Wastewater Treatment and Recycling
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Lecture – 47
Tertiary Treatment: Disinfection and Chemical Treatments

Hello friends and welcome to this last class for week 9. So, the Tertiary Treatment we have discussed the basics, then nutrient removal few processes including membrane processes, then adsorption, ion exchange all this we have discussed. So, this particular class we are going to talk about some other Chemical Treatment solutions for advanced treatment of wastewater and Disinfection.

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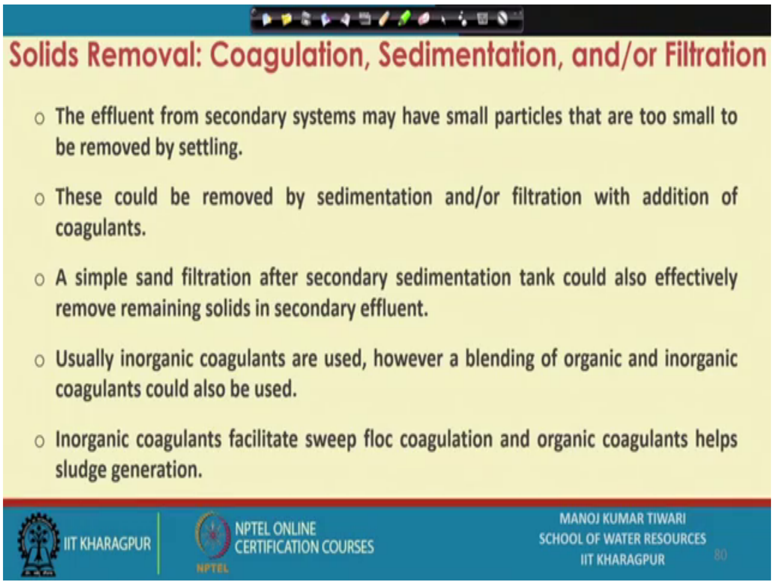

So, to begin with there are at times the secondary effluent that we receive from the conventional wastewater treatment systems, the secondary biological systems. So, the solids are basically removed in two stages in conventional system; one at the primary sedimentation system apart from the grit and the screens because grit and screens are there which removes floating materials and grit. In fact, lot of inorganic solids greats those kind of things are removed in the grate, but in the main treatment chain the primary sedimentation removes large portion of the suspended materials whether they are organic or inorganic and the secondary settling unit or secondary clarifier what typically we call secondary sedimentation tank. So, that removes the microorganisms which are which grow in the biological units before secondary settling.

So, whether it is a trickling filter or it is a activated sludge processes. So, those biomass is settled in the secondary sedimentation basin. Still there are some solids particularly the fine sediments they do not settle in either primary or secondary sedimentation basins because, of their smaller sizes or other things and particularly in the secondary because there is a little gas production as well. So, many times these solids are attached with the gas molecules which makes them lighter and they do not settle. This could include even the bacteria also some of the bacteria which is not removed say in the secondary sedimentation that also comes in the effluent of the conventional wastewater treatment systems.

So, these are actually in general like too small for settling in the conventional settling system. So, they need to be removed by further sedimentation and or kind of either sedimentation or filtration or a combination of both sedimentation and filtration with addition of coagulant ok. So, kind of simple coagulation flocculation process can be employed for that where a coagulant is added and that coagulant then kind of initiate the formation of flocks since the flocks are bigger particle.

So, they agglomerate and they settle in the sedimentation basin. Even if they are not settling in the sedimentation basin; so, we may need to go for a filtration unit where these flocks or micro flocks we can rather say can be settled. So, many times even the coagulation is not needed and a simple sand filtration kind of process right after the conventional secondary settling tank could actually help in the removal of these solids.

So, sand filtration like typical sand bed if we provide with a lower with like the pore spaces and the lower sand size particles within a pore spaces. So, that the hydraulic head does not decrease too much. So, what we can like if we pass the water through these systems we can achieve the removal of these fine sediment particles, these fine suspended particles just through a simple filtration; however, if they are too small to basically be trapped even with the filter of the appropriate sand size.

So, we may need to coagulant and flocculate them beforehand using some coagulation and flocculation ads. So, usually inorganic coagulants are used, in organic coagulants such as salts of iron and aluminum ok. So, alum is used ferric chloride, ferric sulfate those kind of things can be used. However, at times the blending of organic and inorganic both type of coagulants can be more helpful. In fact and at times people use both inorganic and organic coagulant together.

Both have kind of a different mechanism, the inorganic coagulants facilitate more of this free flock formation particularly if there is a significant dose of the coagulant. So, like if we add lot of iron or ferric chloride something like that. So, this will settle as a ferric hydroxide also a large mass of ferric hydroxide is generated and when this mass settles. So, it kind of all the small particles in between settles along with this ok. So, that way it helps the two forms we flock, but the doses requirements are quite high. So, there is additional chemical footprints of adopting these kind of coagulants first we flock formation or that higher concentration ok. The organic coagulant will eventually help in the sludge generation part.

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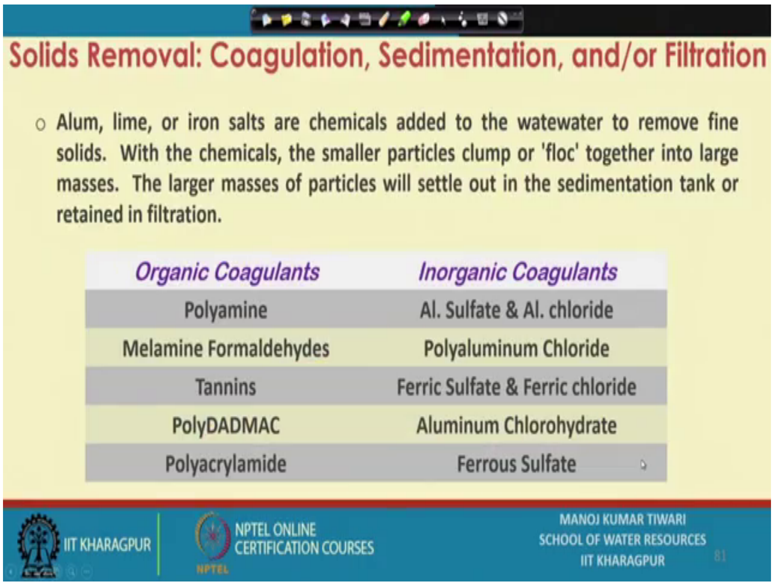

So, if we see the alum lime or iron salts are the chemicals that are used in the wastewater to remove these fine solids. So, with the chemicals the smaller particles clump or kind of flock together into the large mass and then this large mass settles out in the sedimentation tank or can be retained in the filtration basin.

So, if we see the different coagulant. So, there are like organic coagulants like polyamines then melamine formaldehyde all these things whereas, inorganic coagulants include aluminum sulfate aluminium chloride PAC poly aluminum chloride is getting quite popular these days then ferric sulfate and ferric chloride; so, particularly these salts of iron and alum that way. So, these are the methods to remove the process is simple just add coagulant make a rapid mix.

So, as we do in a conventional say water treatment systems. So, we can in a rapid mix we add little coagulant and then allow it to settle for some time or pass it through filter this coagulant can be added actually in a secondary treatment stage as well. So, the like little coagulant could be added in the effluent coming from the aeration basin where in the secondary sedimentation tank itself we can achieve some flocculation and the removal of these solids.

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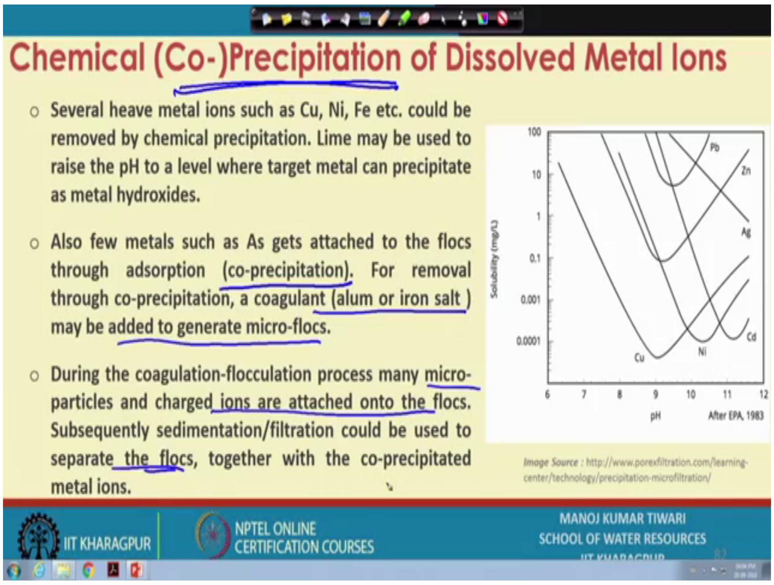

Then there are chemical precipitation methods used for removal of the dissolved metal ions. So, the dissolved metal ions, the metal ions which are dissolved in the water. So, their solubility depends on the pH ok. So, as if we basically make the pH towards the alkaline range normally what we see that the solubility of these metal ions is reduced drastically. So, far say if you bring the pH around 10 your solubility of nickel which usually like earlier which at neutral pH or around 7 or 8 is more 100 milligram per litre will reduce down to say less than 0.001 milligram per litre or that way 1 microgram per litre ok.

So, when's the solubility of these metals reduces they precipitate in the form of metal hydroxides ok. So, copper at around pH 9 has a solubility of less than 0.1 microgram per microgram per litre. So, that way if we adjust the pH accordingly if we most of the metal actually are we know that the solubility increases at lower ph. So, if we increase the pH by adding lime or those kind of thing. So, what happens that as the pH increases these metals precipitate in the form of their hydroxides ok.

So, that way we can reduce these metals by just simple chemical precipitation. So, copper, nickel, iron many of such methods many of such metals actually can be reduced by the chemical precipitation. There are several other metals like for say arsenic ok. So, these kind of metals do not precipitate in the form of their hydroxides usually, but what will happen that they can actually be co-precipitated along with the precipitate of other metals particularly the alum and iron salts. So, if what happens like if say there is iron coagulant is added.

So, it will form ferric hydroxide precipitates. Now, this ferric hydroxide can adsorb the arsenic a species arsenic compounds on their surface through either chemical interaction or through simple adsorption process. Like iron is a pretty good adsorbent for arsenic and many of the field arsenic removal methods are basically derived based on the ability of iron to adsorb the arsenic ok.

So, many methods suggest that we add iron coagulants and form the precipitates of iron and these precipitates will then adsorb the arsenic. So, that way the removal of such metals for say arsenic is actually through co-precipitation they do not precipitate as a hydroxide, but they get adsorbed on a precipitate of some other let us say iron or aluminum hydroxides that way. And, that is how they are removed from the system because when they absorb on that precipitate and those precipitate settle.

So, along with them these metals also settle ok. So, for removal through co-precipitation we must add a coagulant and which will generate micro flocks and on the surface of these micro flocks these particles will settle down. So, during the coagulation flocculation process many micro particles and charged ions will be attached to these flocks and then subsequently we can basically process them in a simple filtration unit or sedimentation unit if they can removed by sedimentation is fine if not we can go for filtration.

For various these kind of particles if you want to reuse the water we go for high order filtration like micro filtration or those kind of thing. So, there these will be these micro flocks will be separated from the water and that way the kind of the water that comes will be devoid of these metals as well.

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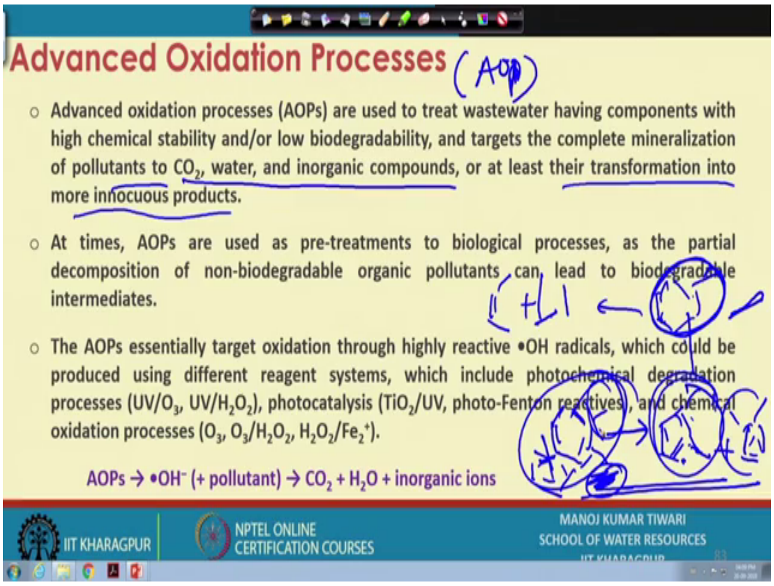

Then there are advanced oxidation processes also there which targets the removal of various compounds which have higher chemical stability or low biodegradability. So, the refractory organic compounds which we discuss that can be actually removed through adsorption or those kind of things. So, they adsorption is a process of removal or phasing out them water, but advanced oxidation process are the one where they can be decomposed and degrade to non toxic elements; only thing is this advanced oxidation process or which typically we call as AOPs are actually energy intensive processes. So, what is done in these that these compounds which have low biodegradability or kind of complex structure are attempted to be completely mineralized ok.

So, the complete mineralization of these pollutants to CO 2 water and various inorganic compounds are targeted. And, if they are if it is not being completely mineralized or the complete mineralization is not being achieved still it is attempted that at least their transformation into the mores innocuous products is ensured. So, that the toxicity or the threat of these pollutants is reduced in the water.

So, at time these AOPs or advanced oxidation processes are used as a pretreatment to biological processes because, even the partial like see if you are having a compound which is very difficult to biodegrade with a complex pretty complex structural compound say some ring compound and then attach lot of functional groups here and there. Now, this kind of compound if you want to degrade by the bacteria probably because of its non biodegradable nature bacteria will not be able to decompose it. Then what to do? So, other process is either you adsorb, but it is still being phased out the compound is still there when you regenerate and adsorb the adsorbent or you are actually regenerating that or if you are removing it through RO or those kind of system membrane processes.

Then that is again coming into the concentrate. So, problem still is persisting. Now other option is to chemically or this through advanced oxidation process you degrade that, but there would be enormous cost. So, what can be done like how these chemical process are how these advanced oxidation process decompose or degrade those compounds is by producing the hydroxyl radicals oh radical.

So, when these OH radical is kind of have pretty high is quite highly reactive ok. So, this can actually attack the compound and break it down. This breakdown is through various intermediate processes. So, it is not that it is like it attack it attacked the compound and it completely of mineralized it immediately it does not happen that way there is a pathway for this. So, one pretty complex molecule let us say you are having a molecule like this for say. And then this will be actually say you had a structure like this a compound like this.

Now, this will first be when this radical goes maybe you see the breaking of just one bond over here. Or maybe this functional group is eased out or maybe this part is separated. So, you may actually see a two compounds like this and another compound like they say ok. So, that way we can have one big compound can be broken into two smaller compound. So, for complete mineralization again this probably will be converted to some compound where this functional group instead of two, now you just have one removed one functional group.

This can further be broken down to a compound say like this and then plus some another compound ok. So, that way this is a sequential step where this degradation or decomposition takes place in the various through various intermediates the biological degradation also takes place in similar way. So, what is the point here that this compound may not be biodegradable, but once it is broken down to probably this or say at least this becomes biodegradable. So, we may not need to basically completely mineralize using advanced oxidation process which are quite energy intensive.

We can initiate the process, we can kind of do couple of steps where the non biodegradable organic compounds are converted to biodegradable organic compounds. So, when they converted to the biodegradable intermediates we can stop the process there and from there onwards we can go for the biological treatment systems where these compounds will then be degraded completely ok. So, that is also can be done and advanced oxidation process are able to do that and that is why many times they are used as a pretreatment to biological process. So, like particularly in the industries if you are having very complex wastes. So, very high COD, but very low BOD that means, there are lot of organics, but non degradable.

So, what many times done is let us say you ozonate that water. So, ozonation what ozonation does is kind of reduces the like do some initial oxidation step and as a result those non biodegradable compound converts to the biodegradable. So, what we may see that the COD is reduced, but large part of COD has been converted to BOD. So, BOD might we might see in fact, in increase in the BOD in such cases; so, that way the advanced oxidation process works.

So, this advanced oxidation process essentially targets the oxidation through this highly reactive OH radical. How this OH radical is produced there are different methods for that ok. So, these OH radicals could be produced using different reagent system which could include like photochemical degradation process. So, UV and ozone or UV or H2 O2 or photo catalysis; so, TiO 2 and UV or photo fenton- reactives or chemical oxidation process where ozone hydrogen peroxide or hydrogen peroxide and iron can be used.

So, eventually all these advanced oxidation processes will somehow generate the OH radical and this OH radical will react with the pollutant and convert them to CO 2 H 2 O and inorganic ions. So, that is what is done in the advanced oxidation process. However, the production of OH radical through these processes is quite cumbersome task and may need significant amount of energy at times.

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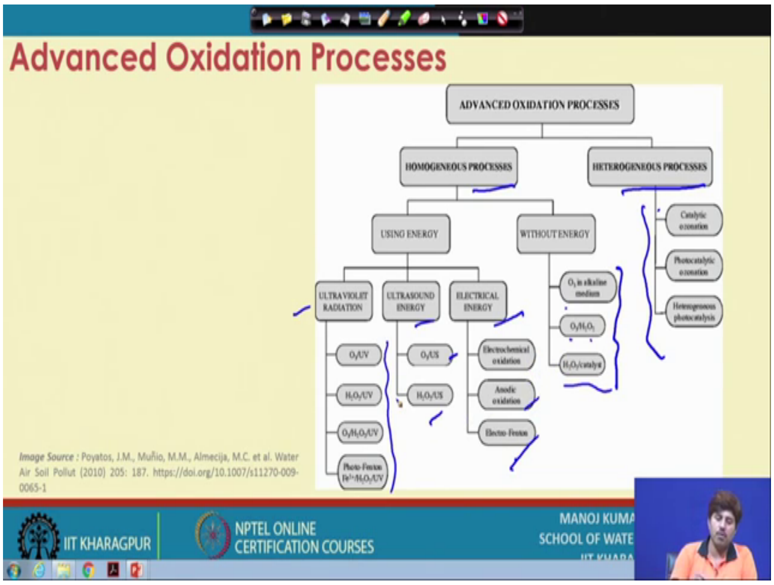

So, if we see the difference different advanced oxidation processes ok. So, we have various homogenous process and heterogeneous process where catalytic oxidation, photocatalytic oxidation or heterogeneous photocatalysis can kind of produce OH radicals. Among homogeneous there are few methods which does not need too much of energy rather works on a chemical this thing.

So, like ozone H 2 O ozone in alkaline medium or H 2 O to and catalysts whereas, there are processes which needs energy in the form of ultraviolet radiation or ultrasound energy or electrical energy. So, ozone UV H 2 O 2 UV ozone H 2 O 2 UV photo fenton or ozone and ultrasound energy H 2 O 2 and ultrasound energy or like electro phone fenton process anodic oxidation. So, there are all these processes. So, these different processes eventually targets to generate the OH radical which can then be used for the process.

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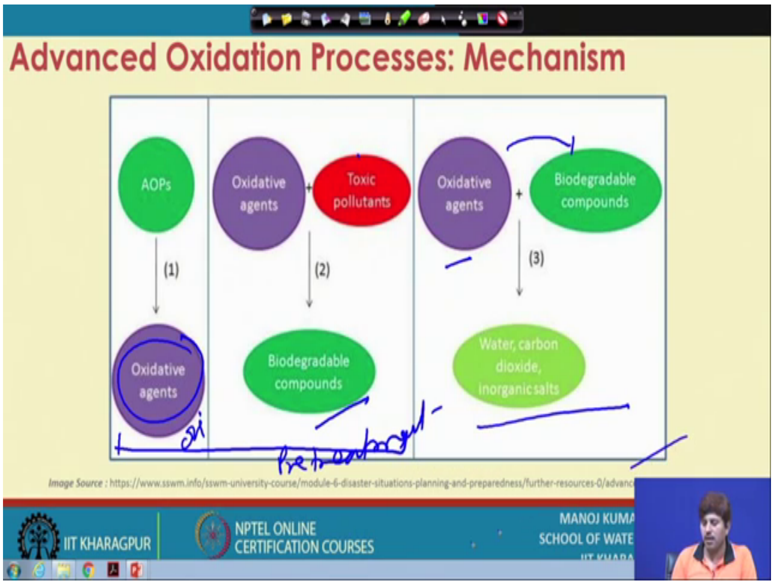

So, how it is done? The process is pretty simple this advanced oxygen the first step is that it actually produces the oxidative agent which is OH radical. Now this oxidative agent reacts with the toxic pollutant and converts them to biodegradable organic compounds. This oxidative agent further will react with the biodegradable compounds and convert them to the mineral stage.

So, for when we are trying to use as a pretreatment purpose we actually end the process here only. So, this is for pretreatment, but when we are willing to go for complete treatment then we will have to kind of take the process further up to this point ok. So, that is how the advanced oxidation processes work.

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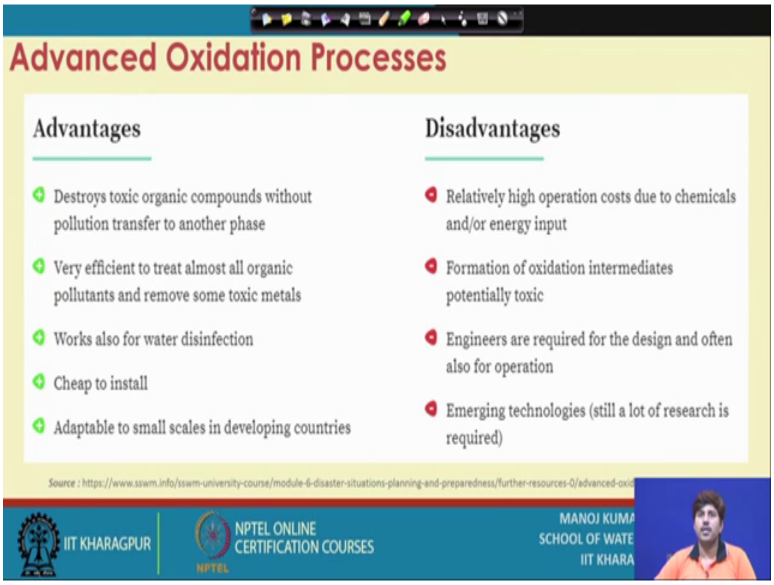

We see their advantages. So, they destroy the toxic compounds without pollution transfer to another phase as many other methods do like adsorption or membrane filtration those kind of things. They are very efficient to treat almost all organic pollutants and can remove the toxic aspecieses. They works also well for water disinfection because ozone or this kind of thing is produced, it can actually oxidize the cell mass and there has the organic compounds in the cell.

So, they also can be like protein can be denatured or those kind of thing can happen. So, that way it can actually have the disinfection properties as well. They are easy to install that is and they are applicable to small scale systems quite well. So, these are the advantages on the disadvantages front. They are relatively high operation cost due to come and chemical or energy inputs needed the formation of kind of oxidation intermediate could be potentially toxic, but if we advanced it they can be degraded the decomposed. So, that is not a big issue that way and the skilled operation and maintenance is needed and this is the emerging technology. So, lot of research is still on to see how actually things happening.

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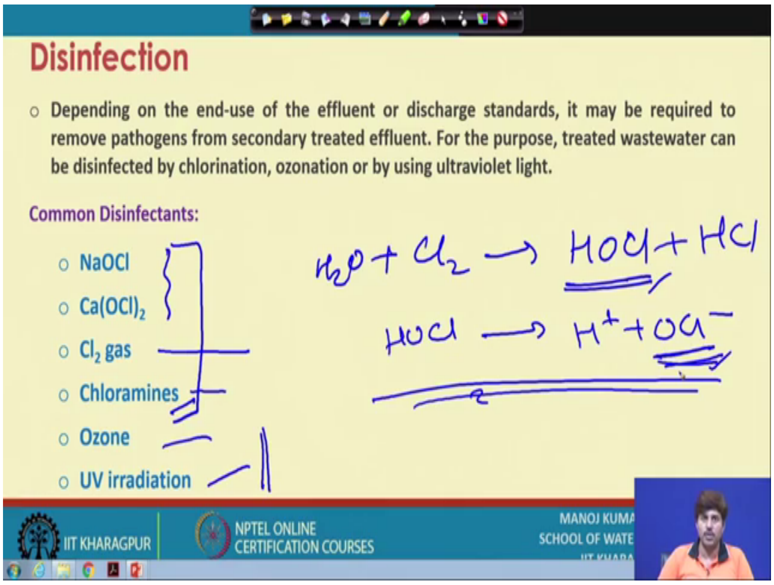

In the last thing that we are going to discuss in this week is the disinfection ok. So, disinfection is actually so, the various processes that we discussed so, far even the RO can also be remove the bacteria those kind of thing. So, we can achieve disinfection through RO system, we can achieve disinfection through the ozonation or advanced oxidation processes as well ok.

However, if we are not like these processes are typically not used only for disinfection if there are other things then we can use these and we can achieve disinfection also, but if we are just targeting disinfection based on our end use of the effluent or based on the requirement of the say National Regulatory Agencies the discharge standards what so ever are there. So, if we need to remove the pathogens from secondary treated effluent without probably going for various other things.

So, we can use the some of the conventional disinfection approaches for treating the water and we can disinfect the water by chlorination, by ozonation, by using ultraviolet light those kind of things can be used. So, if we see the common disinfectant that are used. So, chlorine is by far the most popular and most common which can be used in the form of chlorine gas, which can be used in the form of hypochlorite. So, sodium or calcium hypochlorite or could be used in the form of chloramines.

So, chloramines are generally like I have lesser disinfection abilities as opposed to the chlorine gas or these hypochlorite's which eventually convert to. So, what happens when water reacts with the chlorine it eventually produces HOCl and HCl. So, this HOCl which is called hypochlorous acid has quite high disinfection abilities and this is actually this HOCl depends on the pH.

So, it can be broken down to H and O Cl ions also. So, this OCl ions which is called hypochlorite ions. So, this HOCl and OCl both have disinfection abilities, both can both our strong oxidant and can actually oxidize. Because, chlorine becomes the electron acceptor that way and can oxidize the microbial components leading to the death or decay of the biomass or microorganisms that way.

There are chlorine dioxide can also be used which is very effective, but kind of its difficult to it needs to be produced at site which needs skilled supervision, skilled operation those kind of thing. And, that way it is not like it is not that popular to use chlorine dioxide in the field, then there are ozone and UV radiation. So, that ozone is again is as strong oxidants which can which can kind of have the disinfection abilities as well and UV. So, bacteria cell walls adsorb UV light at some radiations around. So, at few wavelengths they adsorb UV light.

So, if we put the UV light of those radiations those energy is absorbed by the microorganism cell walls and then they that is disrupted and as a result microorganisms become that. So, that way UV also ensures the disinfection UV is getting more and more popular actually nowadays.

So, chlorine has a risk particularly in the wastewater system because if the complete removal of the organics has not been ensured. So, there is possibility of finding disinfection by products DBP’s which could have little potential toxic impact. So, that is what is one of the issues with chlorine, otherwise chlorine is most effective not most effective as such, but quite effective and most popular undoubtedly for the disinfection purpose.

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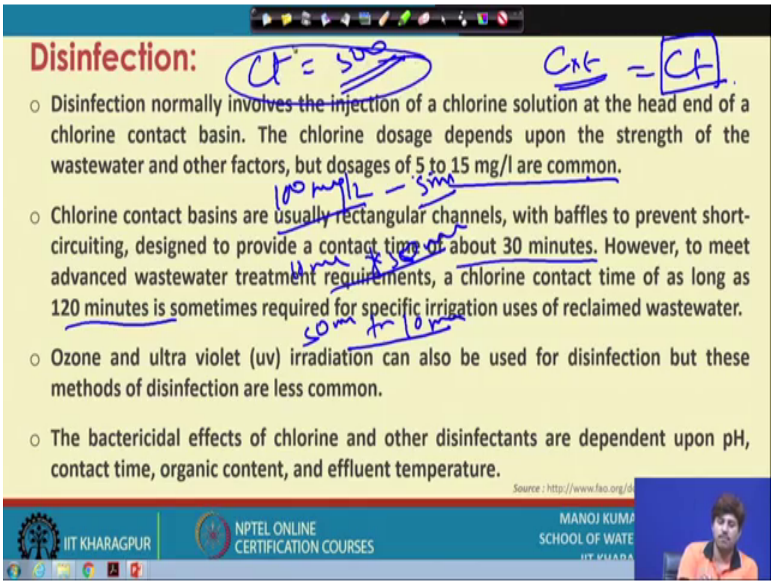

So, if like you see the disinfection it normally involves the injection of chlorine solution at the head of the chlorine contact basing, the doses will depend upon the strength of the wastewater another factor, but 5 to 15 milligram per litre doses are usually normal. The chlorine contact basins are usually rectangular in channel. We can now provide baffles for widening short circuiting ok. So, that and the typical contact time of 30 minutes is good enough.

However, if kind of depending on if it needs to be meet the advanced water quality requirement or those kind of things. So, we may go for higher times as well ok. So, the time requirement or the concentration of the disinfectant will both govern the degree of disinfection. So, there is kind of like concentration into time which is called Ct. So, Ct is used for seeing the degree of disinfection. So, if let us say a bacteria has a Ct requirement of 500. So; that means, we can put a 100 milligram per litre concentration for 5 minutes of course, we need to match the units later on if what is the unit of Ct, but if it is that way.

So, 100 milligram per litre for 5 minutes or 10 milligram per litre for 50 minutes or say 50 milligram per litre for 10 minutes ok. So, that way we can have different combinations to achieve similar kind of impact. So, that is what the Ct concept is there. The ozone and ultraviolet light, ultraviolet irradiation can also be used for disinfection, but these methods of disinfection are relatively less common. The kind of bactericidal effect of chlorine and other disinfection depends on the pH, contact time, organic content and the effluent temperature. So, all these external factors also control the degree and quality of disinfectant.

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So, these are couple of images. So, typical chlorine contact tank will look like this. So, this is a baffled system. So, we add chlorine here and let the water flow through these baffles ok. And, in the residence time say if 30 minutes is needed. So, in 30 minutes we will ensure that is infection. UV irradiation basin we will look like this where water can be exposed to the UV irradiation and that way disinfection can be achieved.

So, conventionally the disinfection is usually last step if it needs to be provided of course, if we are going for UV, if you are going for RO; so, UV is provided before RO and then RO becomes the last step. But, provided like the degree of treatment required, if you do not need to go to r o level. So, disinfection usually becomes your last treatment.

So, with this we conclude the discussions of the week 9, where we have discussed the advanced treatment approaches or tertiary treatment methods. So, that is about the treatment part. Now, next week we will be talking about some the typical treatment systems or typical treatment schemes which are nowadays getting more popular and being used in the field, which are derived their concepts from the conventional treatment system itself. But, the arrangement or the kind of the process flow is amended in such a way to achieve the certain objectives of maximizing the treatment efficiency or minimizing the cost or minimizing the space that way.

So, like we have sequential batch reactor SBR then MBBR or MBR those kind of things. So, we will discuss these selected treatment procedures or treatment systems in the next week. So, see you next week, have a good time.

Thank you.