Physico-Chemical Processes for Wastewater Treatment
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Lecture 15
Aeration - IV

Good day everyone and welcome to this lecture. We have studied in the previous classes, regarding the treatment of water and wastewater and among different units which are used for the treatment of water or wastewater depending upon the designated use, there are various types of units possible.

So, first we studied the flow equalization basin, thereafter, we are studying the aeration unit and in the previous classes, we studied how to determine the solubility of the gases in the water then thereafter, we determine the oxygen transfer rate that how the oxygen is transferred from the gaseous section to the water and within that, what is the oxygen transfer rate, what is the oral mass transfer rate and what are the various resistance cells which are there during the transfer of gas from the gaseous phase to the liquid phase. So, this is there and we studied regarding this.

Mostly air is used for aeration. So, we are more concerned about air as compared to other gases and within air oxygen is our primary thing for which most of the aeration things are performed. Now, for removing aspect that the chemicals or VOCs which are generally removed or oxidized by aeration, they include a number of components and many of these are like volatile organic compounds.

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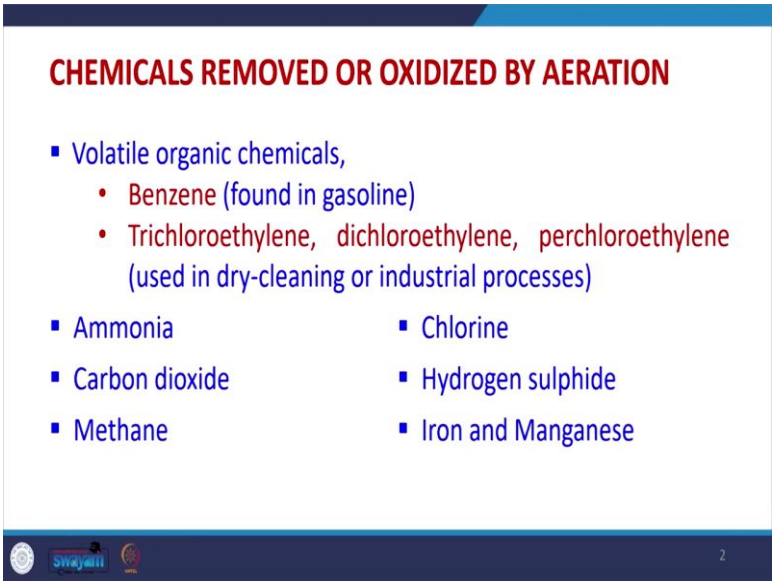

So, they are not in gaseous form as such, but they are highly volatile. So, like benzene, xylene, toluene, if that goes into the water and then it is highly volatile and carcinogenic also. So, we always want these volatile organic compounds to be removed from the water phase. Similarly, a trichloroethylene, dichloroethylene, perchloroethylene, which are very common chemicals used during dry cleaning or industrial processes, they are also have to be removed.

Similarly, many types of gases like ammonia, carbon dioxide, methane, chlorine, hydrogen sulphide, all these gases we want to remove out of the water and for that we use the aeration. So, that if their concentration is higher, so, it will be reduced to its maximum solubility limit, so, what is desirable.

Also iron and magnesium can also be removed via aeration process, because of the change in pH conditions and also their hydro, how much attachment is there with respect to hydroxyl group that depending upon that, there is iron and manganese and some other elements may also get removed or get settled. So, this is possible during aeration. So, this is the target and that is why we use the aeration.

Now, going further aeration can be performed in different types of units. So, it is possible to perform aeration using different types of aerators and some of them are like they can be classified into different categories. So, one of the basic classification is like diffused or submerge aeration in which actually the aeration unit is inside the water itself and from there actually the air is being diffused or pure oxygen may be diffused at depth and it will come out in the form of bubble and that bubble will rise and finally, it will collapse.

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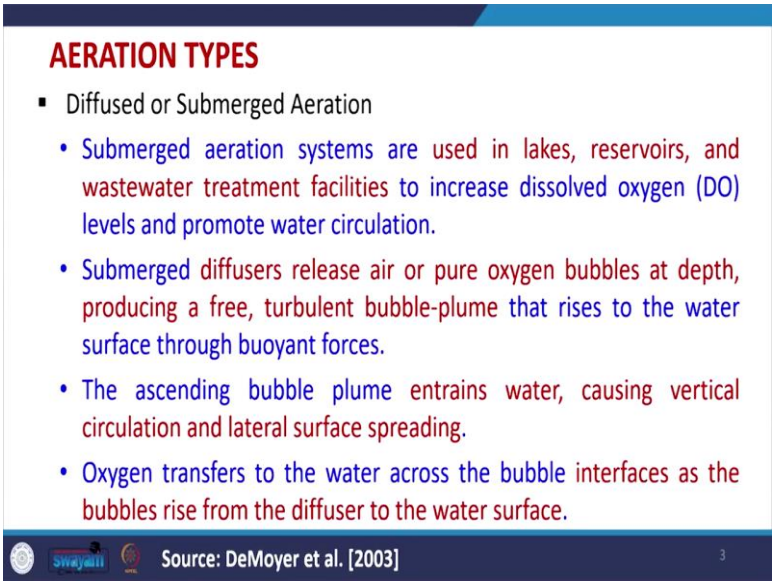

So, this type of unit is very highly used in lakes reservoirs as well as in during the treatment plants also. So, submerged aeration systems that are used in lakes reservoirs or wastewater treatment facilities to increase the dissolved oxygen, levels and promote water circulation, it is this is called submerged aeration systems.

Now, within submerged aeration systems or diffuser what they do is that they release the air or pure oxygen bubbles at depth, depth is highly it may vary. But generally, we want depth not to be more than 15 feet because beyond that the cost increases and there is a problem with respect to saturation and other things.

So, depth is generally taken around 15 feet or less. So, this is more profitable because the cost of pumping of air is not high. So, it produces during the pumping of air the it produces a free turbulent bubble plume that rises to the water surface through the wind surface and that is how it treats the water. Now, ascending bubble when the air bubble rises up actually it entrance the water and which may contain the toxic pollutants also, and where the DO level is low also that this is also possible.

So, summarization is more common for maintaining the DO if it is less and it also causes vertical circulation and lateral surfaces predict during ascending of bubble which rises up from a depth. And oxygen transfers to the water across the global interface as the bubble rises from the diffuser to the water surface. And during this whole process, the aeration happens. So, this is very, very common.

Then the spray aeration we have seen like fountains are there and fountains are very common. So, they are also aeration may happen. So, it is like a spray aeration. So, spray aeration actually removes the low levels of volatile contaminants if present. Also it may oxidize any low level of pollutants present in the water also, so this is possible. In spray aeration system water enters through the top of the unit and emerges through a spray head in a fine mist and that the treated water is collected in a vented tank below the spray heads and so, this way we can treat the volatile contaminants are released and vented to the outside from the water itself this is possible through. Then there are water fall type of aviation units and they involve flow of water over a certain media. They may be packed bed type of units also. So, this is possible through this water fall type of aeration systems.

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- Spray aeration
  - Spray aeration removes low levels of volatile contaminants.
  - In a spray aeration system, water enters through the top of the unit and emerges through spray heads in a fine mist.
  - Treated water collects in a vented tank below the spray heads.
  - Volatile contaminants are released and vented to the outside.
- Waterfall type of aeration
  - It involves the flow of water over media forming droplets or thin film of water so as to contact with air.

Source: Bar-Zeev et al. [2012]

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Aeration in CETP

Diffused aeration

Surface aeration

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Diffused Aeration in Nainitaal Lake, Uttarakhand, India

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So, we will discuss these in detail for the before going ahead will like these are the common you can see here, the aeration units in CETP is our effluent treatment plants. So, you can see here, we need there must be some diffuser installed. So, that is why the air is coming out. So, we can see our circulating things which are there, so these are different diffusing diffuser aeration units may be installed here in this.

Similarly a surface aeration using a centrifugal aerator is shown here. Some froth formation is certainly taking place, but here the main unit is there and that is centrifugation thing and through that a lot of turbulent mixing is also happening and aeration is also happening. So, both ways the aeration is possible. Now, we will discuss some of the things which are related to how to find out the number of units to be installed. So, these diffusion units in a treatment plant or in a lake or reservoir, how to determine the number of units which unit has to be selected.

So, all some of the aspects we will try to discuss in this. Now, diffused if you go to Nainital Lake which is like a very touristic place in Uttarakhand state where we are IIT, Roorkee. Nainital Lake if you go you can nanny lake is like this from the distance we always see like this, but within this naini lake a lot of diffused aeration systems have been installed. And these systems are like this you can see the plume is there with respect to these diffusers which have been installed inside the naini lake.

So, we can see here, here also we can see in this picture, this lake and here also. So, these diffusers have been installed for a number of reasons. Before the installation of these diffusers, there are a lot of problems in the naini lake and the restoration has happened because of the installation of these aeration units, diffused aeration units in the Nainital Lake which is there.

So, now the environmental issues in general which may happen in any lake or reservoir. So, these may be algal plume. That may happen because of various reasons including nutrient which may be there. So, we need to control the nutrients also. Algal plume may happen also because of water scarcity, a bottom oxygen starvation is very common in lakes, if the lake has lot of depth and so, oxygen may not be available at the bottom.

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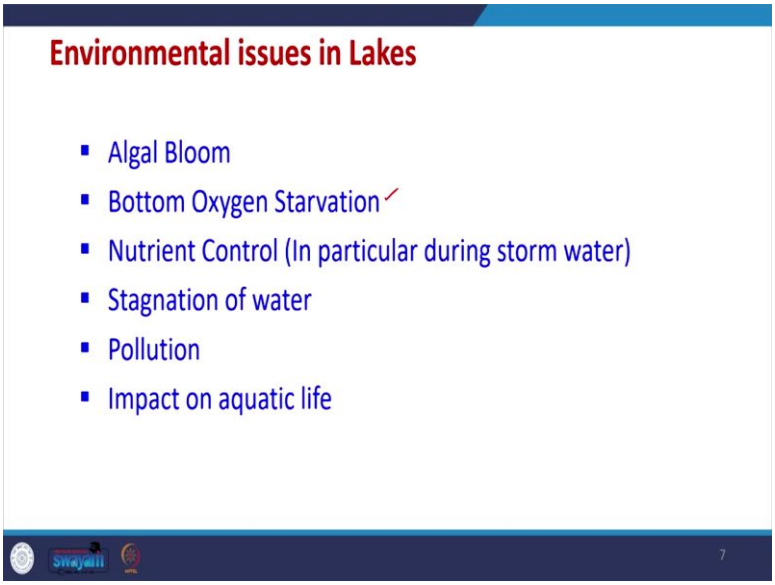

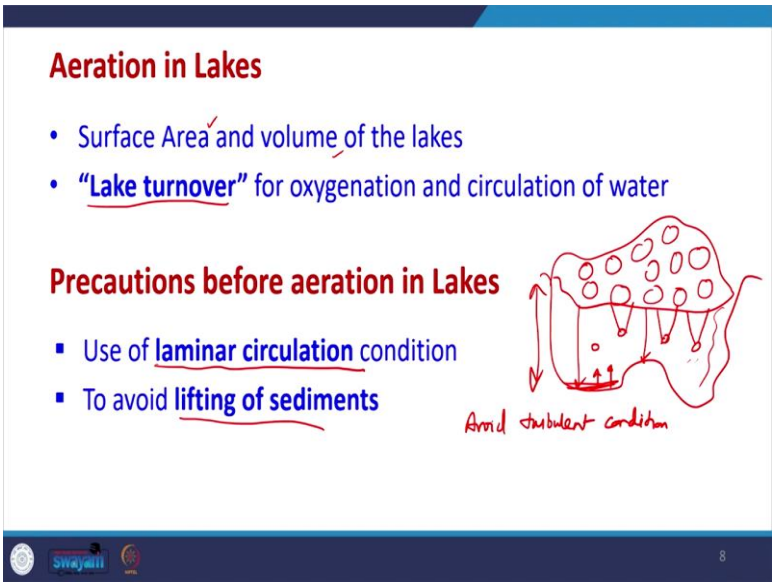

So, all any aquatic species will never go to the bottom because it will not get that much amount of oxygen. So, this is a possible. Also in many other lakes in particular in tourist places it in the municipal corporations generally do not allow any water to go into the lake in normal condition. So, any hotels and other things which are there in the periphery of the lake, they are not allowed to discharge any of the water into the lake.

But, there is a high possibility during a storm, any rain water and other things when a storm water is there, it may go into the lake. So, that will cause problem because it will take with it some nutrients and that will cause problems, so, this is there. Also in the lakes because they are like batch type of systems we virtually know CSTR approach that means, there is no

steering or mixing going on as such except at the surface. So, all the water is stagnated. So, mixing is not happening that much except via the temperature variation.

So, normal mixing very slow mixing may happen a little bit otherwise it will not happen that much and so stagnation of water is a big issue. Also some if any pollution source or anything is there that may be there in the lake and overall these parameters affect the aquatic life inside any lake. So, if aquatic life is not there, the lake will slowly and slowly die. So, for any tourist place, which has a lake, so, many cities are there in Rajasthan, MP, UP, Uttarakhand most of the states, so, they have lakes and they have lots of tourist activity and businesses because of that lake.

And if that lake dies, then there is a problem. So, how to revive all these things. So, one of the common answer is to perform aeration, so that you can avoid the algal plume, if proper aeration can be done. So, bottom oxygen is starvation, which may happen if we not be there, because we can miss the oxygen at a certain depth also. Nutrient control can be performed a little bit because we are continuously mixing and oxygenating also, so, this is there.

Since aeration is being done. So, during aeration there is always a mixing also. So, a stagnation of water can be taken also some amount of pollution load will be removed, because all these things will be oxidized also, because we are discharging air inside and certainly the overall the aquatic life will improve. So, lake quality will also improve. So, that will become more lively and it is correlated to tourist activities will increase.

Now, within aeration in lakes, there are certain calculations which are very important. So, for finding that, how many aeration units are required, diffused aeration units are required? There are certain, so, for that the first and foremost thing is that what is the area and what is the volume of the lake? Also, we should have it topography also.

So, suppose this is the depth of certain lake and from the top it may be like this and this is the depth. So, we should have a detailed topography of the, that where is the maximum depth, where is the minimum depth and what is the possibility of his leg nation of water at certain locations.

So, that these things have to be analyzed before when before installing these aeration units at certain depths, so that the plume rises and there is a proper mixing which happens. So, this is the possibilities of plume when plume will rise again it will cover this material. So, we will install this aeration or aeration unit in such a manner that whole of the lake gets covered and

also because mixing is happening so, whole item mixing is also proper all throughout the lake.

So, we want to convert the stagnated lake into a continuous mix estate type of lake where proper turnover of the water is there and circulation and oxygenation is proper and whole of the water has very good amount of DO with respect to saturated DO. So, there is a term which is called Lake Turnover, that how much air has to be supplied in such a manner that whole of the water gets oxygenated and virtually in how many days or how the circulation happens. So, this is this is a term that we are going to further learn.

During installation of any aeration system inside the lake, it is very, very important that we should we have to avoid the lifting of the sediments, because any sediment which is settled, we do not want this sediment to go up and get mixed into the water, what it will do? If this happens, then the overall concentration level of the pollutants will increase and the amount of concentration of these pollutants will rise in the lake.

If we do not do the aeration under certain conditions and that certain condition is called laminar circulation condition. So, that we want to have mixing, but mixing is not too high it is not under the turbulent condition avoid, we have to avoid that turbulent condition while aeration is being done in the lakes or reservoirs. So, this is very important, avoid the turbulent condition.

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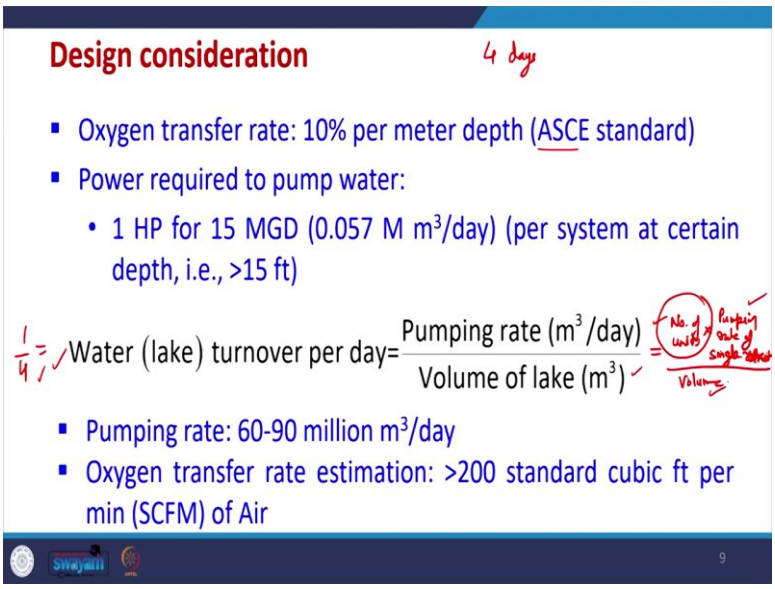

Now, going further with respect to some design considerations that have to be taken care during installation of any aeration unit in the lakes. So, one of the important aspects which is

there, the what is the oxygen transfer rate of that aeration unit? So, that we have to know as per American Standard ASCE standard American Society of Civil Engineering standards. So, what is the aeration with respect to saturation is it 10 percent, 15 percent, 20 percent per meter depth that this aspect is must be known to us, then what is the power required to pump water because each of the aeration unit may have different horsepower requirement.

Like, for example, the one of the thing could be that one horsepower is required for pumping 15 million gallon of air per day. So, like it is a 0.057 million meter cube per day per system at certain depth. Generally the depth is taken around 15 feet. So, this is what is common and through that we can find out the water or lake turnover frequency. So, if suppose the pumping rate, we desire the this is the formula for water or net turnover per day and this is done through pumping rate and volume of water.

Now, if volume of volume of lake if volume of lake is already known to us beforehand for any lake, we can have a tentative calculation of that. Now, based upon that, there may be is a possibility that a single unit has a certain pumping rate. So, here we can have the number of units into the pumping rate of single unit, pumping rate of single unit. So, this is possible and this can be obtained, so data can be obtained, single unit sorry pumping rate of single unit divided by the volume of the lake again.

Now, we generally what is required is that what is the turnover per day it is we desire. So, suppose, we want that within 4 days the whole of the lake should water should get turned over. So, under that condition the per day value will be 0.25 because we want the whole of the lake to be turned over in 4 days. So, that means we required the water lake turnover per day to be 1 by 4. So, if only 1 by 4 is done per day, so in 4 days, we will be able to turnover whole of the water in the lake.

Now, so this is fixed. So, from this and pumping rate is also known, volume is also known. So, we can get to know that okay what how many number of units we require. So, through these methods, we can find out that how many aeration units are required in any lake or reservoir, so, that the amount of water, amount of air or DO is always good in that lake and also there is a proper mixing is happening, but that mixing is not very quick, so, that the sediments are lifting.

So, we have to maintain a laminar condition, generally and there are certain other things like what is the oxygen transfer rate like more than 200 SCFM that is Standard Cubic Feet per

Minute. So, all these things are required to be known, but this gives us a tentative idea that how many units have to be installed and how to calculate that. So, this is possible and similarly, we can calculate the things in any ATP also treatment plant, effluent treatment plant et cetera where aeration has to be done. So, this is possible.

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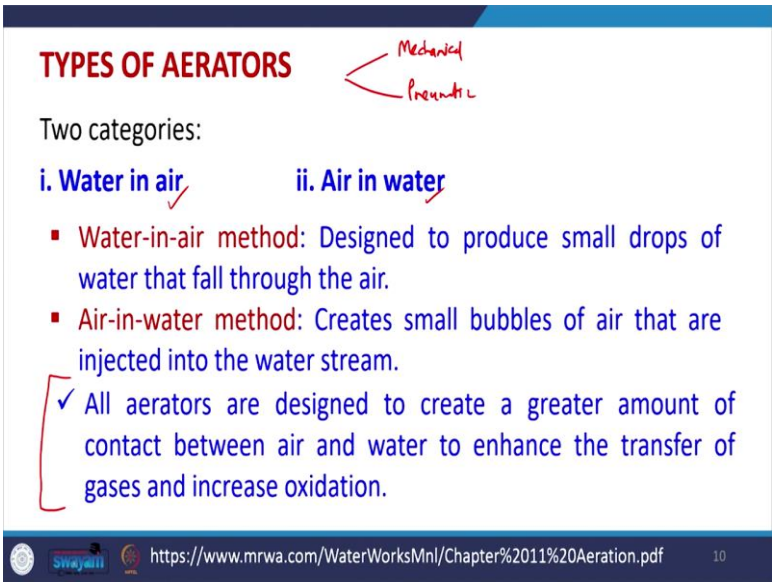

Now, going further now, we will discuss some of the common aerators that there are 2 classifications possible. One of them is like water in air and air in water, there is another classification that aerator types whether they are mechanical or pneumatic, so, that we will discuss later but right now, we will discuss whether water in air or in air in water. So, water in air method actually they are designed to produce very small drops of water that fall through the air. So, we have we tried to have water which is generally thrown in the air and then it will fall through the air. So, this is like water in air.

In air in water, we submerged type of systems like so, create a small bubble of air that are injected into the water steam. So, all the aerators are generally designed to create a greater amount of contact between air and water to enhance the transfer of gases and increase the oxidation. So, this is the major objective of any aerator. But the classifications are given here. Now, we will try to understand each which type of common aerators are there in each of the category.

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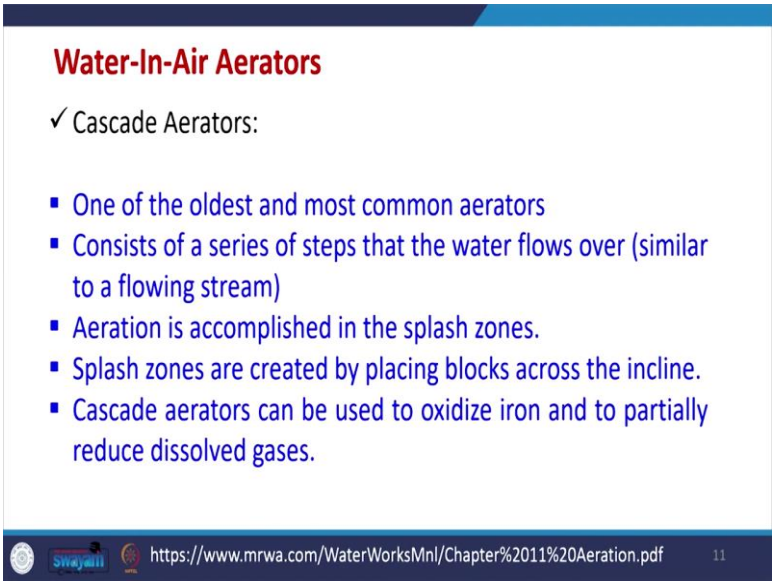

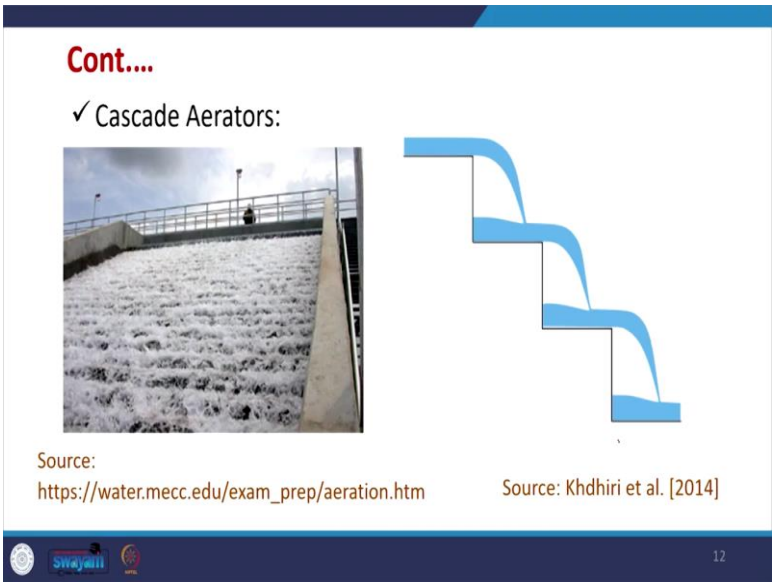

So, going further water in air aerators, one of them very common is cascade aerator. So, you can see here, the cascade aerator is there. The water is flowing from one to another cascade. So, this type of system is possible. They have certain characteristics. So, like this is one of the oldest and most common aerator anywhere, so, way this is we see a lot.

A consists of series of steps over which the water flows. So, it is a like a similar to flowing steam and through that the aeration happens. So, aeration is a comp leased in some splash Jones and splash Jones are created by placing blocks across the inclined space. So, that is possible and they can be also used to oxidize our iron or to partially reduce the dissolved gases. So, these are the cascade type of aerators this is there.

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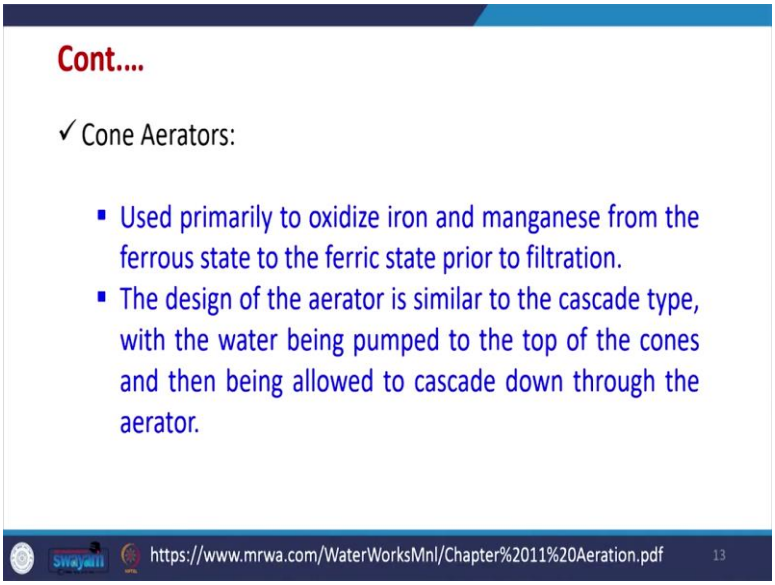

Then second type is called cone aerator. So, cone aerator you can see here. So, this is a cone aerator and some of its important characteristics are like given here, this is used primarily to oxidize iron and manganese from the ferrous sulfate to ferric sulfate state prior to filtration. So, this is commonly used for oxidizing iron and manganese et cetera.

Then the design of the aerator is very similar to the cascade type, and with the water being pumped to the top of the cone and then being allowed to cascade down through the aerator. So, water will be pumped from here and then it will slowly come out through the rater again back and this may happen. So, this is cone aerator, this is called as cone aerator.

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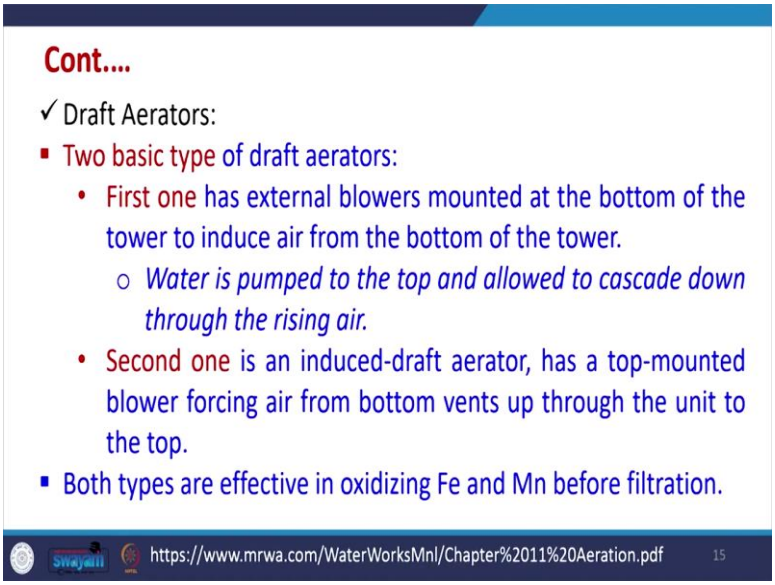

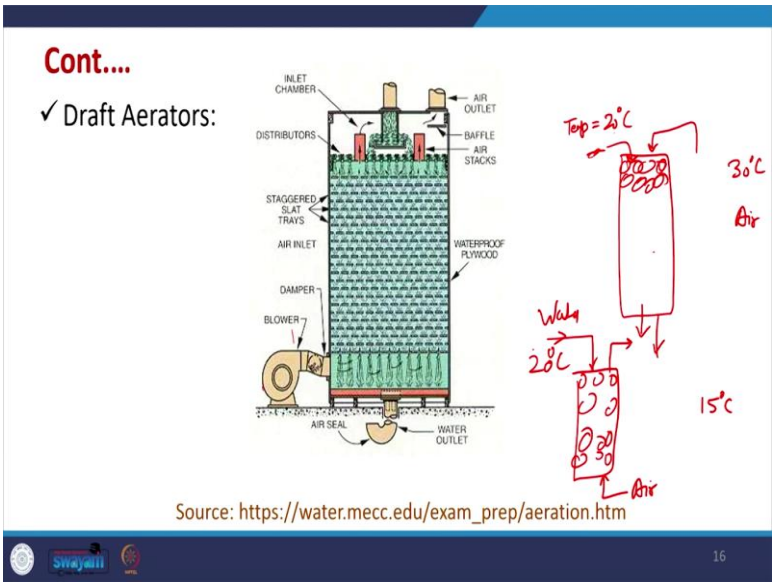

Then there are draft types of aerator, so draft type of aerator can further be classified into 2 types. First one has external blowers mounted at the bottom of the tower. So, this is there. So, what it does is that it induces air from the bottom of the tower and water is pumped to the top and allowed to cascade down through the rinsing air. So, that is rising air, sorry. And so this is possible, so we have blower here and this is the water which is coming out. So, water may be forced to go up and then it will come down and air is going up. So, this is possible.

And the second one is called an induced draft type of editor that has a mounted blower forcing air from the bottom wents up through the unit to the top. Now, I like to give some idea regarding the induced draught aerator and how the flow rate depends upon the temperature and both these types of aerators are good in oxidizing iron and manganese before

the filtration. So, just to give an idea, suppose a simple aerator is there induced type, so, we have a packed bed this is there and through which water is flowing from the top.

So, this is there now, there is a certain condition and water will get collected here. Now, if air outside there is air, now, there is a condition that this temperature of water is suppose we are assuming that temperature of water is 20 degrees centigrade in one condition. So, what is the possibility if outside temperature is 30 degree centigrade, so, air will flow in which direction? So, under this condition, we have to see that, whether the air is going to be cooled down or it will get heated up.

If the air is going to be cooled down. So, that means the temperature will decrease and that means the density of air will increase. So, that means, its movement is most likely to be downwards. So, under that condition the natural induce, the draft of the air will be like this, because once it enters at 30 degrees centigrade, it will come in contact with 20 degree water and it will its temperature will be reduced. So, it will become denser. So, it will go further down.

So, if this will happen, so, under that condition when outside temperature is higher than the temperature of the water. So, natural draft of the air will be like in a coherent mode. Similarly, if the outside temperature is in the second condition, we have a second condition, we are presuming that temperature of water which is going here is still at 20 degree centigrade. So, under that condition, but outside temperature is 15 degree centigrade.

Now, this air when it will get in contact with the water, its temperature is going to increase that means it will become less denser, so, that under that condition, air will go from this side. This will happen and it will come out from here because its temperature is slowly increasing while moving through the bed.

So, these are called induced draft aerator. So, airflow is natural. So, we are not forcing the airflow, it will happen by itself, but certainly they are bigger aerator in size if we have to reduce or oxidize the same amount of pollutant which is present in the water or same amount of gas which is present in the water. So, this will be there, but these are the 2 induce draught type of possibilities and how the movement of air takes place inside these fragments. Then we have spray aerators.

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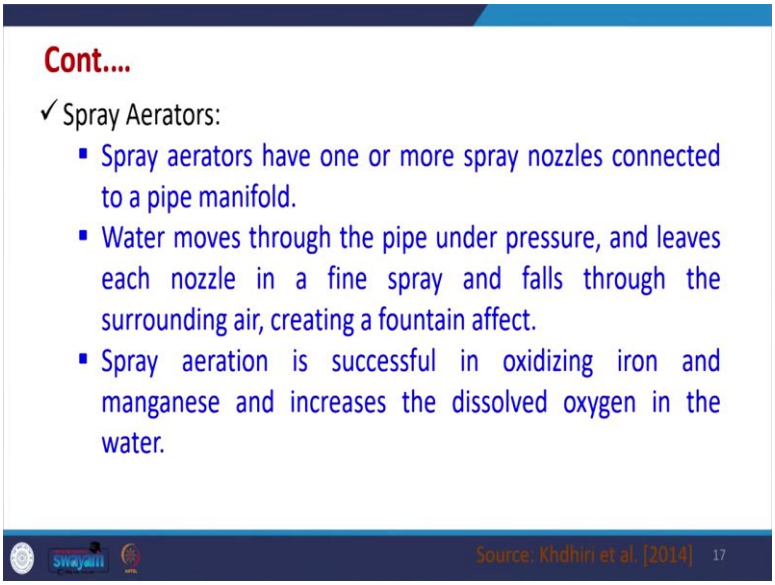

They have one or more spray nozzles connected to a pipe manifold. So, this is that like the you can see they spray aerators are there. So, this is we have seen a lot in any lake or reservoir. So, this is very common and water moves through the pipe under pressure and then leaves each nozzle in a fine spray falls through the surrounding air creating a fountain effect and spray aeration is successful in oxidizing again the same things as earlier. So, going further.

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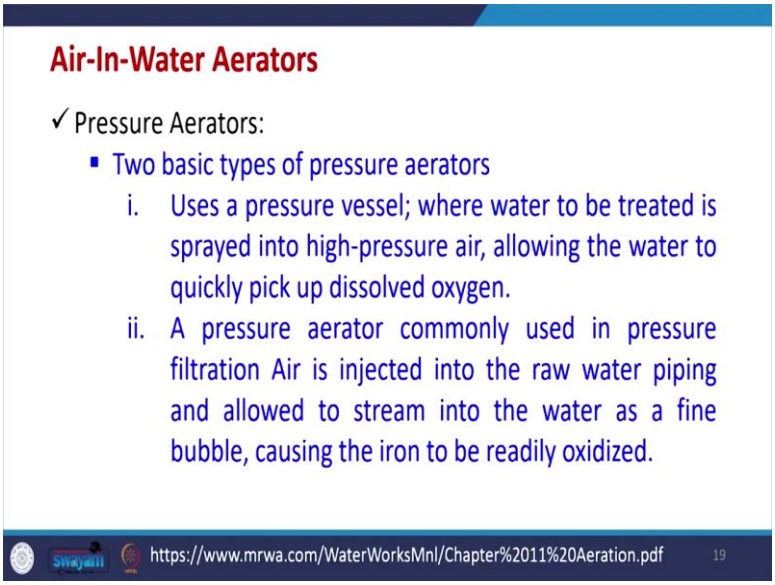

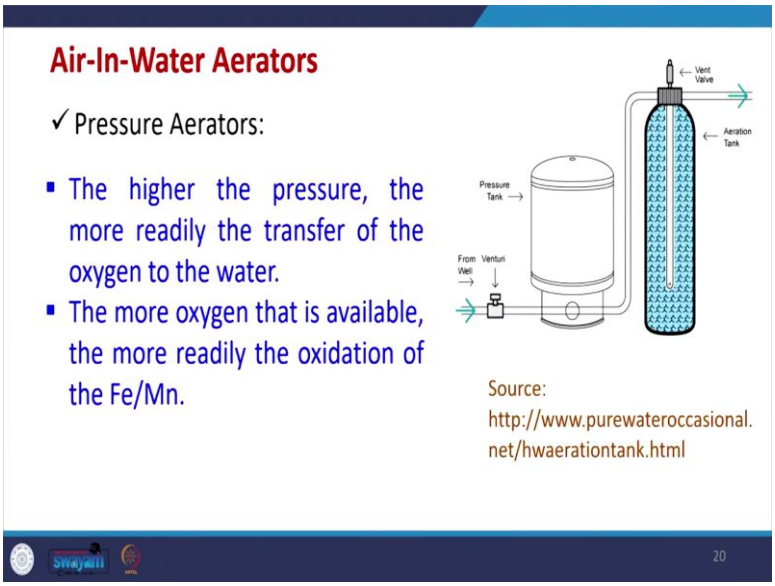

There is another air in water type of aerator. So, 2 basic type of pressure aerators. So, they use one is like uses a pressure vessel where water to be treated is sprayed into high pressure air allowing the water to quickly pick up dissolved oxygen. So, this is one possibility. So, we are using a pressure vessel type of system where water to be treated is being sprayed to a high pressure air. So, this is there.

And a pressure aerator commonly used in pressure filtration. So, second type is air is injected into the raw water piping and allowed to stream into the water as a fine bubble. So, this is already we have discussed a lot earlier. So, these are the pressure aerators you can see here. So, this is the pressure tank and this is a aeration tanks. So, here the air is being bubbled to this pressure unit. So, the higher the pressure, the more readily the transfer of oxygen to the

water. The more oxygen is available and the more readily the oxidation of iron, manganese or of the gases may happen and then we have a very common centrifugal aerators which are used in most of the ETPs.

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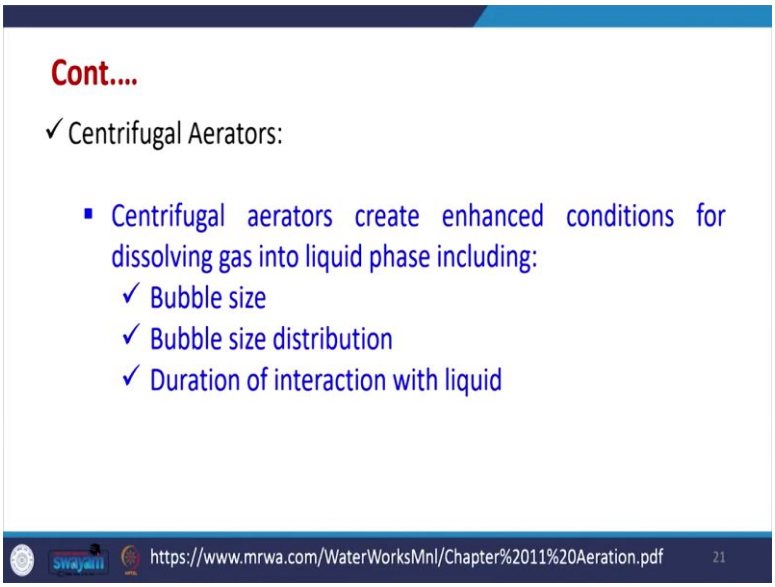

And in the centrifugal aerators they create enhanced conditions for dissolving gases into liquid phase by having proper bubble size, good bubble size distribution and the duration of interaction is also here.

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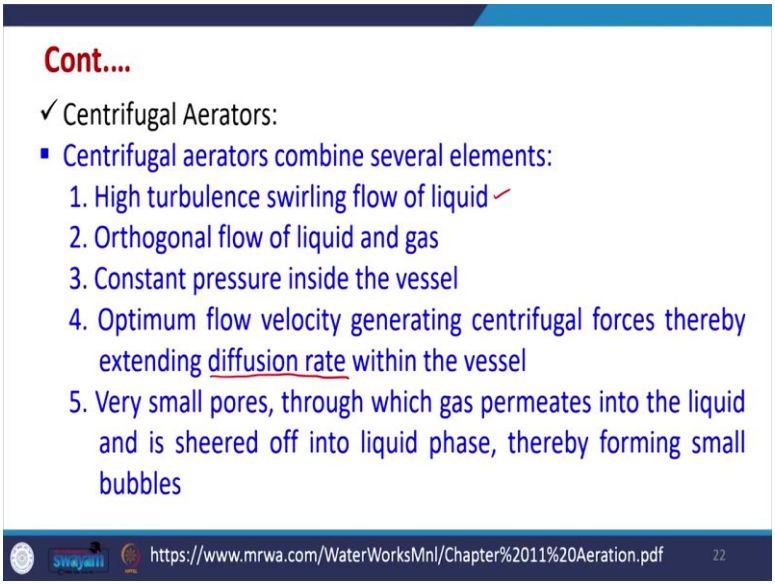

So, these are the centrifugal aerators you can we have already seen one of the photographs earlier, this is the centrifugal aerator and high turbulence due to swelling flow of the liquid, this is one of the basic characteristic of this centrifugal aerator. Then orthogonal flow of liquid and gas, constant pressure inside the vessel. So, this is there. Optimum flow velocity generating very high centrifugal forces thereby extending that diffusion rate within the vessel. So, this this can be this is what is manipulated.

So, we have very high diffusion rate within the vessel and we can easily perform the aeration. Very small pores through which a gas permeates into the liquid and sheared off into liquid phase. So, thereby forming small bubbles, but large number of bubbles. Now, this is very important. So, centrifugal aerators are also very, very common in the deep mill plants.

So, now, we will end this particular lecture and we will continue to learn regarding the aeration systems. And there is another classification that we have discussed pneumatic aerators or mechanical aerators. So, there are some common names for them. So, we will start study that in the next lecture. Thank you very much.