

Water Quality Management Practices
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Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Dhar bhowmick. I am from the Department of Agriculture and Food Engineering of Indian Institute of Technology Kharagpur. So, in this particular lecture video we will be discussing about the biological phosphorus removal and the factors which affects on. So, the content I will be covering majorly discussing about the different phosphorus existing physicochemical phosphorus removal processes and what are the lacunas or what are the disadvantages related to it and how the biological phosphorus removal can actually comes at comes as a you know like you know some the better alternative to the existing physicochemical processes that revolves revolves around all majorly uses we normally using like using it in case of removing the phosphorus from the wastewater treatment wastewater lines and all. So, and what are the factors that affects this enhanced biological phosphorus removal that will also be discussed.

So, majorly in general you know that the phosphorus source like from the wastewater if we talk about like majorly it does have it in food processing industries or the fertilizer industries and the agriculture run offs they are the major sources of phosphorus in the in the wastewater stream. So, what is the reason behind it you know that in a agriculture runoff like it normally washes out the fertilizer that is been applied to the agriculture fields like in the in the agriculture farms and all. So, in this agriculture farms when the fertilizers it does have the same case and all. So, this phosphorus is a integral part of this agriculture practices.

So, this phosphorus most of the cases it during the agriculture runoff it actually along with the agriculture runoff it comes in contact with the wastewater stream and at the end it comes to the sewage treatment systems or sewage treatment line of any nearby municipalities or the city treatment systems. So, other than that the domestic wastewater which also does contain some amount of orthophosphate and other compounds like the phosphorytic proteins and the nucleic acid. So, these are all like you know something related to the presence of orthophosphate the presence of the phosphate related compounds in the wastewater that needs to be treated. So, how the existing removal processes are there which actually target the phosphorus are majorly the physicochemical processes. Some amount of biological and the combination of physicochemical and the biological treatment processes are also there.

However, the majority of the treatment systems that we normally follow in the treatment systems that normally follows the physicochemical methods like the adsorption iron exchange and the chemical precipitation using calcium, aluminum and or the iron. So, what is happening here we use some amount of adsorbent those adsorbent it adsorb the phosphate presence in the systems phosphorus present in the system in the wastewater and it actually somehow be you know you can actually treated in a very confined manner. However, it comes with a lot of lacunas the first of all if I start with it is it requires the addition of chemicals it requires the addition of some external foreign products right. And this external processes and this external chemicals and all it may have some hindering effect on the other treatment units and it may have some additional toxic effect on the prevailing biological units I mean like the all the say suppose any living organisms that is present in this any other living organisms that we need to be there in that biological treatment unit that may be affected by this kind of chemicals right. So, but the iron exchange process it is considered as one of the finest one like you know I mean like in terms of the existing processes that is there.

In iron exchange we somehow design some amount of some kind of iron exchange membranes and with some coating of some iron exchange resins those iron exchange resins are actually helping the phosphorus to be removed from the systems in then converted and specially it takes it from the high stream like you know from the dense stream wastewater line to the less denser or the lighter light stream water line. So, by this way we can collect we can collect those phosphorus from a certain from a certain high strength wastewater and it is one of the feasible and one of the advanced processes that is there in the market right now. Furthermore the additional processing unit like the solid separation is needed as a follow up treatment which is one of the another major challenges that lies with the physicochemical processes. Because those adsorbents that that adsorb all the physicochemical even the ion exchange of the chemical precipitation process it converts into some solid products. Those solid products has to be separated has to be treated separately with a very cautionary measure because those are those will be having very high concentration of those phosphorus content right.

So, this additional treatment processes also needs to be there needs to be added to the treatment line and which comes with some additional like an handy cost of economic like you know involvement. And this biological sludge in general the sludge that we normally that that is being generated out of all these existing processes. It does have a 1.5 to 2.7 days of phosphorus of dry wet basis which is very less.

So, what is happening in the phosphorus removal process if we follow like suppose we have a waste water if you see in the right side in the left side with the red dots being red

this marks are actually representing the phosphorus. So, it when you when you supply some say like you know calcium oxide. So, in presence of calcium oxide what is happening? So, it goes through the hydrolysis process and it forms the calcium ion in the in the system. So, this calcium ion it reacts with the phosphorus and it actually with the phosphorus compounds and it actually it actually converted into some stable byproducts of some solid material which then further settles down or you you can also further use it for adsorption processes ok. So, after the adsorption is done this final output if you see it will be having the phosphorus as well as the adsorbed the final calcium based product that you will be getting out of the precipitated after the precipitation is done.

So, this final adsorbed product is like now you have to separate it and you have to treat it separately. So, this is this is the process that that is generally being followed for the removal of phosphorus in the wastewater treatment systems and all. In this case about 10 to 20 percent of the phosphorus removal is achieved in this conventional aerobic treatment systems. And normally however, but we have to understand that the primary target of this aerobic secondary biological treatment is to oxidize the carbonaceous organic matter. And in some sense the some if we have the design criteria we design it in such a way that it will also enhance or it also encourage the treatment of nitrogen treatment of ammonia rich wastewater that is also something of our benefit.

So, in this process so, carbonaceous organic matter plus the nitrogen plus the ammonia rich wastewater I mean like the ammonia based nitrogen products can also be removed from the system by the process of nitrification. So, addition to that this activated sludge processes this aerobic treatment processes can somehow also be beneficiary up to a certain extent for removal of phosphorus ok. However, there are this limitations that it can only has a certain limit of phosphorus removal from the systems that is why we have to come up with some advanced processes. So, one of this advanced phosphorus removal process with the enhanced phosphorus removal are called the enhanced biological phosphorus removal or EBPR ok. In this EBPR in this enhanced biological phosphorus removal process the polyphosphate accumulating microorganism ok or in short we call it PAO polyphosphate accumulating microorganism or polyphosphate accumulating organisms ok.

See this PAOs it convert the phosphorus into the sludge as a intercellular polyphosphate material ok. So, please remember this is also this is a very advanced process that this is a very advanced like you know like process obviously, it requires a high amount of skilled manpower and all and obviously, it if you can actually maintain all the possible like you know the parameters in that into the systems it can definitely comes as quite handy for removing the good amount of phosphorus from the system itself. So, this what is this enhanced biological phosphorus removal it is a it always favors the growth of

microorganisms in successive anaerobic and aerobic conditions ok. In this kind of systems it can achieve a phosphorus removal rate of up to 80 to 90 percent whereas, in earlier the existing ones it can go up to 5 to 10 or maximum 20 percent is of removal of phosphorus from the secondary biological treatment processes. Whereas, this specific treatment systems can achieve a removal rate of up to 90 percentage.

This process is also depending upon the concentration of phosphorus accumulating organisms and we our target will be to make a favorable condition or get rid of all the possible environmental hazards or environmental nuisance that can actually cause an concern for this kind of PAOs or the phosphorus accumulating microorganism or polyphosphate accumulating microorganisms and all. So, this organisms it is accumulate high amount of polyphosphate and it increases the phosphate level phosphate removal from the system. This dried biomass of this enhanced biological phosphate phosphorus removal process it contains about 4.5 to 5 percentage of phosphorus it enhanced drastically from the regular one as you can see in the earlier slide it can be only 1.5 to 2 percentage phosphorus in the in the bottom you can see in the last here.

So, the removal percentage can be drastically increased. What is this PAOs? This phosphorus accumulating microorganisms or the polyphosphate accumulating organisms. So, these are the aerobic organisms which are crucial for EBPR. These are unable like this organisms these are unable to multiply under the anaerobic conditions, but can use the volatile fatty acids as a as a as a as the respiratory product. So, in the respiratory material.

So, under this anaerobic conditions this polyphosphate it normally it is degraded and it release the phosphorus into the wastewater. So, first in the anaerobic condition what is happening this polyphosphate it it degrade into phosphorus material which then it can be released into the wastewater itself. In the subsequent aerobic zone this this phosphorus accumulating microorganisms they will grow and they will consume those dissolved phosphorus again and store it as their intracellular polyphosphate ok. So, this way what is happening the we can actually eliminate the presence of polyphosphate from the system itself in general from the wastewater stream itself. There is a selective and it is it is exhibit a excessive phosphorus accumulation in the aerobic zone and it is more phosphorus storage is released under the anaerobic conditions.

So, what is happening whatever you are storing in the aerobic conditions in the anaerobic conditions some of them will be released into the system. So, this way it is some of that is the reason why even in case of this enhanced biological phosphorus removal process also we have to get and we have to return some amount of active sludge activated sludge into the anaerobic system itself. So, if you see the process this is how it

looks like in case of anaerobic system in the anaerobic zone what is happening the organic material if you see the accumulated organic matter in the in the in the center with the with the crisscross line and this volatile fatty acid it utilizes and the energy it utilizes and it releases the phosphorus into the system ok. Not only phosphorus, but also some other the potassium magnesium etcetera into the surrounding vicinity whereas, in the aerobic condition it start consuming those accumulated thus start consuming those phosphorus from the systems potassium and magnesium from the systems and it actually converts it into it is biomass So, this is how the phosphate is like you know converted into some biomass and this biomass is a phosphate phosphate accumulating biomass and actually it can be easily easily collected or you know you can easily how to say I mean like get rid of this biomass by properly handling the sludge from the system itself like having us say the secondary clarifier or the secondary sedimentation tank from that you can easily accumulate those sludge you can easily collect it and you can actually disperse it you can in the in the you know sludge handling units and all ok. So, this is how the process the biological phosphorus removal process looks like ok.

So, in general so, to give you any brief so, anaerobic treatment phase what is happening the phosphorus is being released due to the degradation of polyphosphate in the aerobic treatment phase this phosphate accumulating organisms it will grow and it will consume those dissolved phosphorus and it converted into store it as a intracellular polyphosphate ok. This excess biomass removal it results in the phosphorus removal during the EPBR process and this way at the end in the secondary it may secondary clarifier you can easily collect those sludge and you can actually get rid of the phosphate from phosphorus from the wastewater stream. In general this phosphorus accommodating organisms is which the sludge that we get out of this EPBR process is enriched with this PAOs and requires a sequence of in case of aerobic and anaerobic treatment processes ok. And this EVPR configuration it involves in anaerobic zone where the influent wastewater is mixed with the returned activator sludge also sometimes as I have mentioned followed by aerobic zone for sludge and the effluent separation. In some cases which we call it A2O process where we sometimes add additional treatment unit in the between which we which is normally prevailing with the anoxic condition ok.

So, what is happening this simultaneous nitrogen and phosphorus removal it is can be added with this modified process with the additional anoxic zone in between that is why I call anaerobic anoxic-oxic processes. So, A2O process ok. What is what does it do in general this anoxic zone? This anoxic zone whatever is says in the second phase we have the aerobic tank right. In the aerobic tank or the aerobic zone whatever the nitrate that is being formed there it is re-circulated back to the anoxic zone so, that the denitrification process can occur right. So, this kind of system this A2O process this anaerobic anoxic-oxic zone or this kind of processes is actually helping you to get rid of the phosphorus as

well as the nitrogen.

So, complete nutrient removal like or nitrogen or phosphorus considered as one of the major nutrient that needs to be removed in the form of pollutant from the wastewater and that can be achieved by this kind of systems like this A2O process. How it looks like? It looks like this like in the figure itself if you see in the beginning in the inlet you have this anaerobic treatment processes which is which you have keep on you have to keep on mixing it. So, what is happening in this anaerobic treatment processes as you know the polyphosphate is released in the form of phosphorus into the system ok. Then it will come to the anoxic processes and through anoxic processes it will come to the aerobic treatment processes. In the aerobic treatment processes it will we provide them with the favorable condition to go this phosphate oxidizing microorganisms and all and those PAOs will actually start consuming those phosphorus and the potassium and the calcium released into the systems and it converts it into its biological like you know in like in its biomass.

So, once it is converted into its biomass those the percentage of phosphorus will drastically reduce from the system. However, because of the aeration and the because of the favorable condition prevailing for the nitrifying microorganism also there in the aerobic treatment process those nitrifying microorganisms present in the aerobic treatment processes it will start consuming it will start converting the ammonia if there is there in the system in the wastewater stream converted into nitrate. So, once it is converted into nitrate that nitrate again we are recycling it back to the anoxic treatment system for denitrification purpose. So, those nitrate in the denitrifying in an in the anoxic treatment this because of this mixing and because of this denitrifying microorganisms which will which is growing in the anoxic treatment process it will also increase it will also convert those nitrate into nitrogen then nitrogen gas and it will come simply escape from the system. So, this is the this is how the whole system is holistically removed a holistically remove the nitrogen and phosphorus from the wastewater stream and whatever the rest amount of a nutrient which is now converted into sludge biomass it connect it will be easily collected from the secondary sedimentation tank and from the supernatant of the secondary sedimentation tank can be it will be released from the outlet line and this outlet will be theoretically almost the devoid of nitrogen and phosphorus present in the inlet wastewater body instead right.

So, this is how the biological nutrient removal process looks like in this A to O processes or anaerobic anoxic-oxic treatment processes ok. So, what are the factors in which the enhanced biological phosphorus removal process is really depending on. So, to start with the first thing is the influent wastewater characteristics. What do I mean by the influent wastewater characteristics because the wastewater that is entering into the

system it should have certain amount of like the nutrient available for the phosphorus for the phosphorus accumulating microorganisms to grow comfortably. So, it normally relying on the volatile fatty acid source for the release of phosphorus stored in the cell.

So, that is also that is the first thing. Second thing the source of volatile fatty acids it can be synthesized in situ in the anaerobic zone because of the anaerobic degradation of the of the fat or lipid present in the systems in the comes along with the wastewater stream or you can supplement it externally into your anaerobic system anaerobic registration. So, in general we do not have to supply it in general they they they have enough amount of fat and the process of hydrolysis it converts into the volatile fatty acids which are enough for those enough source for the phosphorus release from the system from the cell ok. Then the optimal BOD to total phosphorus ratio a ratio of 20 is to 1 to 25 is to 1 is considered to be ideal for survival of this phosphorus accumulating microorganisms in the anaerobic zone. So, we have to maintain this BOD to total phosphorus ratio into the into the systems.

Why we need to maintain this BOD to total phosphorus ratio because you understand that this BOD is nothing, but the source of carbon. The source of carbon is like like a food for them right. So, you have to maintain a certain the balance in the the the in the diet of those microbes right in I mean like the they they have to they have to maintain certain balanced food for your microbes to be able to consume. So, that they will they will act optimally. So, in case of enhanced biological phosphorus removal process you have to maintain a BOD to phosphorus ratio of 20 is to 1 to 25 is to 1 ok.

This is a thumb rule. So, please remember it. What is the unfavorable conditions? Definitely the lower BOD to total phosphorus ratio then the original range may hinder the fermentation process and leading to the incomplete phosphorus release into the system into the wastewater. So, unless until there is a release of phosphorus along with the phosphorus that comes into the wastewater in the anaerobic system it also needs to release some amount of phosphorus into the system. It consumes the polyphosphate it converts it into phosphorus and makes it easier for its follow up treatment systems to consume it for its for in during the anaerobic treatment processes right. So, we have to maintain the this bare minimum BOD to total phosphorus ratio into the system.

So, that is how the the influent character waste water characteristics can you know make some like you know certain can affect the overall enhanced biological phosphorus removal process ok. Second important thing is the hydraulic retention time. In case of anaerobic zone this shorter HRT its results in a higher volatile fatty acid concentration in the aerobic zone anaerobic zones. So, we have to we in this higher anaerobic I mean like it. So, it is actually in a way it is better for us right.

So, the HRT is very important the shorter it is like you know you can increase the it can increase the volatile fatty acid concentration. So, it may also have some other benefit in the follow up treatment systems. Next is the phosphorus release the hydraulic retention of 1 to 2 hour is typically sufficient for the fermentation in the phosphorus release. So, you have to have a very short not very short like you know comparatively shorter HRT of 1 to 2 hours is beneficial. Denitrification trade off very short retention time in the anaerobic zone may affect the waste water denitrification as well.

So, that is why you cannot have a very little denitrification little I mean like very small very short retention time. You have to maintain this 1 to 2 hour if in best cases up to 4 hours like you know commendable I mean like your suggested because the anaerobic the denitrifying microorganisms needs also some time to convert the nitrate into nitrogen right. And they also have some shorter growth period and all. So, that is why it is better always to have a certain tradeoff between the phosphorus removal as well as the denitrification process.

So, optimizing this HRT is very important. So, this balancing the contact time for denitrification of phosphorus removal it really requires a careful optimization because phosphorus removal needs smaller shorter retention time whereas, denitrification needs higher retention time. So, you have to maintain certain balance. So, that most of the both of the process will occur simultaneously without compromising the without compromising the need of this nutrient removal and without compromising the like you know reduction in the efficiency of this nutrient removal like nitrogen or the phosphorus removal from the system. Third and foremost is the dissolved oxygen concentration obviously, there should be enough adequate DO of 4.5 to 5 milligram per liter for the growth for the growth of glucose accumulating microorganisms.

However, in the lower DO it always favors the growth of phosphorus accumulating microorganisms right. So, your erosion tank you have to design it in such a way that it will you have to optimize that it will favor the phosphorus accumulating organisms as well. At the same times the amount of microorganism that amount of microorganism that is needed for converting the organic matter I mean like the carbonaceous organic matter that also you have to keep it in mind ok. So, please maintain the DO of around 3 to 3.5 which sometimes it is like you know mostly suggested.

So, that the phosphorus accumulating organisms can also grow at the same or what you can do you can have a one same erosion erosion basin only you can separate it with a small baffle in between. So, one of the basin will be having much higher addition of erosion systems which will encourage to grow the glucose accumulating organisms

which will increase the carbonaceous organic matter degradation. Whereas, in the second stage or like second I would say like sub stage in that erosion tank itself there will be less amount of erosion that you will apply. So, that you will prevail a certain desoroxane level of say like 2.5 to 3 milligram per liter which will actually encourage you to go for encourage the system to be for the growth of phosphorus accumulating microorganisms and so, it will eventually reduce the phosphorus load from the system itself.

So, you have to play with it you are being an engineer you have to think about what possible design will actually somehow meet the demand meet the demand of your client or meet the demand of your like you know the treatment system and all ok. Activated sludge oxygen level the return activated sludge should have a devoid of dissolved oxygen because along with the activated sludge if some amount of oxygen will dissolved oxygen will also come into the system what will happen in that case it will affect the whole I mean like it will definitely it will change the I mean like the start affecting the desired denitrification process and because it is anoxic condition should be prevailing here right. Absence of dissolved oxygen in return activated sludge process it promotes the volatile fatty acid formation in the aerobic treatment system. So, definitely we have to be make sure we have to make sure that dissolved oxygen level of your in your activated sludge process should be almost 0 or near to 0 ok. I mean like it is better to have it in 0, but it is very hard to have it 0.

So, you can at least maintains this condition. So, that it will be completely devoid of dissolved oxygen. So, in conclusion we got to know about the different type of phosphorus removal processes existing once and we also get to know about the like you know how we can enhance the biological phosphorus removal by using this APBR process where it involves that anaerobic zone to be followed by aerobic zone where phosphorus accumulating organisms can release and uptake the phosphorus effectively. And what are the factors that affect the APBR? In general the effluent wastewater characteristics the hydraulic retention time, the dissolved oxygen concentration and other operation and the environmental parameters which can actually influence the performance and the efficiency of this enhanced biological phosphorus removal processes. These are the references I would request you to go through it and I hope you get to know about some very basic idea about the how phosphorus is being removed from the systems. There are lot of advanced techniques those are coming into the picture and I would request you to please go through it and Google it and you get to know more in details about it.

And please go through the references also that I have suggested. So, it will also help you with understanding the remove this APBR processes more in details. So, thank you so

much I hope you understand you had a nice session. So, we will meet you in the coming lecture. Thank you so much.