sludge will be applied in the surface. How this reed is helping in dewatering. We can see that the reed is going here and the root zone is this one. So because of this root zone it will improve the water permeability through this media and water from the sludge will be getting removed at a faster rate. This is the fine sand (Refer Slide Time: 20:35) this is the course sand and this is the gravel and here we put the under drains and under drains collect whatever water is coming through the sand and this reed the root zone helps the passage of water. That's what I have written here.

Plants provide pathway for continuous drainage of water from the sludge layer that is the advantage of this reed bed. As I have already mentioned it is somewhat similar to some surface wetlands but the only thing is in subsurface wetlands the waste water will be flowing only in the subsurface but here we are applying the sludge in the top portion and from there the water will be oozing out and it will be getting collected in the under drainage systems.

Another way of removing water from the treated sludge is going for lagoons.
These lagoons can be used for sludges where the dewatering is faster but we cannot go for lagoons if the sludge is chemically treated are aerobically digested. In such cases what is happening is the water holding capacity of the sludge will be very high and lagoons will not be able to perform better in such cases. Now we have to go to the digester and dried sludge is stabilized. In some cases if sludge is containing only organic matter and also hazardous material we can use that as manure or we can use it as a soil conditioner.

But if we are using if you are using the treatment plant for the treatment of industrial waste water in most of the cases what happens is the industrial waste water will be containing lot of hazardous materials. So if you use that sludge as manure or as a soil conditioner some of the hazardous or toxic materials whatever is present in the sludge may not be completely destroyed or degraded. So it will be present in the soil and in some way or the other it will be coming to the living organism or living system either through water or air or soil or even the plants can bi-accumulate those pollutants an once we consume the plants or plant product it can come into our body so it is not advisable to dispose the treated sludge especially that is originating from industrial processes.

In such cases what we do with the treated sludge because the volume will be so high and if you want to dispose them we have to go for land filling and land filling we know that if it is a hazardous material we have to go for chemically secured land fill. That means the usual land fill should be properly lined so that the lechate will not be going out and contaminating the surrounding soil as well as ground water.

In such cases also if the volume of the sludge is very high the process will be uneconomical or it costs a lot. So in such cases we need to reduce the volume of sludge further. For that we go for this incineration. The advantage is maximum volume reduction because in incineration what will happen is this is nothing but the thermal oxidation.

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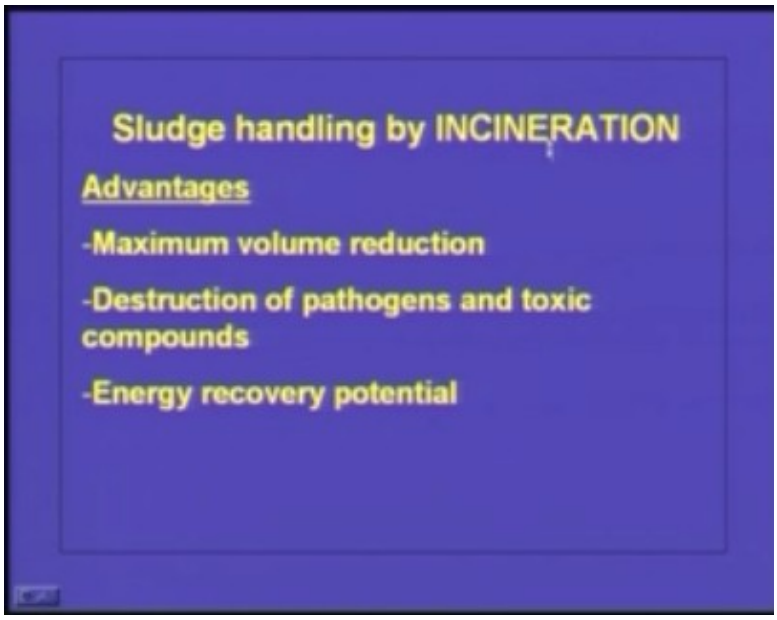

At high temperature whatever is the organic matter present in the system will be getting oxidized and converted to carbon dioxide and water if the process or the system is working with 100% efficiency. Here the destruction of pathogens and toxic compounds are almost cent percent. Moreover, because when we incinerate the solid waste lot of heat energy will be produced and that energy we can recover it and reuse it so energy recovery potential is also there for this process.

The disadvantages are high capital and operating costs. The thing is we have to construct or we have to make the incinerator. How we get the operating cost?
If the fuel is having or if the digested sludge is having high calorific value or high heat content then it will burn by itself. If the heat content of the sludge or the dried sludge is not enough then we have to supply auxiliary fuel for the burning of the dried sludge. In such cases operating cost will be significantly high.

The second one is highly skilled operating and maintenance staff is required because the process requires lot of knowledge about the working of the system so highly skilled labors are required and the residuals produced may have adverse environmental effects and disposal of residuals are also a problem.

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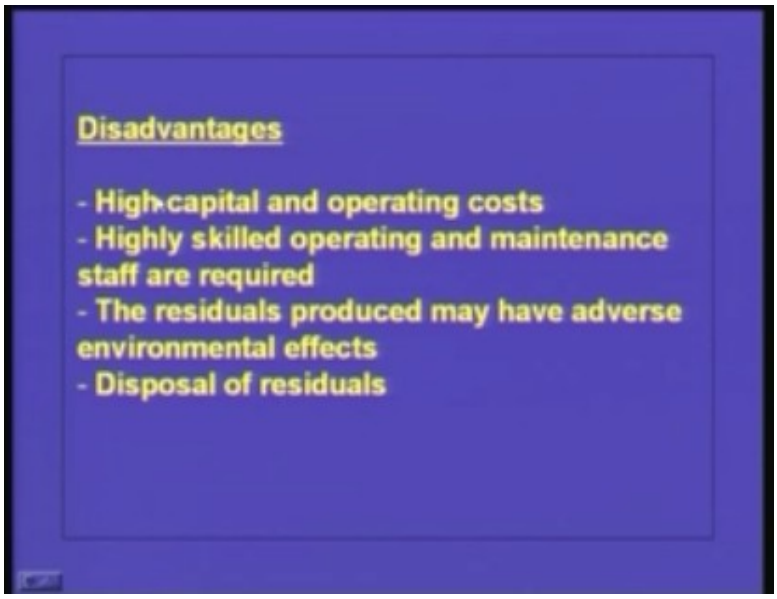

Why the residuals produced may have adverse environmental effects?
I have told already that if the incineration process is hundred percent efficient the byproduct coming is either carbon dioxide water or nitrogen gas or other inorganic gases at some hours. But if the process is not complete or the process efficiency is not hundred percent and if you are not able to maintain the same temperature for the incineration then some of the organic component whatever is present in the sludge will not be getting oxidized completely so, so many byproducts will be generated and some of these byproducts are very very toxic.

For example, we have heard about dioxin and furan. if the sludge is containing chlorine as well as the organic matter and if the oxidation is not completed these type of compounds can be produced and otherwise also the gas whatever is coming or the flu gas whatever is coming from the incinerators will be containing all sorts of pollutants like carbon monoxide, sulphur dioxide if sulphur containing compounds are there and other volatile organic compounds. So we cannot just dispose the gas to the atmosphere that requires further attention.

The ash whatever is coming out of the incinerator will be containing mainly the toxic metals because metals will not be getting oxidized so majority of the metals will be staying in the ash and it will be containing other hazardous compounds also so we cannot just go and dispose this ash so we have to be very very careful about the disposal of the residuals. We have to go for chemically secure land fills otherwise it will create lot of problems. This is what is happening in an incinerator.

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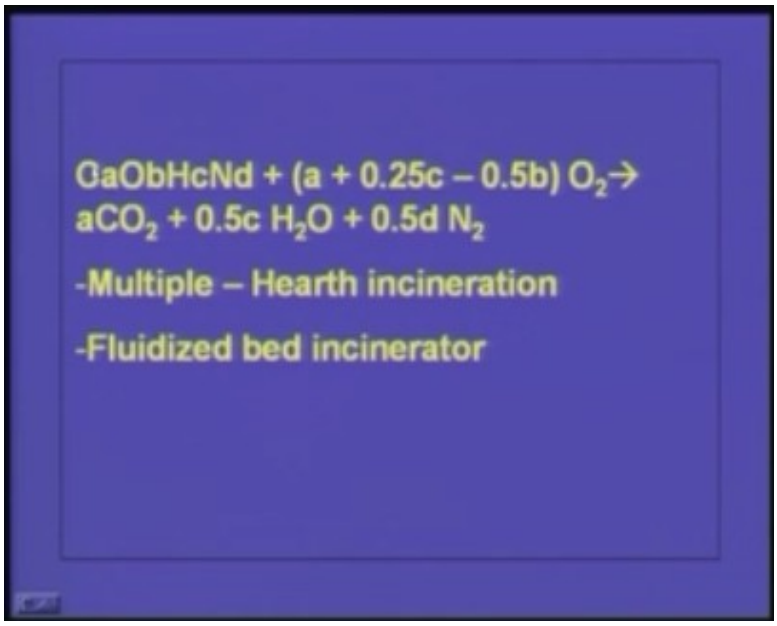

We have organic compound with a) carbon atoms; b) oxygen atoms; c) hydrogen atoms; d) nitrogen atoms and it will be combining with a + 0.25 c – 0.5 b oxygen to form a carbon dioxide + 0.5 c water + 0.5 d N_2 this will be the reaction if the process is hundred percent efficient. Sometimes what is happening oxidation will not be hundred percent efficient so along with carbon dioxide we will be getting other partially oxidized organic compounds. Incinerators are of different types; either we can go for multiple hearth incinerator or fluidized bed incinerator. The incinerator can be used for the handling of treated sludge especially if the sludge containing toxic and hazardous materials. And if you want to reduce the volume of the sludge considerably then this is the best method.

Let us see, the bio solids are there and we have stabilized them dewatered them and dried them and now if it is not containing much of the hazardous material toxic compounds we can use it as a manure or we can use it as a soil stabilizer. So now we will discuss how can we dispose these bio solids in the land.

Application of bio solids to land: That is nothing but spreading of bio solids on or just below the soil surface. This is known as bio solids application to land. And whenever we talk about the land application we cannot just throw away the bio solids to the land without any treatment. First we have to stabilize the sludge then only we can go for land application. If we just throw away the sludge to the land then lot of microbial activity will be there and all other nuisance will be there.

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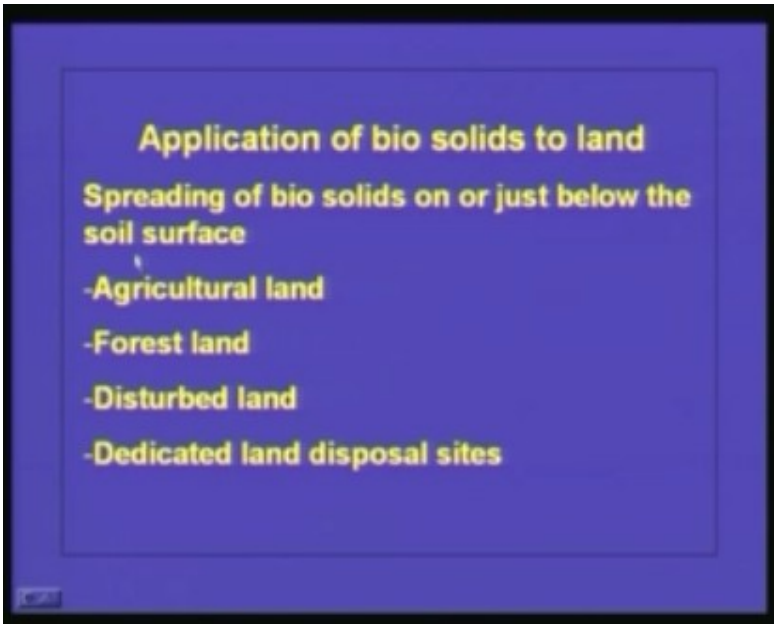

What are the lands we can use for the bio solids disposal? Definitely we can go for agricultural lands, and then we can go for forest land, other disturbed lands or dedicated land for disposal purposes. These are the four types of lands we can use for the bio solids disposition.

What are all the factors to be considered for the site selection?
We cannot select a land and dispose the bio solids there because it will be creating adverse environmental condition. So the topography is very very important because if the land is having a very high slob then what will happen is when we dispose the bio solids there and when rain comes everything will be coming out and it will be disturbing or polluting the water bodies, so the topography is also an important factor to consider.

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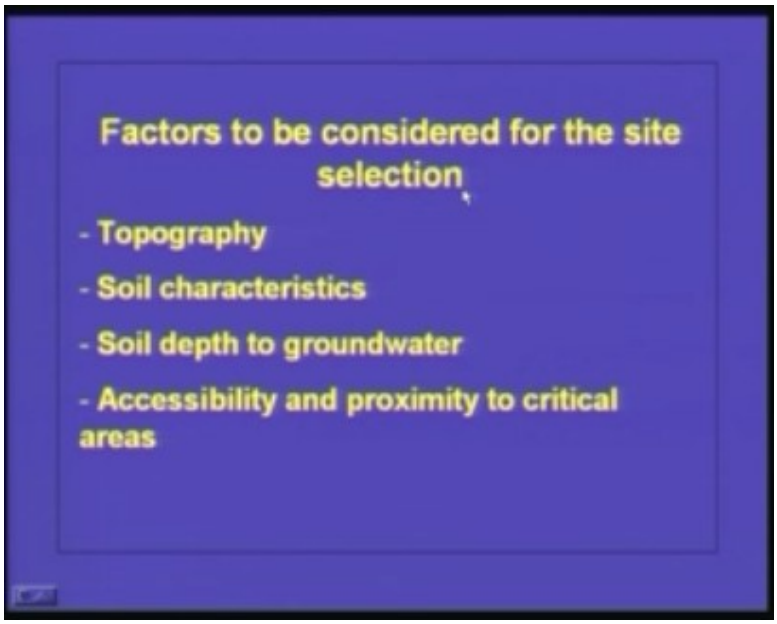

Therefore we can go for lands up to fifteen percentage slob. If it is a forest land and proper measures are taken for the holding back of the sludge we can go up to a slob of 30 percentage.

The soil characteristics are very very important. The soil should be highly permeable. If it is a clayey soil and if you go and dump the bio solids there then whatever moisture content is present in the sludge it will not be able to go through the soil so everything will be remaining there and it will not even get dried properly. Therefore, soil characteristics are very very important when we decide or when we select the site for this bio solid disposal.

Another one is soil depth to the groundwater. A minimum of 0.06 m depth is essential otherwise the lechate whatever is coming from the bio solids will be containing lot of organic matter, organic nitrogen, other nutrients like phosphate etc and heavy metals and inorganic salts so everything will be coming and it will be entering in the ground water if it is very close to the disposal sites so definitely it will be polluting the ground water. Therefore it is always essential to check the depth of the soil available between the application point and the ground water.

The next one is accessibility and proximity to critical area. If we are going to dispose the solids in some place and if it is very close to any residential area or any important highway or any sensitive buildings or sensitive areas then it is not acceptable so we have to select the site in such a way that it is far away from all the critical areas or sensitive areas. These are the factors we have to consider when we select the land for bio solids disposal.

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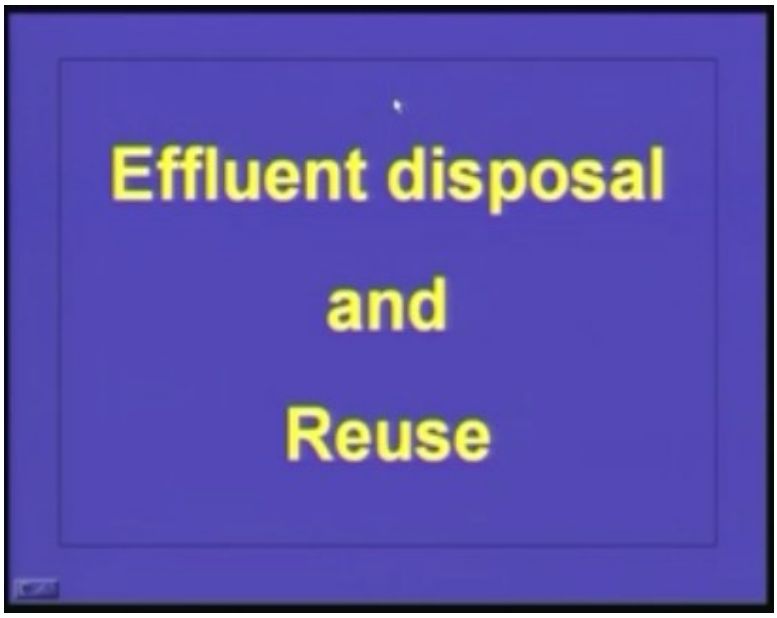

Till now we were discussing in detail about how to handle the solids generated in the water or waste water treatment systems. We have also seen what all are the different sources quantities characteristics etc in detail and we also discussed in detail how we can handle the bio solids or how we can treat the bio solids and what are all the different disposal methods.

Now we will see how we can dispose off the effluent whatever is coming from the treatment plants especially the waste water treatment plants because none of the treatment processes are able to meet 100% efficiency but around 90 to 95 percentage depending upon the process and the nature of the waste water so definitely the effluent coming out of the waste water treatment plant will be having some organic matter, some inorganic compounds and even some toxic compounds. Therefore, let us discuss about what we have to do with this effluent, where we can dispose it off and what is the effect of this disposal on the existing water bodies.

Most of the time water scarcity occurs in most of the places so if we can reuse the treated water in some where or the other that will be more economical. So we will be seeing all these aspects in detail. We will see what all are the things we have to consider or what is the thesis behind or the fundamental behind the land application or the effluent disposal methods. When we talk about the treatment plants the treatments plants remove as much pollutants as possible but the ultimate disposal of wastewater is by dilution in receiving water bodies that means rivers, lakes and oceans or by discharge on land or desert areas or by evaporation into the atmosphere and seepage into the ground because these are the most commonly used or these are the three common methods for the disposal of waste water.

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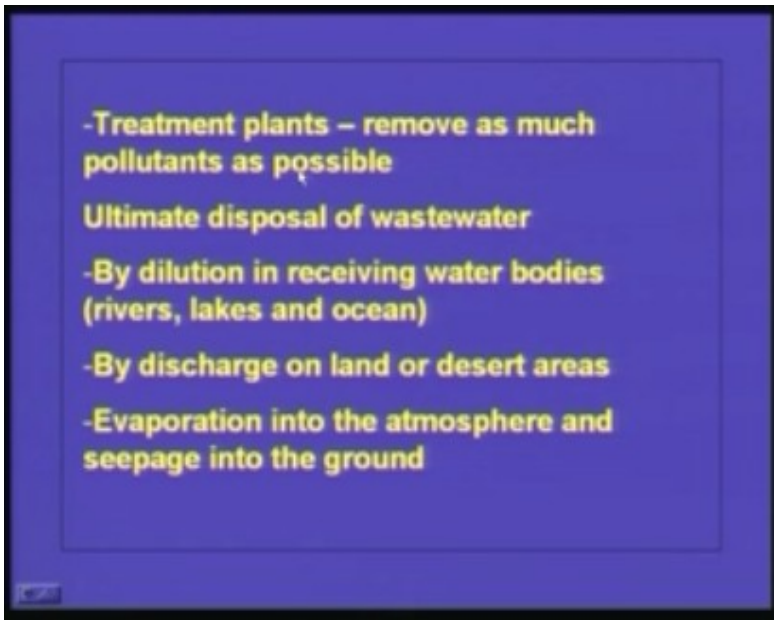

The dilution in receiving water bodies that is rivers, lakes and ocean is the one that is most commonly practiced and the other one is discharge on land or desert areas as irrigation water and the third one is evaporation into the atmosphere and seepage into the ground water recharge. We will see each process in detail and the most common method is disposal into large water bodies.

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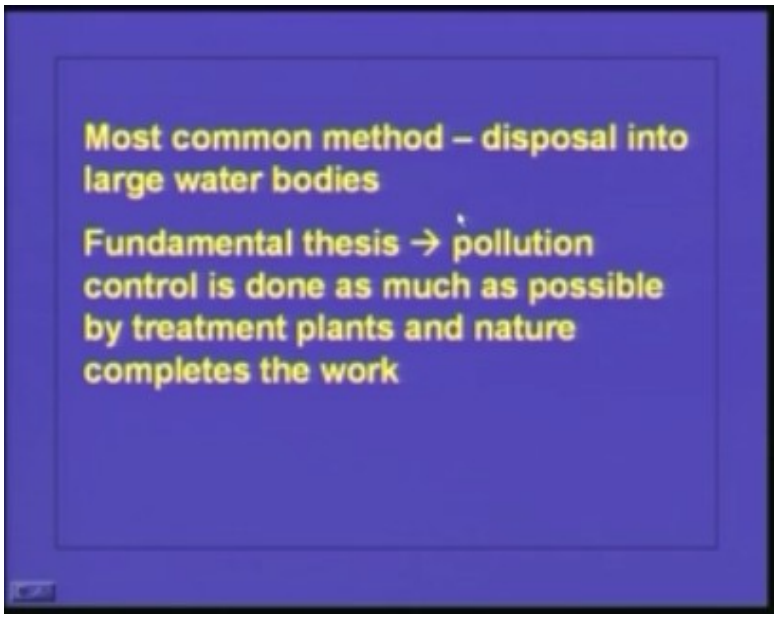

What is the fundamental behind this one?
The pollution control is done as much as possible by treatment plants and the nature completes the work. I have already told that the treatment plant is not able to take care of

100 percentage of the pollutant whatever is present in the waste water so most of them around 90 to 95 percentage is taken care by the treatment plant and the remaining whatever is coming we are disposing it to the large water bodies so the lechate with its various processes will be completing the treatment work.

The amount of natural or self purification: Depends on the flow rate or volume of the water body where we are discharging the waste and oxygen content of the water body.

The next one is ability to re-oxygenate itself. If you want to discharge the treated water to the water body we have to see what is the flow rate and volume. If you have a high volume of treated water and the receiving body volume is very low then if you discharge this high volume of treated effluent from a waste water treatment plant to the existing water body its quality will be deteriorating. In other ways if the treated effluent volume is less compared to the water body then when we discharge to a huge water body it will be getting diluted and its effect on the existing system will be very less.

The second one is oxygen content. We know that the treatment plant will be removing most of the organic matter present in the waste water and remaining will be coming along with the effluent. So when it goes to the existing water body definitely it will be exerting an oxygen demand because micro organisms will be present there and organic matter is there and it will always have a tendency to biodegrade or micro organism will be utilizing them and converting them to new cells and carbon dioxide and water so for this purpose oxygen is required. If the water body is able to supply the oxygen then the treatment will be very very fast and the water body oxygen content will not be falling down below the permissible limit so oxygen content of the receiving water body is very very important.

The next factor is any way when we discharge the waste water it will be utilizing the oxygen present in the water body so there will be air replenition or a decrease in the dissolved oxygen concentration in the water body. But if the water body is able to regain the dissolved oxygen at a faster rate, because the water body is always in contact with that atmosphere we all know that in the atmosphere around twenty percentage of oxygen is there so there will be always a mass transfer of oxygen from the atmosphere to the receiving water body. So, if this transfer is at a faster rate compared to the oxygen utilization by the micro organism then definitely the dissolved oxygen level of the stream will not be going down. That is what we have written here.

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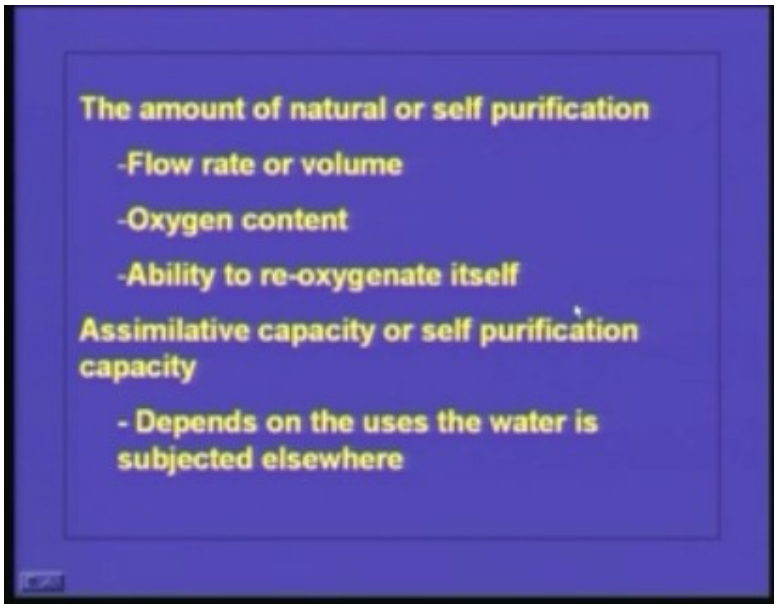

The flow rate and volume oxygen content and ability to re-oxygenate itself are important whenever we consider a water body for the effluent discharge. All these things together we call as assimilative capacity or self purification capacity of the stream. That means we are putting the waste to the stream and by dilution and by physical, chemical and biological process the stream can take care of the pollutant coming to the system and meanwhile because of the re-oxygenation from the atmosphere the stream will be regaining its initial conditions so that is the assimilative capacity of self cleansing capacity.

If we are loading the pollutant more than this assimilative capacity or self cleansing capacity of the stream then the stream itself will get polluted. For example, if you talk about Ganga or Yamuna we know that the flow rate of those rivers is very very high. But so many big cities are situated on the banks of the rivers so most of the cities are discharging treated and untreated effluent to the streams and the stream is having high self cleansing capacity but the quantity of waste whatever coming to the stream is so high compared to its own self cleansing capacity so what is happening is the quality of the stream is deteriorating as it flows and once it meets the ocean it is just like a seaward canal or something like that.

Similarly we can see in south India especially in Tamil Nadu we can see that many rivers are just acting as waste water carrying canals that's why whenever we discharge the effluent to any existing water bodies we have to see what is the self cleansing capacity of the system. If you go beyond that one the system itself will be failing and the quality of the water will be coming down.

How can we decide the self cleansing capacity?
The self cleansing capacity we are measuring or we are deciding depending upon the uses of the water subjected elsewhere. For example, we are discharging the treated effluent to a stream and just in that downstream of the river the water is taken for drinking purpose

so the effluent quality or the raw water quality required for drinking purpose is very very high. So, in that way the self cleansing capacity of the river is less because we cannot pollute the river more than a specified limit but if the river water is only used for navigational purpose the standard or the water quality standards set for that is much above the drinking water or the drinking water standard is much stringent compared to the navigational water quality standards. So depending upon the downstream used the self cleansing capacity will be varying. We know the standard the receiving water should maintain that decides the assimilative capacity or self cleansing capacity.

Whenever we talk about the effluent standards any treatment plant when we design we have to make sure that the treated effluent is meeting the effluent discharge standards. How are we setting up the effluent discharge standards?

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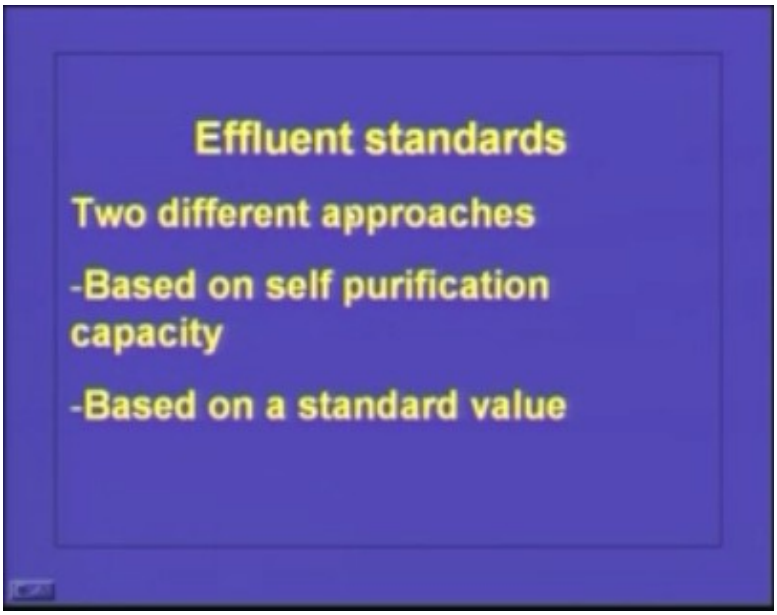

There are two different approaches. One is based on the self purification capacity and another one is based on a standard value. In India we are following the second approach based on a standard value. In first approach if the receiving water body is having a high self cleansing capacity why we want to spend so much of money for treating the water in treatment plant. If the river or stream itself can take care of most of the treatment then we can reduce the treatment cost in the treatment plant. and if not many industries or not many waste treatment plants are situated along the bank of the river then only a very little quantity will be going to the stream so if the quantity is less then the river can take more pollution load or pollutant load. So, depending on that one, we can decide the extent of treatment required because the total load going to the river should not exceed the self cleansing capacity. But it will become very very difficult. If many industries are there then we don't have any control over them.

In some of the European countries they still follow the effluent discharge standards based

upon the self purification capacity. Now we will discuss in detail about the disposal of effluent into the rivers. Here is a famous statement by Earle B. Phelps.

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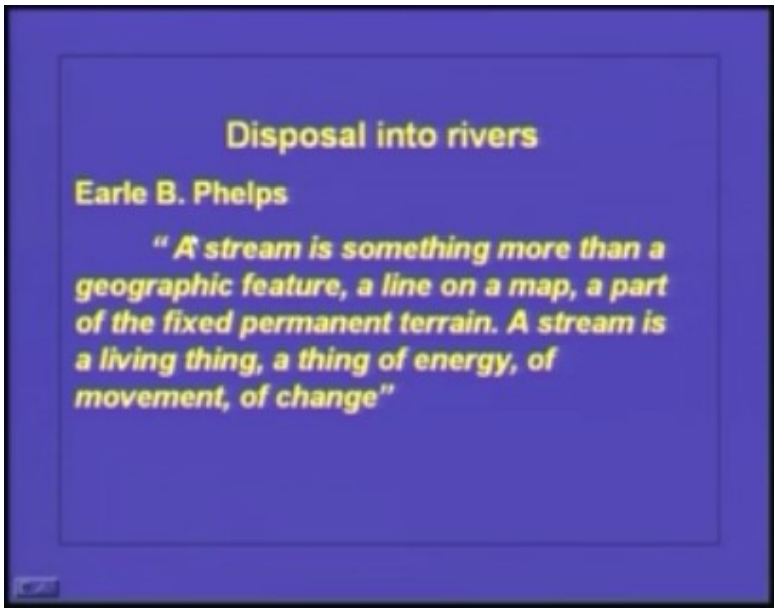

A stream is something more than a geographical feature, a line on a map, a part of the fixed permanent terrain. A stream is a living thing, a thing of energy, of movement, of change. This shows how important a river is and if you see the history we can see that most of the old civilizations generated and survived on the banks of the streams. And if you come back to the rivers they serve as drainage channels for large areas and because of this one what is happening they are subjected to pollution and because of their self cleansing capacity or assimilative capacity they are able to take care of a certain extent of pollution.

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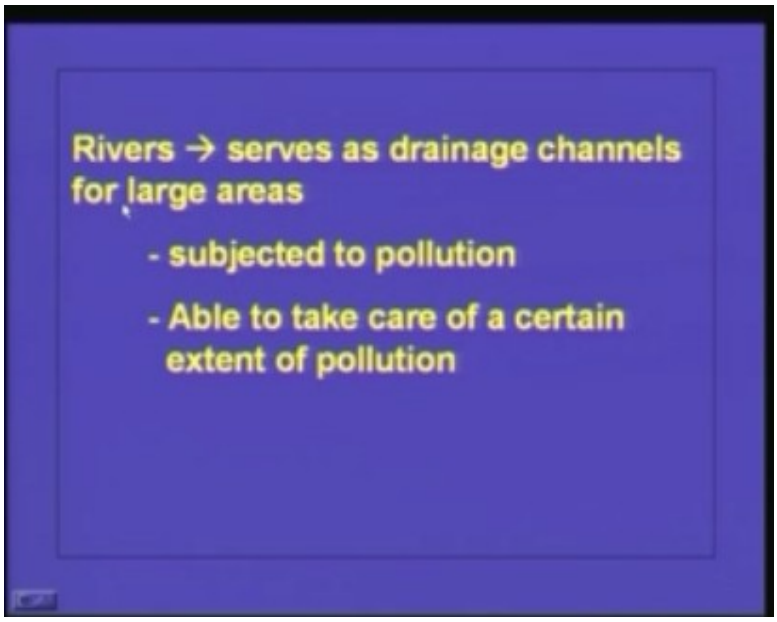

It is not that we cannot discharge the effluent to the streams but whenever we discharge the effluent we have to see what the assimilative capacity of the stream is. We should not overload the streams. Now we will see response of streams to biodegradable organic waste.

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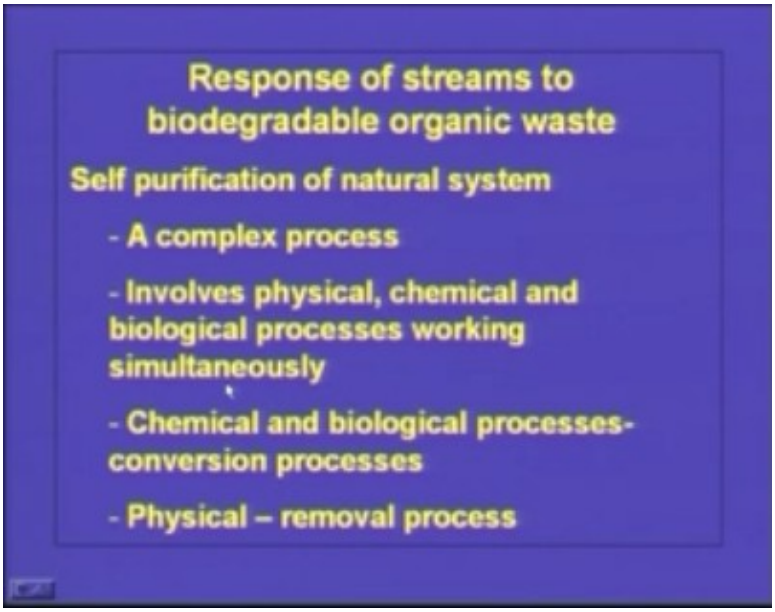

Most of the treatment plants especially when we talk about domestic waste water treatment the treated effluent will also be containing lot of organic matter which are biodegradable. If it goes to the stream what will happen to the streams? Definitely self purification will be taking place so the self purification process will be taking care of a

portion of or the completely biodegradable organic matter present in the effluent. And this self purification process is a complex process. It involves physical, chemical and biological processes working simultaneously.

We were discussing about what are all the physical, chemical and biological process involved in water and waste water treatment. So definitely all those processes will be taking place in nature also. But in treatment plants what we are doing is we are engineering the natural process so that the rate of the process will increase and we can attain treatment efficiency, high efficiency in a short period or small reactor volume, that is the basis of al these environmental treatment processes.

Therefore, all these things are either a physical process or a chemical process or a biological process or a combination of all these processes. In chemical and biological process what is happening is conversion of pollutant is taking place and in physical process removal is taking place. In biological process it is conversion because the organic matter is getting converted to something else and in chemical process also what happens is they are changing the nature of the pollutant. This is what is happening in most of the chemical processes so conversion takes place. In physical process removal takes place by physical forces.

We have discussed in detail about the sedimentation, aeration, floatation etc so there the pollutant is getting removed from the system because physical forces. When we talk about the stream or a river the self purification process can be modeled based upon the fact that if you know the waste characteristics and system variables of water bodies.

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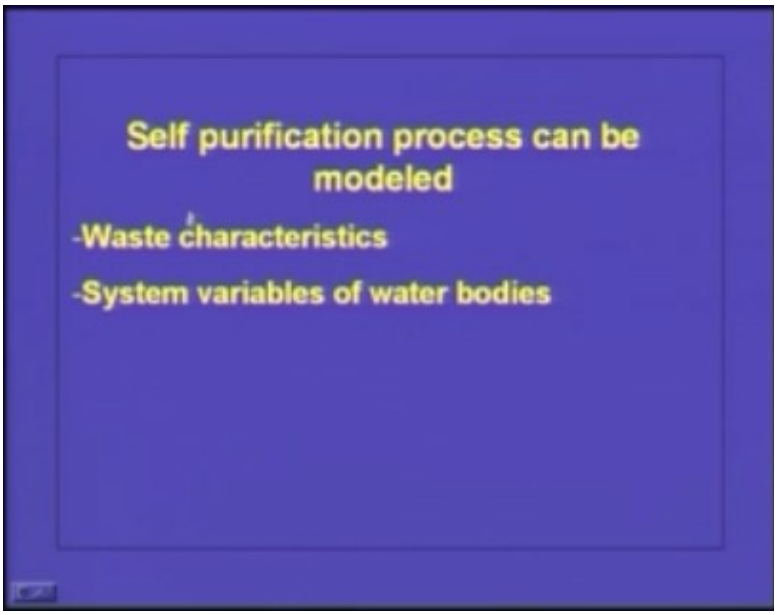

If you have the waste water characteristics and system variables of the receiving water body we will be able to model the self purification process. Now we will see that one in

detail. The most important single parameter of any stream is the dissolved oxygen content. Because if the dissolved oxygen content of the stream is less that means the stream is polluted. When the dissolved oxygen pollution can go down?
If more and more organic matter is present in the stream so definitely microbial activity will be there and micro organisms will be utilizing the organic matter in presence of oxygen and converting that into carbon dioxide and water. So, if the microbial utilization of oxygen is at a faster rate compared to the re-aeration of the stream then the dissolved oxygen concentration of the stream will be reducing. That is what I have written here.

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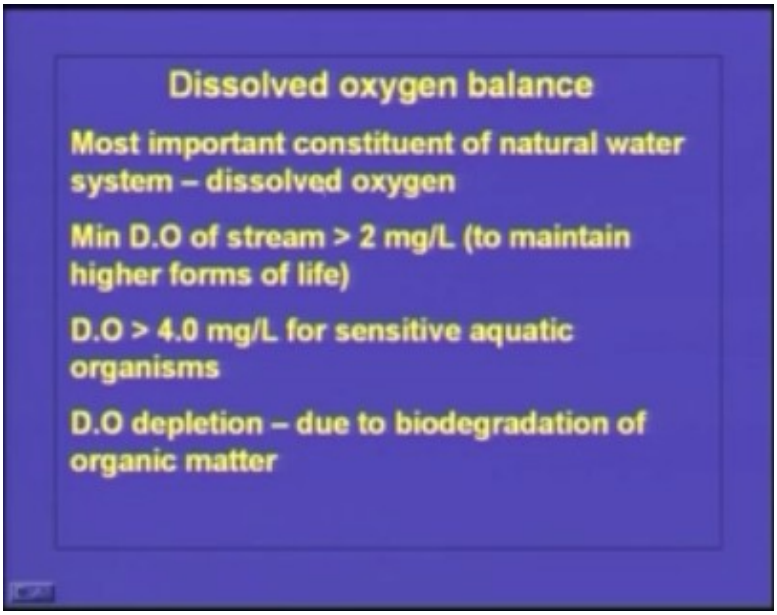

The most important constituent of natural water system is dissolved oxygen and a stream should have a minimum dissolved oxygen of 2 mg per litre to maintain higher forms of life an dissolved oxygen should be more than 4 mg per litre for sensitive aquatic organisms. The dissolved oxygen depletion is taking place due to biodegradation of organic matter. So, if you want to see the rate of oxygen utilization it is a function of the quantity of organic biodegradability or the quantity of biodegradable organic matter and the dilution capacity of the stream. If the stream can dilute them then the oxygen utilization rate will be less. Now we will see what are the processes contributing oxygen to surface waters.

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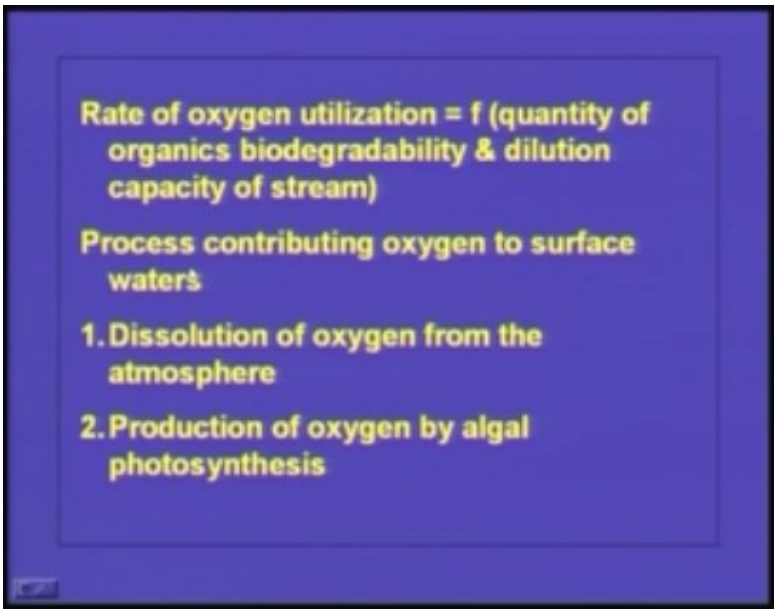

We have seen that the organic matter is responsible for depleting the dissolved oxygen whatever is present in the stream. What are the processes responsible for providing oxygen to the stream?
This is very important otherwise what will happen is within a short period whatever oxygen present in the stream will be getting consumed and the stream will be going to an anaerobic condition very fast. But we all know that that will not happen in a stream because the stream or the water is always in contact with the atmosphere and from the atmosphere oxygen transfer is taking place. So the process contributing oxygen to surface waters are dissolution of oxygen from the atmosphere because high concentration of oxygen is present in the air and if the oxygen concentration in the stream is less because of that high concentration gradient the oxygen will be getting solubilised in the water.

The second process is production of oxygen by algal photosynthesis. We have seen this in detail when we were discussing about oxidation ponds. What is happening in an oxidation pond?
The bacteria was utilizing the organic matter and consuming whatever is the oxygen present in the system. But algae will be using the carbon dioxide generated by the bacteria and do the photosynthesis reaction and as a byproduct oxygen will be liberated. So this algal photosynthesis will liberate oxygen and that will be increasing the oxygen concentration of the receiving streams.

Now we will see what this re-aeration is or how the re-aeration is happening?
Re-aeration is nothing but the oxygen whatever is present in the stream is getting utilized by the micro organism so we want to re-aerate it. So, what are all the factors that decide the re-aeration is we will see. In most of the streams we usually neglect the oxygen or oxygen coming from algal photosynthesis. What is happening in most of the streams is there will be high turbulence and this algae will not be able to grow under high turbulence so the contribution of oxygen by algal photosynthesis will be very very negligible compared to the oxygen or re-aeration from the atmosphere. So the dissolved

oxygen model will only consider the re-aeration from the atmosphere not the oxygen coming from the algal photosynthesis.

If you want to find out the driving force or the D oxygen deficit how can we find out? Oxygen deficit is the amount of oxygen or the difference in the oxygen concentrations. If you want to find out oxygen deficit you can use this formula; D is equal to Cs minus C.

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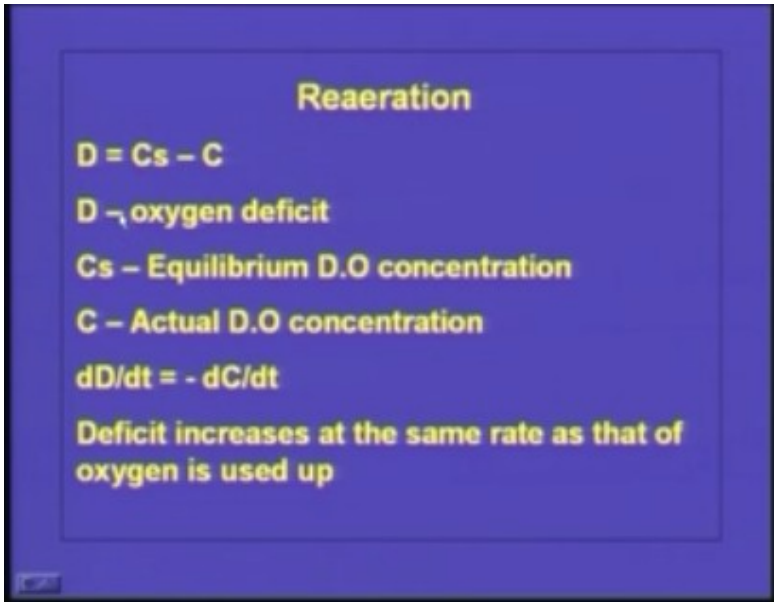

Cs is equilibrium, D.O concentration and C is the actual dissolved oxygen concentration and the rate of change of this oxygen deficit is equal to dD by dt that is equal to minus dC by dt. Or in other words we can tell that deficit increases at the same rate as that of oxygen is used up. So this is the concentration of oxygen present and this is the saturation concentration (Refer Slide Time: 54:27).

For a given condition what is the maximum dissolved oxygen concentration the stream can have? That is the Cs value so definitely the deficit is nothing but difference between the saturation concentration and existing concentration. So we can find out the rate of change of deficit also that is equal to the rate of change of concentration.

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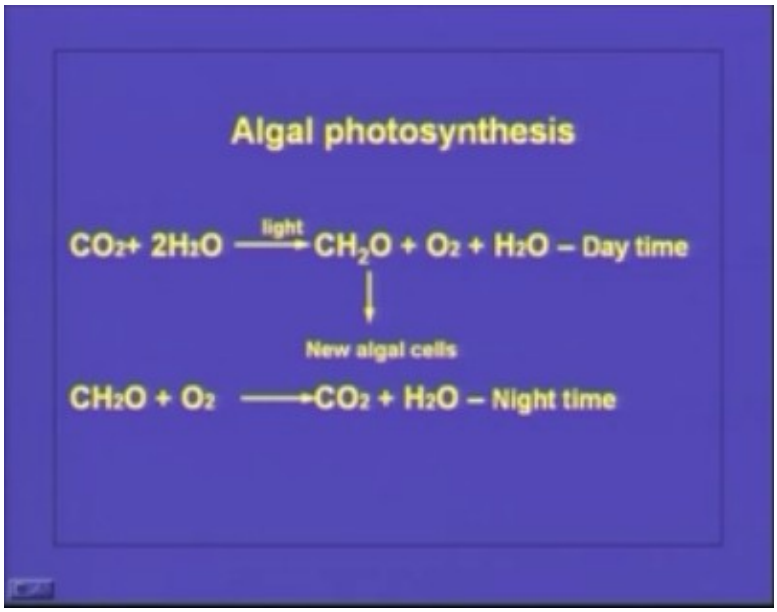

This is algal photosynthesis reactions. This we have discussed earlier also. Carbon dioxide plus water in presence of sunlight new algal cells and oxygen and water, this is the reaction happening in day time and we all know that at night time since the sunlight is not available photosynthesis will not be possible. So during the night time the algal will be utilizing oxygen for the respiration and that also will be creating carbon dioxide and water. this we have discussed in detail as how the oxygen concentration and the pH of a system especially the oxidation pond where algal bacterial symbiotic activity axis vary, how the oxygen concentration and carbon dioxide concentration or the pH of the system vary during day time and how it is during the night time.

During day time definitely the oxygen concentration will be high but night time both the bacteria and algae will be utilizing the oxygen so the oxygen concentration will be less.

Now we in see in detail what all the things we have discussed today.

We were discussing about the sludge treatment or bio solids treatment and we have seen the difference between bio solids and sludge. Bio solids are the one which after the treatment will be having some beneficial use. In most of the cases it is like that. Especially if it is organic sludge we can use it as a manure or soil conditioner. But the raw sludge will not be able to use it because if you put it, it is containing lot of active micro organisms, pathogens and lot of organic matter which is prone to bio degradation so we have to treat the sludge.

We have also seen what are the different treatment steps involved?
First one is pre-treatment. That means grinding, degriting, blending, storing etc,
then we have to go for dewatering then stabilization then conditioning and we have also discussed how we can dewater the sludge and if you want to go for volume reduction what all are the different methods commonly used. Most commonly we go for incineration and it is practiced mostly for industrial bio solids or industrial solids because

that will be containing in most of the cases some hazardous material or toxic compounds so it is not advisable to just dispose them in the land.

Now we are discussing in detail about the effluent discharge because the treatment plant is not able to meet hundred percentage of the pollutant removal so the treatment plant we design in such a way that it will be removing as much pollutant as possible and the remaining thing will be either disposing it to large existing water bodies for example rivers, lakes or ocean or we can dispose it into land or we can put it in soil where the seepage and ground water recharging will be taking place. These are the three common methods mostly used for the effluent discharge. And among these three methods the most commonly used one is discharging the treated effluent in existing water bodies.

We were discussing that if we want to discharge the treated effluent to a water body we should be aware about the self cleansing capacity or assimilative capacity of the water body. If we put organic loading or pollutant load more than the self cleansing capacity or assimilative capacity of the existing stream the stream water quality will be coming down and more over assimilative capacity is calculated based upon the downstream use of the water from that river. If it is for drinking water purpose then definitely assimilative capacity will be less and if it is for navigational purpose the assimilative capacity will be more.

We will see the dissolved oxygen model in a stream in the next class.