Water Quality Management Practices

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Systems used for Nitrification and Denitrification, Anammox Process

Hello everyone. Welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Bhowmick. I am from the Department of Agriculture and Food Engineering of Indian Institute of Technology Kharagpur. So, in this today's lecture, we will be discussing about the systems used for the nitrification and the denitrification process and the anamos process in continuation with our discussions in the earlier lecture material. The module, this in this module which is like the emerging biological processes that that is there for the nutrient removal of the tertiary treatment systems and the concepts that I will be covering are the systems used for the nitrification and denitrification, the design guidelines for biological nitrification and the denitrification, anamos process, the factors affecting the anamos process, anamos reactor systems and the anamos versus conventional nitrification and denitrification systems which one is better, we will be discussing about that as well ok.

So, this is a very fascinating technology the the the the the the science that you you are going to learn today. I mean like I hope if you do not know yet you know. So, the systems that is used for the nitrification denitrification process are first to start with the simultaneous nitrification denitrification process. Second one is the pre anoxic single sludge system, second one is post anoxic single or the two sludge systems and the fourth one is the closed loop systems.

To start with the first one is the simultaneous nitrification denitrification process. If you see the simultaneous nitrification denitrification process what is happening? The dissolved oxygen which is present in the bulk waste water when it does not reflect its concentration within the biosolid or the sludge flocs ok. So, in the sludge flocs in the outer outer layer it can still be supplied by be available with the oxygen aerobic oxygen or say like you know aqueous oxygen the dissolved oxygen, but the sludge or the floc which is in within. So, oxygen cannot penetrate till then unlike the because of the boyfriend formation that area becomes the anoxic in nature. In this anoxic zone there prevails the denitrification denitrifying microorganisms understand.

So, this is like a this like a like in a two cluster systems like the upper layer it is like a aerobic microbes in the inner layer or the core itself act as a anoxic zone or the anaerobic zone. So, there the denitrification because of that the simultaneous nitrification denitrification can occur because anyway the nitrogen obviously, nitrogen rich waste water will definitely roam around in the floc right. So, inside the floc what will happen this ammonia rich waste water in the first it will converted in the into nitrite to nitrate and that nitrate rich waste water will come in contact with the anoxic zone and it will convert into nitrogen gas. So, this is how the system runs ok. So, what is happening here in general this this low because of the low DO concentration that is outside of the sludge flocs it is exposed to the aerobic conditions and whereas, the inside it is anoxic in nature.

Due to the utilization of DO in the outer layer it cannot permeate inside the sludge flocs and because of that this anoxic condition can develop much more interestingly. Then it justifies the possible nitrification in the flocs external surface and the denitrification then inside the flocs systems ok. So, in general this two zones of aerobic and anaerobic can be observed depending on the mixing conditions. So, but however, the aeration tank should not be having a DO of more than 0.5 milligram per liter.

So, it should be somewhere around 0.5 milligram per liter better. So, next one is the pre anoxic single sludge system. In the pre anoxic single sludge system what is happening here if you see this picture itself in the first we have the anoxic tank where the denitrification is taking place and the second one is the aerobic one. And then there is a secondary sedimentation tank to get rid of the sludge or the whatever the biomass that it generates or nitrifying biomass that it I mean the nitrifying microbes that it converts into the biomass.

So, that can be collected as a in the form of sludge from the secondary sedimentation tank ok. What is happening in the first stage in the denitrification process? See first you may be confused like you know if there is no the ammonia is not yet converted into nitrate. So, why to use the denitrification in the beginning? Suppose you still have some amount of nitrate rich waste water as well right. So, you can have the nitrate rich waste water in the systems or some amount of ammonia also in the systems. So, same almost in the same all with the same value 10 milligram per liter 10 milligram per liter just for your understanding.

It enters to the system in the denitrifying microbes denitrification systems which is in anoxic in nature. So, because of that what is happening whatever the nitrate fraction is there it converts into nitrogen ok. So, ammonia it stays as it is along with the carbon fractions there are carbon fractions as well like the which still be there available. Then this carbon fraction because in denitrification process some amount of carbon will get dissipated. Then the next stage will be the nitrification where then whatever the rest over of the ammonia whatever the I mean like whatever the rest over of the nitrogen in the form of ammonia it will come to the nitrification chamber.

Because of the aerobic nature whatever the rest amount of carbon and whatever the rest amount of ammonia it will also convert into ammonia will convert into nitrogen and COD will obviously, convert into bacterial biomass there is something like the organic matter ok. Now, then it goes to the sludge system secondary sedimentation tank. So, there along with the return activated sludge excess sludge we also return some amount of activated sludge. What is there in the activated sludge? First of all it has the bacterial biomass ok. Second thing it does have the high amount some amount of nitrate still present because the nitrification is in the second stage ammonia has converted into nitrate.

So, this nitrate rich activate a sludge again it enters to the system in the just before the denitrification chamber and it also helps converting it into nitrogen you understand. However, why to put the denitrification in the beginning then? There is a one of the best like one of the best I mean like the what is the why it is one of the best process to be followed in case of in terms of nitrogen removal because denitrification process needs some amount of COD. It is a COD demanding process it there should be some amount of because it is a heterotopic microbes it also needs to consume the organic organic matter. So, when you can when you can supply it if it is if it first flow through the aerobic systems all the COD level will drastically drop down. So, the amount of COD that is available for the nitrification may not be enough denitrification may not be enough.

So, because of that it is always better to introduce the wastewater directly into the denitrification system along with the with the high carbon source. So, your problem is solved your denitrifying microbes are happy they will perform at its best at the same times because of the retained activated sludge you are also taking care of high amount of nitrate in the system you understand. So, that is how the this pre anoxic single sludge system works ok. So, in this case in general it is because of the denitrification process alkalinity is produced and in the nitrification some of the alkalinity is whatever the alkalinity is produced in the denitrification process that rather helps the denitrification process to occur. So, you do not have to relying on additional supplement of alkalinity I mean additional supply of like sodash or calcium, caramel, lime stones etcetera because it is it already have the enough alkalinity that will that will that is developed in the denitrification process ok.

Second one is the post anoxic single or two state systems. So, what is happening in case of post anoxic single or two state systems you see this in series design. This is in general our with the basic understanding there should be the that is how it is supposed to be right. The first the inlet the waste water will enter to the denitrification chamber. The whatever the ammonia whatever the ammonia present in the waste water it will convert it will be converted into nitrate whatever the cod is there that will also convert into the cellular biomass and the all the carbon dioxide right.

So, then it will then that waste water will go to the next chamber which is the denitrification chamber which is an anoxic in nature. Because of that because of the anoxic environment that is prevailing there because of the denitrifying microorganism that is present there. So, this denitrifying microbes will convert the whatever the nitrate that generates in the nitrification process into dinitrogen gas or the nitrogen gas. However, you may have a issue with the carbon source because of that sometimes from the inlet you can have bypass the line and you can supply the carbon source and the raw waste water as a source of carbon in the denitrification chamber that is how it works. And after the denitrification sometimes you add a tiny bit inlet aeration also in the next like you know like you know accompanying chamber accompanying chamber.

Therefore, further removal of if any amount of ammonia still left in the systems that will also be removed from the systems because some amount of carbon source you are by you are bypassing right. Some amount of waste water you are bypassing from the systems. So, this is one this is also very nice design like you know design I would say sometimes you may if you do not have enough amount of like your waste water does not have enough amount of carbon in that case bypassing will also not do the job. So, you may have to add additionally the methanol or other carbon sources into the system ok. And you have to have maintain a sufficient hydraulic and the sludge retention time also.

So, that the methanol degradation can occur with the with the time that you are providing the sludge retention time that will provide into the system ok. So, in general the aeration of around 15 to 60 minute are provided to release the attached gases for better solid removal in the secondary sedimentation tank as well ok. And so, because the all the gases are whichever is converted into the nitrogen gas in the denitrification chamber gets entrapped into the into the into the effluent itself. So, with this aeration process or you know you are making some agitations and at the end you are actually letting the gases also flow along with this aerated water aerated and that with the air that is that you are supplying through the aeration process ok. So, I hope you understand how the post anoxic single and two stage system works.

So, if I ask you what will be your suggestion which of the system is better this post anoxic is better or the pre anoxic is better I mean like this one is the better. Either this one is the better this pre anoxic where the anoxic chamber is there before the nitrification or this one is better where nitrification is done before the denitrification. Obviously, the pre anoxic one what is the reason because the oxygen is released in the nitrate reduction during the nitrate reduction is used for the oxidation of the incoming organic matter as well in the pre pre anoxic chamber ok. Second thing no external methanol should be addition should be required incoming wastewater serve as the whatever the carbon source that is needed right in the pre anoxic one the last one. As well as the aeration is not required prior to the sludge slating which is required in this case sludge before the sludge slating you need to attach the small aeration you see the denitrification chamber does have a tiny teeny accompanying structure which actually provide the aeration there.

You do not need it in the case of pre anoxic system as well. So, overall with my suggestions definitely the pre anoxic system is much better than the this post anoxic systems and all. There are other type of systems as well for the nitrification denitrification process it is called the closed loop system we all know with the name of rest way isn't it. So, what is happening here? It is used for the treating of wastewater in small or to medium size plants they are operated with a longer hydro retention time of say 20 to 30 hour and sludge retention time of more than 20 days. It is capable of achieving around 90 percent that nitrification provided the temperature of above 10 degree Celsius that is the oxidation ditch we already discussed we already know about it.

We normally reposition this aerators in such a way that the aerobic zone is quite tiny teeny bit in small area and the aeration zone like you know the aerobic or we can actually extend it. So, that we can play with the aerobic zone or the anoxic zone in the system ok. In general in this anoxic zone what is happening there denitrification right and in the aerobic zone the nitrification is occurring. At the same times because of the flow of aeration flow of the aeration the direction that it provides to the system and it continuously revolving around the erase phase and because of that you can actually get rid of the wastewater get rid of the nutrient present in the wastewater in a much higher amplitude ok. So, if you see the inlet it has to be designed the inlet is there from one side just right next to it you can have the outlet because anyway so, that it will take maximum along path to be followed and it will go through first aerobic zone then the anoxic zone then it gets out of the system through the outlet processes ok.

So, this is how this kind of closed loop system works for the process of or simultaneous denitrification and the denitrification process. So, there are some design guidelines some basic numerical that basic stoichiometric equations that we need to understand is the correction for the maximum specific growth rate for nitrifying the denitrifying microorganisms. To start with we all understand that we already understood that the biological nitrogen removal it is susceptible to the external factors such as temperature, diesel, oxygen, concentration, pH etcetera. Based on the practical conditions corrections are to be applied in the kinetic coefficients as follows. If this equation 1 to 6 if you see this equations where these are normally being used please take a picture of it and like if you may need it for if you ever will design any nitrification denitrification chamber or the reactor you may have to follow through this equations and all.

$$\mu_{N\,\max\,actual} = F_T \times F_{DO} \times F_{pH} \times \mu_{N\,\max} \qquad (1)$$

$$F_T = \theta_T^{T-20} \quad (2)$$

$$F_{DO} = \frac{DO}{K_{DO} + DO} \quad (3)$$

$$\text{For pH} < 7.0,\ F_{pH} = 0.0004017 \times e^{1.0946 \times pH} \quad (4)$$

$$\text{For pH of } 7.2,\ F_{pH} = 2.35^{pH-7.2} \quad (5)$$

$$\text{For pH of } 7.2 < \text{pH} < 9.5,\ F_{pH} = \frac{1.13(9.5 - pH)}{9.8 - pH} \quad (6)$$

So, I am not going into details of this equations because it is quite thorough quite easy and where you just need to know the numbers and that is it you can get the values of this specific growth rate easily. So, in this case you just to give you a brief key this F_T it is this it stands for the temperature correction factor DO is the DO correction factor and the pH is F_{PH} is the pH correction factor. So, we will discuss about it more in details in the coming slide. So, in case of denitrification this denitrification this actual growth rate constant for the denitrification last one is there this last one is actually the $\mu_{N\,max}$ actually is actually showcasing you the maximum specific growth rate concentration is in growth rate in terms of nitrification. Here we are talking about in terms of denitrification that is why it is $_{DN\,max}$ actual.

$$\mu_{DN\,max\,actual} = F_T \times F_{DO} \times F_{NO_3} \times \mu_{DN\,max}$$

So, here we introduce another concept we another factor called F_{NO3} it is a nitrate correction factor. So, in this nitrate correction factors what it is all about it can be easily calculated by

$$F_{NO_3} = \frac{F_{NO_3}}{F_{NO_3} + K_{NO_3}}$$

So, this K_{NO3} is denotes the nitrate half saturation constant for the denitrifying microorganism which you can easily find out by this by the other equations that is there in the last. So, specific growth rate the same monoid equations we can follow we can find the value of μ_N specific growth rate with this equation 9

$$\mu_N = \frac{\mu_{N\max} \times N}{K_N + N} - K_{DN}$$

And the effluent tick end concentration also with the equation 10

$$N = \frac{K_N \times (1 + K_{DN} \times \theta_{CN})}{\theta_{CN} * (\mu_{N\max} - K_{DN}) - 1}$$

where capital N is equal to K_N plus 1 plus K_{DN} into θ_{CN} divided by θ_{CN} into $\mu_{N\,max}$ minus K_{DN} minus 1.

If you remember this is having a quite resemblance with the equations that we have solved for activated sludge processes as well. So, the fraction of the nitrate microorganisms in the aerobic reactors in general most of the aerobic systems it is heterotopic and autotrophic are present. So, however, for the ammonia oxidation only ammonia oxidizing microbes are actively involved. Hence the quantification of the specific quantity of microorganism is very information very in essential or informative for us for designing a nitrification system. So, and this is done by the on the basis of the biomass growth rate for both the both the microorganisms hydrotropic as well as for the autotropic.

For the heterotropic this *Pxc* is can be done can be easily estimated by

$$P_{XC} = Y_c(C_o - C)$$

And in case of autotrophs its

$$P_{XN} = Y_N(N_o - N)$$

where this Y_C and Y_N it represents the observed biomass yield for heterotropic as well as for the autotropic microorganisms in the aeration tank respectively ok. So, in based on the fraction of autotropic microorganisms present in the biomass we this equation with this equation you can easily calculate the equation number 13 you can easily estimate the value of it.

$$F_N = \frac{Y_N \times (N_o - N)}{Y_N \times (N_o - N) + Y_C \times (C_o - C)}$$

So, another important very important technology that we are going to discuss today is called the anammox process. It is a very fascinating process because in case of anammox process it is more like you are achieving your goal you are treating the ammonia rich waste water and you converted into the nitrogen dinitrogen gas without involving oxygen like or very very tiny bit of oxygen.

So, that means, even in anoxic condition also you can go ahead with this equation. If you see this figure in the right side you have the ammonia, ammonium ion. So, it is ammonium ion if you go say one fourth quarter you remember we need 4 number of oxygen right to complete the process to from nitrate to nitrate. So, you suppose instead of like you know 4 there like we divided into 4 quarters suppose just to give you a one glimpse ammonia you need one number of oxygen molecule. So, it converts into nitrate this is the call the partial nitrification after then you stop the process.

Then you maintain then you design then you supply some amount some type of microbes which loves to convert this loves to consume this nitrate this nitrite and in the presence of nitrate and ammonia they convert directly this 2 products to raw material into 9 nitrogen gas. They do not follow the whole circle they do not go through the nitrate they do not in the as an intermediate they do not produce the nitrate from nitrite and ammonia it ammonium it directly consumes and it converts into the nitrogen gas ok. So, this is called the anamos this red arrow sign is actually see the anamos process and the whole circle if you see this 2 3 arrow this bigger arrow like in the 2 green and 1 blue this actually make is actually showcases the whole nitrification this green one is the nitrification deep green is the nitrification. So, ammonia it becomes nitrate and nitrate it because of presence of carbon source the nitrification process occurs and converts into nitrogen. So, in case of anamos we take a quick shortcut ok.

So, there we do go for the nitrogen removal without the need of the external carbon source second thing with the minimum uses of oxygen. So, is not it is not it better is not it much better in than the regular processes regular nitrification process. So, in general what is happening here the ammonia first convert into nitrate in the presence of say 1.5 of oxygen O_2. So, it converts into nitrate this nitrate and ammonia now it converts into nitrogen gas.

So, the overall 2 number of ammonia in presence of nitrate it converts into in 2 number of ammonia in presence of 1.5 number of oxygen it converts into nitrogen and 2 number of H_2O 3 number of H_2O molecules plus 2 H_2 H plus this is the overall reactions. In the first step we call it the equation number 14 it is called the partial nitrification in the second step is the actual anamos process.

$$NH_4^+ + 1.5O_2 \rightarrow NO_2^- + H_2O + 2H^+ \quad (14.25)$$

$$NH_4^+ + NO_2^- \rightarrow N_2 + 2H_2O \quad (14.26)$$

During the initial days of invention these 2 stages steps were applied as a 2 separate reactor, but now ever now a days the with the recent advances in the research we design the both we design the system in such a way that the anamos microbes can actually work on it and actually convert do the whole process in the same unit itself ok. In this ammonia oxidation process it is restricted to nitrate only we do not it there is a it completely eliminated the need of additional oxygen demand in terms of aeration energy for oxidation of nitrate into nitrate during the process of nitrification isn't it.

It also can reduce the 25 percentage of oxygen requirement during the nitrification stage and while eliminating the external carbon source completely as required in the denitrification stage also. Also this anamos microbes are autotropic in nature which can oxidize the ammonia using the nitrate as electron acceptor under anoxic conditions ok. This battery is a slow growing and having a 10 fold lower maximum specific growth rate compared to that of nitric microorganisms. The sludge retention time of minimum 20 days is required for proper growth of anamos bacteria and this anamos microbes produce extracellular polymeric substances or in short we call it EPS ok, which causes the better agglomeration of the agglomeration in the granule formations which is may which makes it easier for us to separate the sludge or the de sludge the I mean like the system or de water the sludge at the same time right. And it also causes the high settling rate of sludge flocs and it is does allowing the easy settling of the sludge in the secondary clarifier.

So, what are the factors that it affects on the first of all the free ammonia. It is identified as the major process inhibitor for the anamos process to occur. Ammonium concentration it needs it loves ammonia it is obviously, it helps the ammonia to convert into some other process by product, but the ammonium concentration of up to 1 gram per liter can be handled by the anamos. If it is like less than 1 less than 20 to 25 milligram per liter it is on obviously, the best. If somehow it increases up to 1 gram per liter then that is it the system will there is a chance it will collapse ok.

So, free ammonia concentration should be very low preferably less than 20 to 25 milligram per liter. Dissolved oxygen concentration it should be somewhere around 0.6 to 0.8 milligram per liter which is beneficial because it needs some amount of oxygen for the partial denatrification process to occur right. However, they will die if exposed to the excessive DO levels ok.

So, the DO level also has to be maintained very tiny tiny bit like you know somewhere around 0.6 to 0.8. The pH it should be somewhere around 6.7 to 8.3 it is obviously, ok for functioning the anamos process to avoid the inhibition of inhibition in the process due to the free nitrous oxide or nitrous acid or say like free ammonia present there. Temperature it definitely affects the any kind of microbes growth rate to start with the anamos process they love to have a temperature somewhere around 30 to 40 degree Celsius and it is considered as to be the optimal range of temperature that is to be prevailing in the anamos reactor. So, that the optimal growth can be achieved for those your target anamos microorganism. The salinity it causes the buildup of osmotic pressure in the systems which definitely not expected to be there to which will put in put them in stress condition and it is also harmful at high concentration. If the salinity is very high it is very harmful because it will literally rupture the their cellular cell walls and all.

The lab experiments prove that the effect of salinity is depending on the type of salt and the type of the with the anamos species definitely and this research was done by the Jean et al 2012. So, they have mentioned that this anamos process is depending upon it depends on the type of salt not only the salinity, but the type of salt and also the type of species that you are catching there are hundreds of anamos species that is present that is present there. So, in general this anamos process it can be implemented in either in single reactor or in two reactor two reactor system. Single reactor system it comprises of simultaneous partial denitrification and that successive anamos process in the same reactor itself. Nowadays we are researching more on a system like this single state systems.

Ammonia oxidizing microbes it grow in the outer layer of the microbes a biophil which consume the oxygen for the partial denitrification and in the deeper layer in the cores of it prevails the anoxic conditions and because of that it creates the ideal condition for the anamos microbes to grow in the into the systems. The control over this DO concentration is a very critical operating parameters for this kind of configuration because tiny tiny bit of excess in DO will completely ruin they will complete they will be complete they will die all the anamos microbes will die in the system. The two reactor systems the both the process partial denitrification and the anamos occur in the separate reactors where individual optimal parameter has to be maintained. The first of all in the suspended growth aerobic process the dissolved oxygen level can be controlled to say like 0.3 milligram per liter and in the initial stage we can have a system we can have the first systems where we can go for the partial nitrification with the little bit of oxygen as I have mentioned that 0.3 milligram per liter dissolved oxygen level. Then in the next stage that this water should come to the next stage of treatment system where the only the anamos microbes are there and where there is no addition nothing is they provide no DO is provided from anywhere. So, in that systems what is happening it is providing them with the perfect or ideal condition for the anamos to grow and there will be less risk involved as we can see in the single reactor systems for growing the anamos in the system like this. So, while limiting the growth of 95 micro isms and all. So, this is how it works in the anamos system this is how it performs. So, what are the what are if I ask you why we should go for the anamos processes and why there are multiple research institutions are now working on the process of anamos and which can be a futuristic model for not only forget about futuristic even already they started implementing anamos as a process for converting the nitrogen rich waste water into some by product ok.

What are the benefits of anamos process over the conventional nitrogen removal process? First of all the requirement of oxygen is reduced only it is required for this partial denitrification process to occur from ammonium to nitrite that is it. Second thing it do not require it does not require the addition of external carbon source for the nitrogen removal which is which either otherwise we may have to introduce during the denitrification process. This process also minimizes the release of carbon dioxide emission during the biological nitrogen removal since the carbon source is eliminated and the reduced sludge generation is another advantage of the anamos process this over the conventional nitrification nitrogen removal systems or the processes that we have right now with our in our hand. What are the technical challenge that we may also face? It is not always the like you know the like you know grass is not always greener in this side as well. So, here also there are issues like the longer start up period is required in this kind of anamos period because we try to do it in IIT Kharagpur we have our partner in Europe where we are working on with them on this anamos type of microbes this to grow them and to use them to treat the in a different type of pollutant and all.

So, we get a success we have a couple of publications, but it took us enormous amount of days, enormous amount of failures to reach to that level ok. So, longer start up duration is something that is very important that actually required because of the slow growth of the anamos microbes and it is also susceptible to the high nitrate concentration and high oxygen level. So, very precise process control is required in this kind of anamos reactors and all. And so, you know the precise control can only be done with the skilled operators and which is very hard to find I mean like you have to train them for couple of months and or so, in order to have them ready for operating this kind of systems. So, in conclusion we understood about the pre anoxic single sludge systems which prioritize the anoxy treatment before the aerobic and it enhances the nitrogen removal efficiency by recycling the nitrified effluent plus utilizing the non oxidized organic matter for the denitrification.

In case of post anoxic nitrification system and denitrification nitrification denitrification systems it involves the treating wastewater aerobically first. So, the ammonia will convert into a nitrite and then nitrate sorry nitrate and this nitrate it then it convert into nitrogen in the second stage. However, it necessiate the external carbon addition in the systems and which may face challenges we may face challenges in this kind of systems because of methanol methanol optimization or with the economic disadvantages as well. In the closed loop systems it provides the efficient nitrification by controlling the aerobic and anoxy zone through aerations, but it is it is a it takes a huge amount of land or the land footprint is quite high.

So, because of that it is not encouraged much. Consisting on the partial denitrification subsequent ammonia to direct nitrogen gas conversion anamos reduces the oxygen demand during the nitrification plus completely remove the need of external carbon source in denitrification process. So, this anamos process is coming out as a very budding technology in nitrogen removal from the wastewater treatment systems. And however, this microbes they are slowly slow growing and autotropic in nature it requires minimum sludge retention time requiring some minimum sludge retention time to be there. And several factors which impact the efficacy of the anamos process like and because of that it is very important to have a very careful control over this parameter in the systems and that makes it a little bit difficult for the any layman to actually work on it. So, specially it needs a very high end skilled operators to perform the to work on it to like you know find a way to like you know make it to the next level like to the to use the this process parameters in its optimal way.

So, that the ammonia will be completely converted into the nitrogen gas and without the application of carbon sources and without reducing the aerobic aeration requirement like anything. Because it is it is needed needs anoxic conditions with the only the partial nitrification process to occur which is very little that oxygen amount and that is it ok. So, very good so, we understand some very important concept about the different type of nitrification, denitrification, anamos processes which are actually essential for us to understand to in order to get an idea about how nitrogen is being removed from the system from the wastewater ok. So, anyway in the activated sludge process in the all the existing treatment unit that we have designed we understood they anyway are doing some amount of nitrogen removal from the system anyway I mean like that is there for sure. But there are there should be some specific arrangement that has to be made in case of wastewater does have when it does have a higher amount of nitrogen concentration ok.

So, that is pretty much it. So, thank you so much thank you so much for this for attending it and for listening it carefully. I hope you get to know some very nice and informative information about all the knowledge about this subject. And in the coming lecture we will be discussing about the biological phosphorus removal from and what are the different advanced mechanism what the technologies available in the worldwide right now ok. So, till then thank you so much see you in the next video.