Water and Waste Water Treatment
Prof. Bhanu Prakash
Department of Civil Engineering
Indian Institute of Technology- Roorkee

Lecture -26
Phosphorus Removal - II

Hello, everyone, welcome back to the latest lecture without wasting further time, I will discuss the relevant aspects. First let us take a holistic view of where we are. Wastewater is coming in and I want to treat that because it does not do not want it to contaminate and pollute my surface water bodies like lake, streams or rivers. What is it that I need to do? I need to remove some particles.

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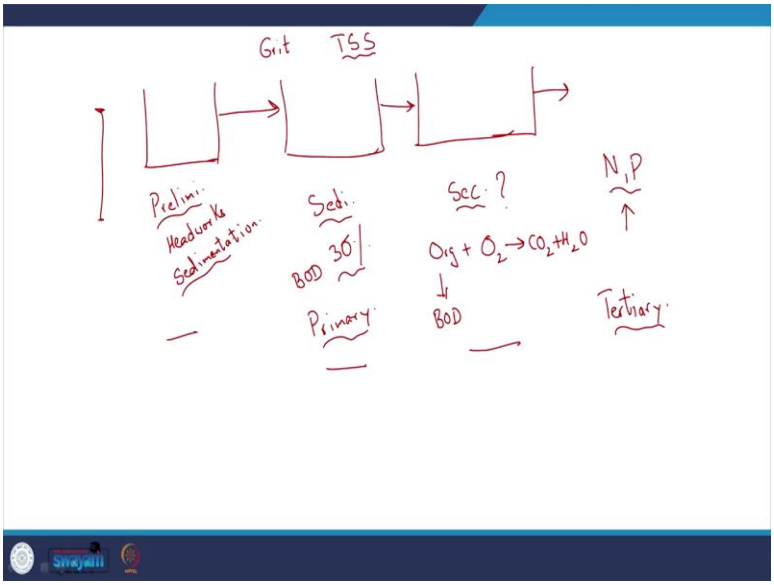

or decrease some variables. What I am I concerned about first grit. So, for; Grit and other respects have preliminary treatment, preliminary treatment. And this I also need to pump the water up if required so head works will also come into the picture. And what is the principle gravity, we are going to use gravity. Sedimentation is the principle yes. We were done with that, sedimentation. And then I am going to remove the Suspended solids.

Suspended solids typically sedimentation is my primary mode of removing suspended solids. Some of what we say organic content will also be removed. BOD we are about 30 of 35% BOD

will also be removed here. And then we moved on to looking at biological processes, which we are calling as secondary treatment. This is secondary. This is Primary, primary treatment.

Secondary treatment what is the principle I am using microbes and microbes in the presence of Oxygen will degrade the organic matter. Organic matter is the dissolved BOD or soluble COD and they will go to the byproducts. This is what we are trying to do so, preliminary primary and secondary of the biological process. Here, principle we discuss this in detail. We will not go to that and now we are talking about nitrogen and phosphorus removal the nutrient removal. This is the tertiary treatment process.

So, tertiary, this is where we are. In that context, we already looked at nitrogen. nitrogen first, we are going to look at nitrification as NH_4^+ being oxidized convert NO_2^- , NO_3^- by the microbes. And then de-nitrification we looked at that. We will relook at it today or in the session but I will not look at it now. We will now discuss a slightly in slightly greater detail about Phosphorus removal. What is the principle now unlike removal of the traditional Organics of the BOD or removal of degradation of Nitrogen.

We are not going to look at what we say Phosphorus being oxidized or search. But how are we going to achieve removal of this Phosphorus? We are going to achieve removal by phase separation. Phase meaning, gaseous phase 1 Phase, solid phase is another phase, Aqueous phase of the water which is another phase. I am going to see to it that the Phosphorus which is in the aqueous phase is taken up by microbes and they are removed via sludge or the solid phase and then settled down. So, that is the principle.

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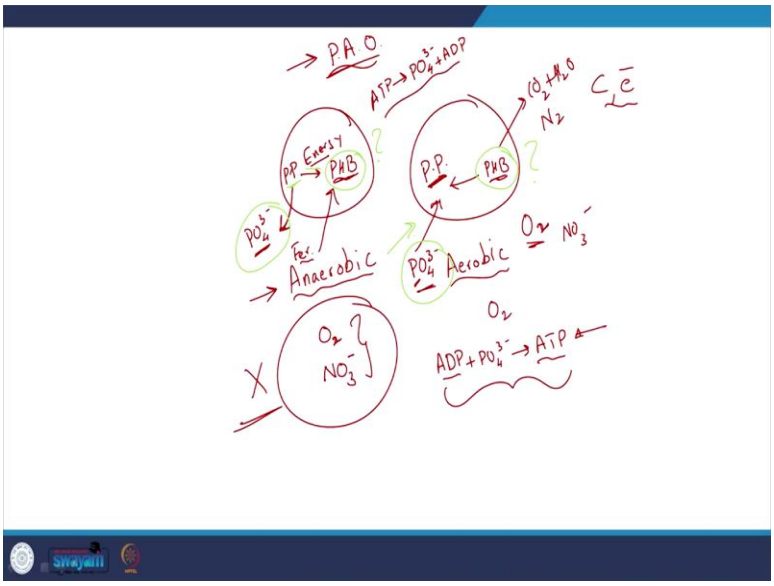

But, in general, these Phosphorus accumulating organisms do not predominate, but I want them to thrive. I need to come what we say see to it that the ecological pressure or the environmental conditions suitable to let this Phosphorus accumulating organism thrive. I need to see that those conditions exist. So what is this condition? We looked at that. I will talk about it briefly. Then we look at it more detail.

For most people the brief understanding is good enough for those who want to look at in detail, you can pay attention to the aspects will discuss after we look at the slide. So, one is anaerobic conditions meaning we do not have any electron acceptors here, . Not an anoxic, not anaerobic. Anaerobic, Anoxic is the electronic electron accepted. In this case, we typically in the anoxic case will have what is it, NO_3^- as the electron acceptor.

In an Anaerobic, we do not have oxygen or NO_3^- and the next will have aerobic conditions. So, when we are having these alternating conditions of aerobic and anaerobic we are trying to put the system when I say system, the microbes under pressure. So, sometimes during not sometimes during the aeration phase, they have the electron acceptor, which is Oxygen they have carbon from the waste, yes.

They have the carbon or the waste water is the source of electrons or electron donor. Oxygen is the electron acceptor. So, they can use this redox process to either for self census or for

generating energy needed for their growth. But when you put in an aerobic, well there under stress they cannot thrive . The usual what we say at Heterotroph, that we look at. But here we are trying to see to it that the conditions favor, Phosphorus accumulating organisms.

Let us understand why these can thrive while the others cannot. So, during the aerobic phase, what happens now? As we know as I mentioned too, Phosphorus will be taken up. Phosphorus from the water will be taken in and polyphosphates will be formed. During this, during part of this, how does it work? Adi-phosphate + PO_3^{4-} will go to ATP. We discussed this earlier. This is part of it which is involved in the, , for Phosphorus being taken up to form polyphosphorus .

Phosphates are being taken up from the water and wastewater. We see that the phosphorus being accumulated from poly Phosphorus and , why is it that they are trying to do this because Poly Phosphorus is used as a source of energy. During this aerobic phase though, when electron acceptors are plentiful they use this PHB switch, they will accumulate during anaerobic phase. They will use these PHBs. It is a source of carbon. It is a source of electron.

So, and they will use the oxygen available here readily available. And what is it now this will go to either, CO_2 and H_2O or if it is Nitro: NO_3^- is electron acceptor. It will go to N_2 and saturates depending on what it is. Oxygen will be used to what is it, now oxidized the PHB hydroxybutyrate and then go to the end products. But where is this energy going into? This energy will be needed for the formation of polyphosphates.

And also this energy that they gain when there is enough carbon not carbon, , sources of carbon and the electron donor and also electron acceptor in the form of oxygen. So they can thrive. So, they will use that also for cell synthesis and also for accumulation of this polyphosphate. Why do they accumulate it here? Because in the; anaerobic conditions they will not have this Oxygen or the electron acceptors.

So, what they do under this stress conditions. Under the stress conditions which we are trying to maintain by anaerobic what we say conditions these, what is it, now, fermentation product will be formed and these Phosphorus accumulating organisms like the fermentation by products. So,

they will take these by products and they will form PHB. Why because they can be used later, why?

So PHB will be formed but for formation of this PHB from the soluble Organics in the, or the fermentation by products from the fermentation by products. You will have the PHB being formed. For this, they need energy. They need the energy and how will they get this energy by the transformation of polyphosphates during which Phosphorus will be released. So, from this energy will be released and that will be used to accumulate this PHB.

And in this process , you are going to , have the energy carried out and electron carried in this way. This is part of it. PO_4^{3-} is being released. Let us see what we do not need to look at this in detail. This is a part of it which is involved in the formation of PHB, not PHB pardon me, Poly Phosphorus being degraded such that phosphate survives. , what is the Crux of this issue now?

Here energy is being , released internet internally from the polyphosphates being degraded to form PHB. But why are they forming PHBs here? What is the role of this PHBs see? Why do these microbes do that? Everybody wants to thrive. Similarly these Phosphorus accumulating organisms want to thrive. They want to out compete for the food whenever it is available later on, meaning in the aerobic phase.

In the aerobic phase as we see here, you already have these microbes, in to have these microbes already having a source of carbon or an electron donor, which is the PHB . They already have a reserve of energy. You can think of it in that way. So they will outgrow The Other microbes that can thrive in the aerobic conditions. why is it that when to do that because they want to dominate the microbial community.

And these conditions we want to recreate because as you see here do Phosphorus is being given out here. It is being taken up here. And then we see that if you look at the net Phosphorus uptake it is relatively higher. So, all these microbes will take up the Phosphorus and will remove them with the sludge. So that is the aspect. Keeping in, keeping them under stress , alternating aerobic and anaerobic conditions.

And then, what will I do these microbes will start thriving and we just saw the reason. And we looked at in slightly more detail.

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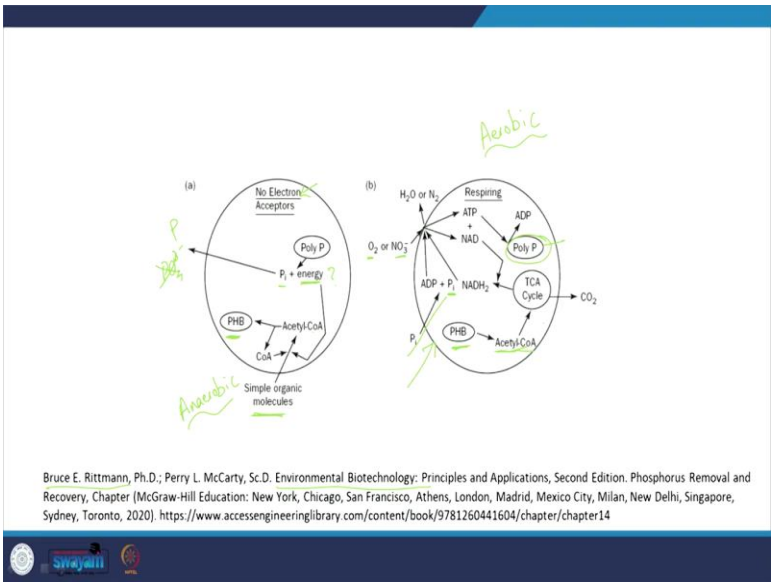

This is from Bruce E Rittman, Rittman and Environmental biotechnology principles and applications. Bruce E Rittman and the L McCarty so, here we have the anaerobic conditions where there are no electron acceptors. Yes and as we discussed what is happening out here PHB has to be formed. And for PHB formation energy is required. Where is the energy coming from?

Energy is coming from the degradation if I may use this layman's term of polyphosphates into Phosphorus. So Phosphorus is being on the phosphates of phosphorus maybe is being released and energy is released. And this energy is used for the formation of PHB polyhydroxybutyrate. But as you see within this, you have some steps, H_2O and so forth which is required for polymerization and for the formation of this carbon.

Where is the carbon coming from? It is coming from the fermentation by products, in this particular anaerobic condition. This is the anaerobic condition. So, here we see that they are accumulating Carbon and electron donor sources. And now when it comes to aerobic conditions later when the microbe comes into the aerobic conditions, what is happening now? Now they have oxygen available or nitrates available.

These are the electron acceptors and they already have the PHB available. With this PHB polyhydroxybutyrate which is an electron donor source of carbon. They can outcompete or outgrow the other microbes . They can use the carbon sources from outside but more importantly they also have stores of if I say energy or search or carbon and electron donor here. And , you can see it goes to styles COA and its cycle.

And in this context, energy is released and what does or where does that energy go or part of that energy? It goes into formation of this polyphosphates. , for polyphosphates formation you need this Phosphorus and the phosphorus will be taken from the solution, . So that is what happens with this cycle. As you see in the aerobic cycle, you will have the Phosphorus being taken in more details. You can look at that. there is the role of Style COA, for which the energy is required . Here at least so let us move on.

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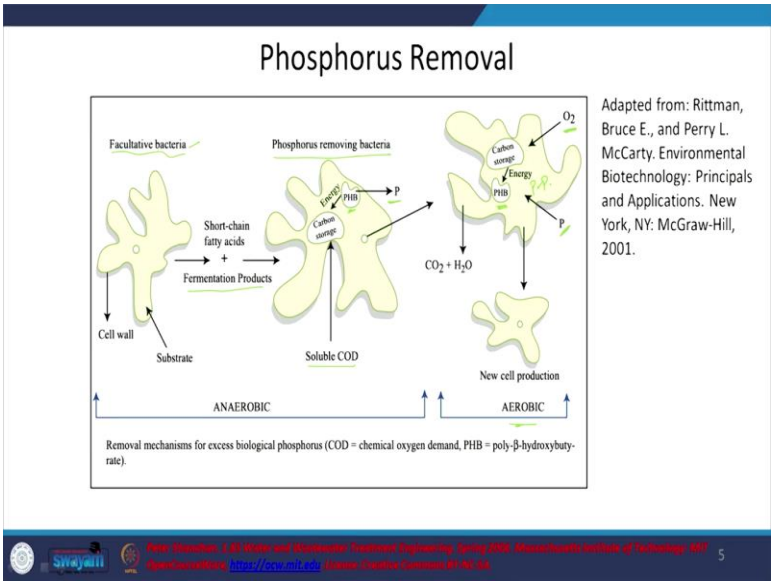

So MIT open courseware. We look at adaptation of the previous figure. So what do we have here? This is the Facultative bacteria that can thrive in both aerobic and anaerobic conditions. And during anaerobic conditions you have the fermentation products . Why is it that we want this? Because these fermentation processes are liked by the Phosphorus accumulating organisms . This soluble COD will go into formation of the here PHB and the energy required will come from the polyphosphate releasing Phosphorus and being degraded.

And then in the aerobic conditions of what is been happening is the reverse happens. Now, you will have the PHB being degraded in the presence of oxygen, . PHB is a source of carbon and source of electrons . And you have an electron acceptor and these carbons and electron results will be used by the microbes for new cell production and they will outgrow the other microbes.

That is why they want to do this and in that process estimating that they will be under stress later. They will take up this Phosphorus to form the polyphosphates which will be used during the anaerobic conditions for source of energy, , for the formation of PHB. So this is the cycle that we have polyhydroxybutyrate , .

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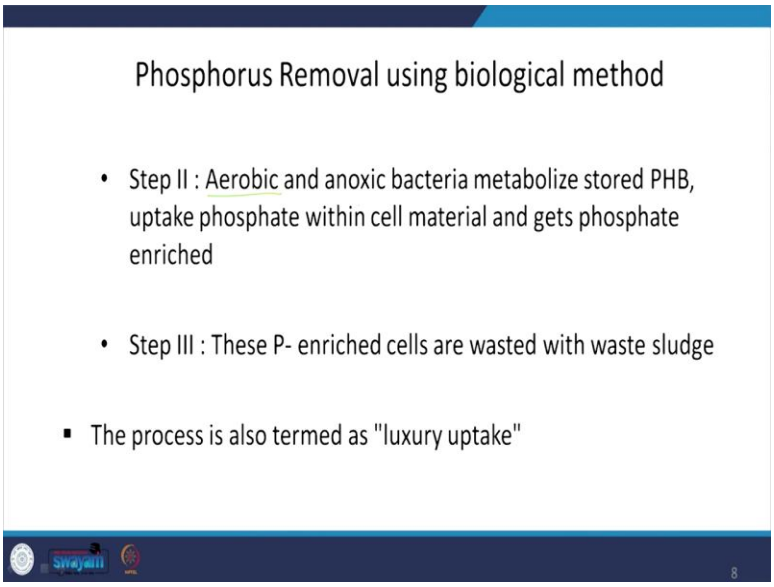

So let us move on. So, Phosphorus removal as we mentioned. I can skip this aspect. Let me see if I talked about the fermentation bipod's is released into the ok, release occurs. In anaerobic conditions let me just highlight this ok and then anaerobic conditions, Phosphorus or ortho phosphate will be released. Under the aerobic conditions, we will have Phosphorus being taken up, updates. So that is something but we can also look at our view can also look at the details.

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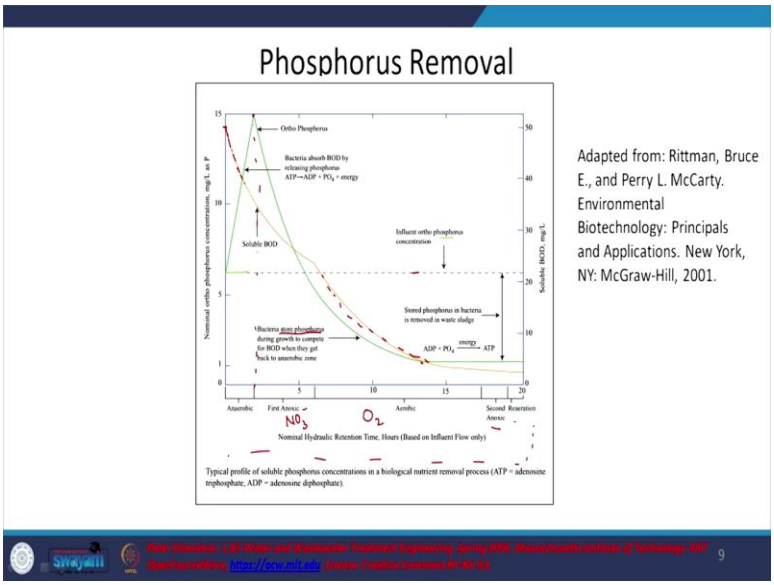

And what else happens in the system, what happens to the soluble BOD? So, first if there is an anaerobic case, , how is this going to be achieved? You are going to have recycled. But in one cycle, let us see what happens. So the waste water is coming in here. Yes, influent of the phosphors concentration is highlighted here that is the influent of the Phosphorus concentration and let us see what else we have?

We have been influent soluble BOD out here, so this is anaerobic. In the anaerobic conditions, we know that faculty to microbes will transform this particular, you will have the fermentation products being formed and there is fermentation products will be taken up by your bacteria the phosphor accumulating bacteria. That is why you see your BOD decreasing. And during that time we know that the Phosphorus will be released so that is what we see, that the Phosphorus increased during this peak, yes.

After that anoxic condition, you will have nitrate as electron acceptor, so now, you have respiration in a way. And here O_2 as electron acceptor and during this phase what is going to happen Phosphorus is going to be taken up, that I will store Phosphorus during growth to compete for BOD when they get back to the anaerobic zone. Well that was explained in a slightly different way, but that is that you see phosphorus. Though you see initial increase in Phosphorus, if you look at the net Phosphorus here? It is much lower than or lower than the initial concentration of phosphorus.

And you see that the BOD is decreasing . And then second anoxic and rehyration later you will have recirculation out here. So stress, no stress, stress and the bacteria that can best, adapted will be the ones that will thrive.

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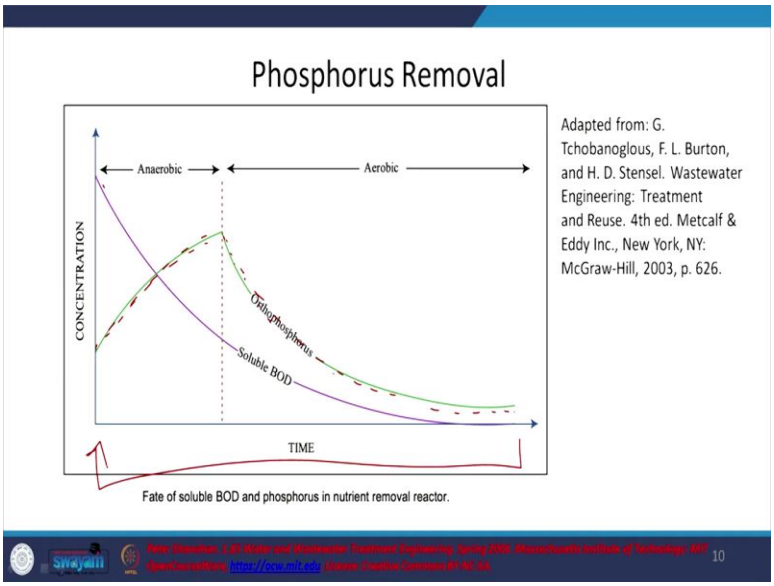

So, in a different way that what is mentioned in a clearer picture out here. So anaerobic conditions, Phosphorus is being taken up, soluble BOD will also decrease and of the Phosphorus will be pardon me, it will be released here in the aerobic conditions. Aerobic conditions for stress Phosphorus will be taken up into the microbe. That is why for the Phosphorus in the water or wastewater will decrease all the times soluble the BOD will decrease.

And then, you are going to have recycled of the water so that the microbes, , over time understand that there are going to be put into stress. That is why they take up the Phosphorus. So, let me just summarise nitrogen removal.

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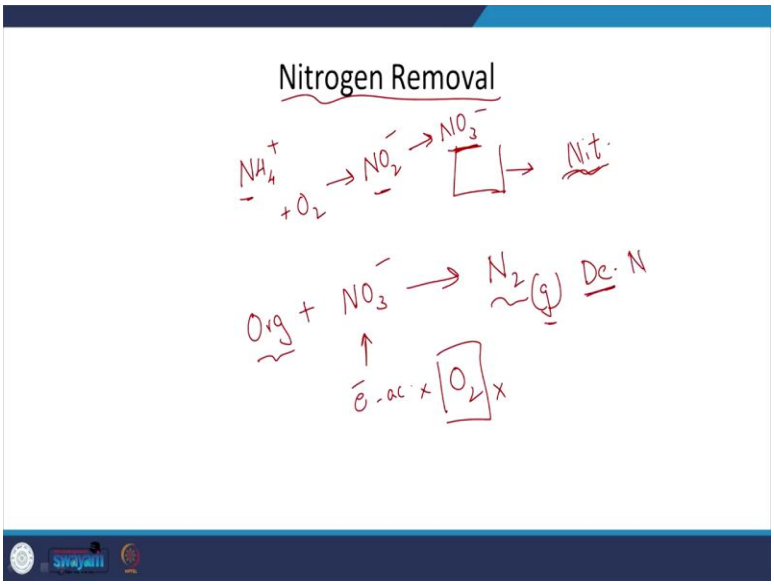

Why because we are going to look at aspects we looked at earlier, the kinds of configurations, where you can achieve nitrogen removal. We did look at briefly earlier. I also want to spend some time now because you can then compare it with Phosphorus removal configurations. Nitrogen removal, what are we trying to do or how do we try to achieve that? Primarily we have NH_4^+ and then in the presence of oxygen, we want oxidised it to NO_2^- and then NO_3^-.

Ammonia oxidizing bacteria and nitrite oxidizing bacteria, But NO_3^- is very soluble. I still need to remove it. So, how do I do that? I will see to it that this is used and an electron acceptor. But for this to be used in electron acceptor oxygen should not be there, if not Oxygen will be the preferred electron acceptor because more energy is released that way. And what is electron donor? Organic compound is the electron donor.

And then at the end of the day you will have formation of Nitrogen which is gas. And then can be released into the atmosphere we will see. And tells you are going to have denitrification here and nitrification here. Nitrates are being formed that tells nitrification, , nitrogen is being removed from the system by formation of gas which will leave the water so, denitrification, denitrification.

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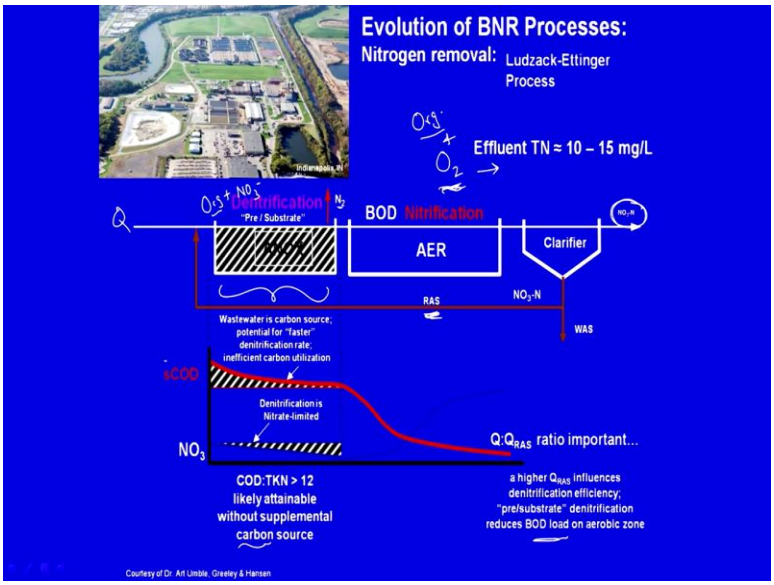

So let us look at the configuration once. Let me change my ink color, Nitrification and nitrogen removal. So here, what is a nitrogen removal and we have the conventional activated sludge , this is the conventional activated sludge. And what do we have here the BOD and depending upon the solid retention time, the sludge age and the oxygen concentration you will or can have nitrification.

So, during that nitrification, or during this BOD aeration, you will have the soluble COD being decreased. Ammonia too will be degraded depending on how you are maintaining it. If ammonia is being oxidized pardon me, nitrates will also increase but when will this typically take place only when most of the BOD has decreased only then will Ammonia start be, start being used as an electron donor.

If not the preferred electron donor is the organic matter. Only when most of the organic matter has been degraded, well Ammonia dictation come into the picture. That is one thing and that is why you see an increase in the nitrate formation out here. So, this is what we have, . But then, you have a lot of nitrate in the outlets. Ammonia comes in, nitrate is going out nitrogen removal is due to cell synthesis collect.

As we know 12% of Nitrogen will be taken up by the microbes' . So, that will be the Nitrogen removal. And then I still have nitrogen here. So what can I do? There is a process work man

process. we have the same system as earlier but now I am going to put an anoxic tank after the aeration system and anoxic. What is going to happen during the anoxic phase endogenous meaning the bacteria will use their own selves for or feed on their own self for cell matter.

That is endogenous respiration. If I message you why because I, as you see here, by the time it comes into the anoxic tank, you do not have the, , carbon source anymore? They need a carbon source for cell synthesis, we looked at the reaction earlier. , they are going to feed on their own selves. And here we have nitrate, as from earlier case.

A Nitrate will decrease and this particular system . Endogenous respiration is the carbon source and typically that slow so typically this denitrification rate is slow. But to improve this, what can I do? So a different quality looks like total nitrogen will be 15 mg/L which is not too low. So, to sustain this, this is the ratio of COD to TKN organic and Ammonia nitrogen to sustain it.

But with in general, this is not possible without supplemental carbon source. So, I need to add a carbon source or an electron donor source. So I typically add methanol . With that methanol, what is the profile going to look like? So this is what we see the red dotted line is increasing because they added methanol. COD is increasing and then is decreasing because, why is it decreasing because the microbes are using that as an electron donor.

Methanol is being used in electron donor and nitrate which was there is being used as electron acceptor, and then you have the relevant denitrification and to and that is what you see is what you get. So this is one particular way to go about it. Let us look at another configuration here. So here we have the anoxic tank before the aeration tank. And let us see how the profile is going to look like theoretically you will have denitrification.

But when will you have or what will be the denitrified here, whatever nitrate is coming into the picture or the nitrate that is in the aeration tank, which is being recycled will be degraded to N_2. But you the issue are that you will also have nitrates leaving the system which is not something that you want. So, let us see what else or how this system is going to look like? So, COD or TKN, I mean TKN can be greater than 12. So you do not need to add an external carbon source.

Why this is fresh wastewater? So, typically even though with recycled the COD to TKN ratio is available. So soluble COD and nitrate though is relatively less even though you recycle them, Ok so that the decrease in COD and the decrease in nitrate which is not great. Wastewater is the carbon source, , it can go faster, but it is not because there is not enough Nitrates out here. So what can you do?

So this ratio Q : Q_{RAS} return activated sludge the Q : Q_{RAS} is important. A higher Q_{RAS} will influence the denitrification efficiency. Pre-sub state denitrification reduces BOD load on aerobic zone, why is that? Here I need to put in money to pump in oxygen, But what is happening? What am I trying to remove? I am trying to remove organic matter here. Organic matter will have to be degraded by in the presence of microbes by oxygen, .

The presence of oxygen by the microbes, but some of the organic matter will be degraded here itself. NO_3^- for which I am not supplying any oxygen. So that is why it will decrease the BOD load on the aerobics or so affluent quality will be little better than earlier. But still not pretty good. So that is one aspect modified single process. So what do we have? This is the simple system as what we had earlier.

Let us see but then we have an internal recycle, . And looks like this internal recycle is 2Q to 4Q. This is Q this is Q_{RAS} and this is 2Q to 4Q. Why are we doing this? For example, earlier we saw that here, we do not have a lot of nitrate. And if I can get that or more nitrate then I can, , improve the kinetics in this part of the system, this part of the system.

But I cannot increase the return activated sludge to whatever level I want to. It is going to depend upon the mass balance. The RAS return activated sludge is going to depend upon the mass balance and only then will I know how much I can pump as such. But without disturbing that, what can I do?

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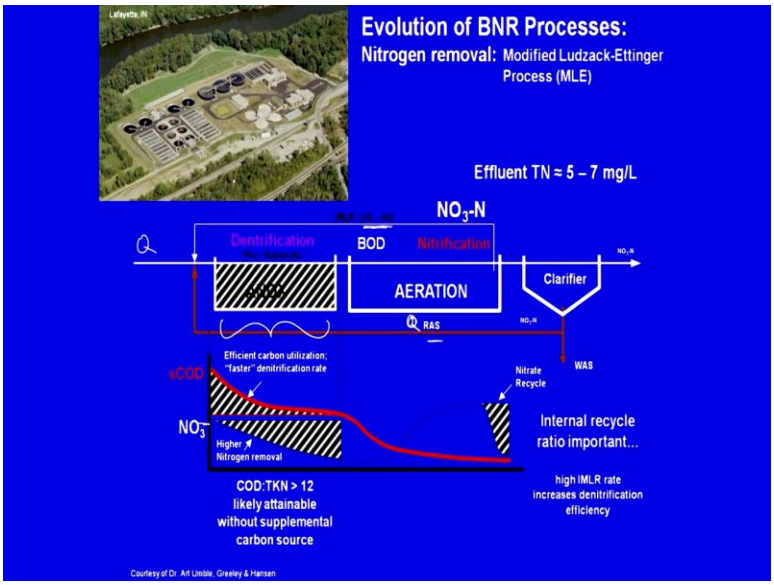

I can look at the internal recycle of the MLSS or switch to 2Q to 4Q. Nitrate is being recycled. Why though some nitrate but now only well to be less nitrate will leave the system, we will see why total in general. So, soluble COD higher degradation during this anoxic phase why is that there is more nitrate. So efficient carbon utilization and higher nitrogen removal and during aeration you have for the removal of the COD or BOD.

And during aeration, you will have nitrate being increased but because it being recycled you there in effect saying that it this is what it will look like. In general net, you will have a greater nitrate removal. So the source of nitrate for the anoxic tank is not only from the return activated sludge, but from the internal recycle. Internal recycle rate important higher increases the denitrification efficiency.

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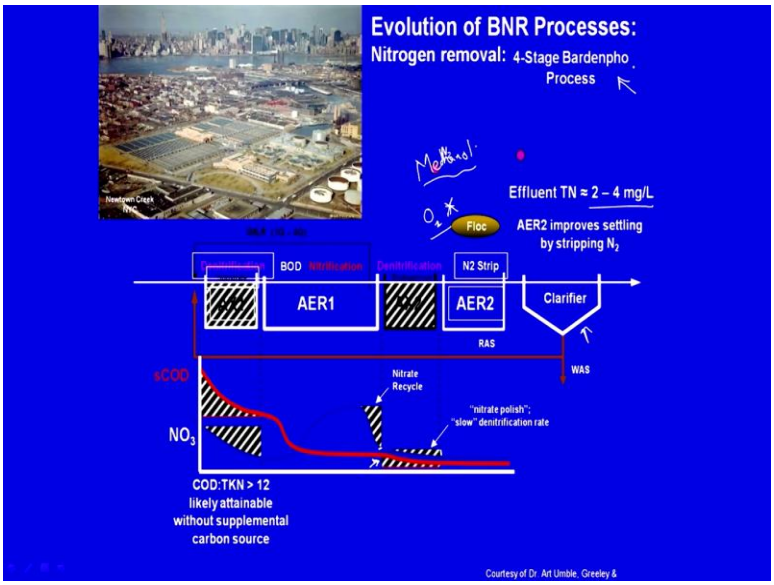

And as you can see total nitrogen ratio is pretty low. And this is the four stage Bardenpho process. Let us see what we have. We have denitrification, nitrification, anoxic tank here, aeration and internal recycle here. This is more or less the same as what we had earlier internal recycle and the General sludge we can say. But, what else we have a denitrification anoxic second anoxic tank, what is going to happen?

Similar profile until now and here you have further denitrification, . So, thus level of nitrate too is being removed because you have a second denitrification tank for nitrate washing tank. Earlier case you had only one anoxic tank before aeration, pre-substrate. Now, you have an endogenous one, in this endogenous, am I supplying anything? No, I am not going to supply oxygen, I am not going to supply anything. I am not going to supply any methanol.

Why because I want the residual carbon or organic compound also to decrease . I am not going to add any methanol so the remaining what is it now. Nitrate and remaining organic carbon or the, , what is this, organic carbon or endogenous respiration by cell mass being used for respiration will take place. That can affect the quality of your this thing but how to maintain at the endogenous growth phase. This is the 4 stage Bardenpho process.

Then aeration to strip your nitrogen say, aeration here improves settling by stripping nitrogen. Nitrate what is it, Nitrogen gas will have to be removed. So you will bubble air through it to strip

the air. What is it? Nitrogen from your system so here, much lesser total nitrogen (TN) is 2-4 mg/L. This is now being used especially in cases where nitrogen is an issue. So let us move on.

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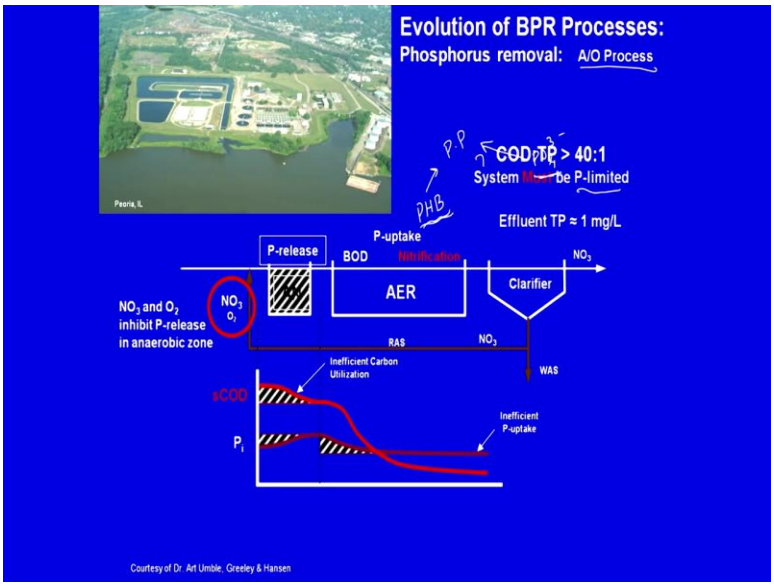

Phosphorus removal we already discussed the aspect. But here we have we are not requiring or not look like just anoxic process. We want anaerobic process no electron acceptor in the form of nitrate or oxygen. So let us see what the configurations look like. So, we have the evolution of the biological Phosphorus removal, initially A/O process. So this is the typical activated sludge process here, and you can have Aerobic before.

So what do we have net here anaerobic or stress conditions and then no stress conditions and then recycle. So, these microbes which are being continuously recycle. What is the, their experience in stress and no stress? So here, they are going to accumulate that PHB while releasing Phosphorus and during this phase they will use of that PHB, use of the PHB that they stored so that they can outgrow the other microbes.

And where is this energy going from, this not going from where is the energy from this degradation of PHB going into? It is going into formation of the polyphosphates. For formation of polyphosphates, what is needed? The Phosphorus from the water will be taken up, , . So that is how Phosphorus removal will take place within this aeration system. So what are the issues here? So, phosphorus uptake Phosphorus with these let us see. So COD is decreasing fine.

Why is this decreasing slightly? Because as in the; anaerobic phase Phosphorus will be released when the polyphosphates are being degraded to give energy for formation of PHBs. And some of it is decreasing not a lot of the soluble COD, why is this? Fermentation products and then, they being taken up by the microbes and search or even for cell synthesis of some microbes.

In the aeration tank kinetics is faster. Phosphorus will be taken up that is why it is decreasing but as you see R net is not great. Why the, r is net removal or net removal
of phosphorus not very good? Well because when you are recycling it here you see that there will be some oxygen here and also nitrate certainly. And that nitrate is coming into the picture here.

And as we look that the Thermodynamics if you have nitrate or the relevant electron acceptor like some oxygen or at least nitrate which is an electron acceptor. They do not let your Phosphorus accumulating organisms thrive not denitrifiers of such might thrive. Let us see what else we have. So this is the COD and phosphorus removal their For increase and then decrease, inefficient carbon utilisation inefficient Phosphorus uptake, .

COD to total Phosphorus must be greater than 40:1. System must be Phosphorus Limited Effluent total phosphorus is around 1. Why is it the nitrates and the oxygen, inhibit be released in the anaerobic zone and not really anaerobic zone, so difficult to maintain anaerobic conditions.

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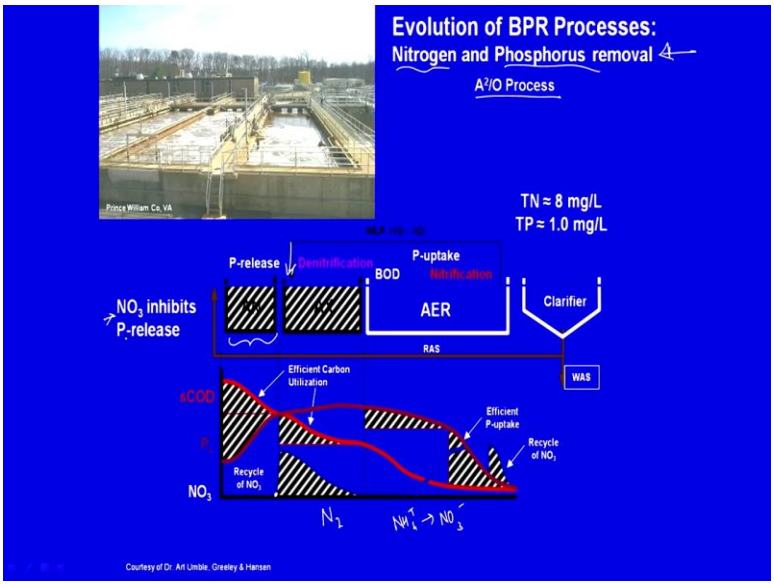

So this to A/O process is widely used at least in India. Let us see what it is about. Here also you have the aeration base and before that you have the Ax for anoxic. So this will in a way will remove nitrogen that something we looked at. So that is why I wanted to look at nitrogen removal also earlier. So we are now looking at nitrogen and phosphorus removal, . It was finally looking at Phosphorus removal here.

Anyway, we are looking at what is this? Nitrogen and phosphorus removal so it is A/O process. So what do we have? Anoxic tank here, aeration system out here with internal recycle, internal recycle nitrates form here, will come here in anaerobic tank and you are having denitrification. So, with the Addition of this anaerobic zone, what are you going to have? You are going to try to achieve Phosphorus now, let us look at the system.

So we have the soluble COD decreasing as such and why is it relatively better because as we looked at it in the case of Nitrogen removal with the internal recycle the nitrate concentration that goes through to the clarifier and is returned to the anoxic tank will be well to be lesser. That what you see recycle of NO_3, . So that is going to be pretty less. So the anaerobic conditions are pretty well maintained. No source of electron acceptor, like NO_3^- or such.

And what else is happening out here, Phosphorus as you can see has been taken up Board during the aerobic phase and during the nitrification phase so, efficient Phosphorus uptake. So phosphorus released during the anaerobic system not much during the denitrification phase

when nitrates are present in a lot . And then slowly you have the Phosphorus uptake happening in the aeration and then during nitrification Phase you have a lot more efficient Phosphorus uptake rate.

And what is happening to nitrates. This is increasing here. Why is this because there is a recycle coming in. So nitrates are increasing and then, denitrification is taking place, nitrates are transforming into N_2 during denitrification and then they are increasing because NH_4^+ is going to be oxidized to NO_3^- so they are increasing and then recycle is occurring here.

So that is how more or less we are getting Nitrogen and phosphorus here. So, total nitrogen is 8 and total Phosphorus is 1. So we are getting more nitrogen and phosphorus removal . But , depending on the level it is how efficient you maintained. If NO_3 is present here. It will inhibit the Phosphorus release .

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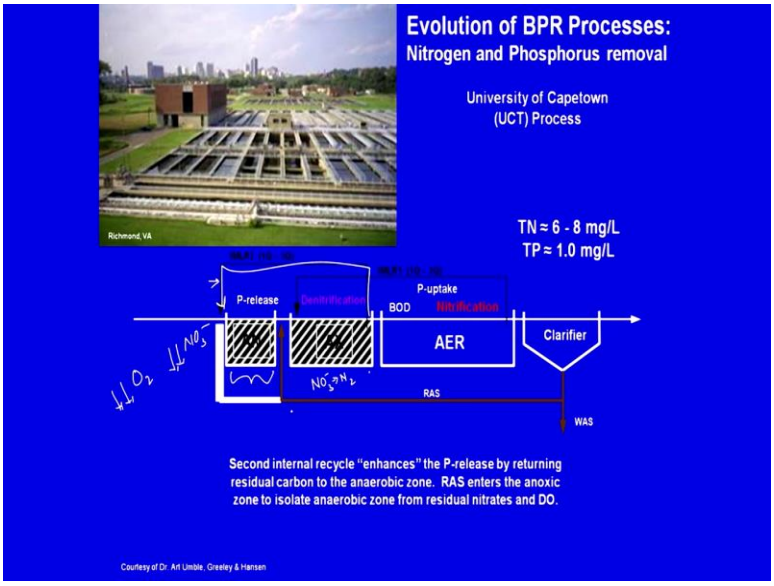

So looks like we have another variation. We will just look at two more variations and end the session. So this is what we looked at until now, But the issue was that here the nitrates if any or those which might be present in this waste or return activated sludge will affect the Phosphorus, , accumulating organisms here or phosphorus release here.

Without Phosphorus release they cannot store the PHB, . So let us see what are they doing? I will not recycle it before the anoxic tank, but I will recycle it just before the, not before the anaerobic tank pardon me, but just before the anoxic tank. So this way the nitrates they are not coming into the picture. They are not coming in contact with your anaerobic phase.

But they are directly going into your anoxic tank nitrates. And then you need to have a internal circulation. Why is that? If not if it is just straight flow, there are going not going to be any microbes in the anaerobic tank, . you need to have a recirculation here. So here you are going to have anaerobic conditions not anaerobic conditions, but nitrate is being degraded to N_2.

And you have system that has relatively to be less nitrates at the end of the system. So if I recycle from here, the nitrate concentration will be very less. And anyway influent wastewater I know that oxygen concentration will be able to be less. So, anaerobic conditions are usually better maintained. Let us see the second internal recycle, which is this, enhances the Phosphorus released by returning residual carbon to the anaerobic zone.

Return activated sludge enters the anoxic zone to isolate anaerobic zone from the residual nitrates and DO so that something we already discussed. So I better total nitrogen removal, .

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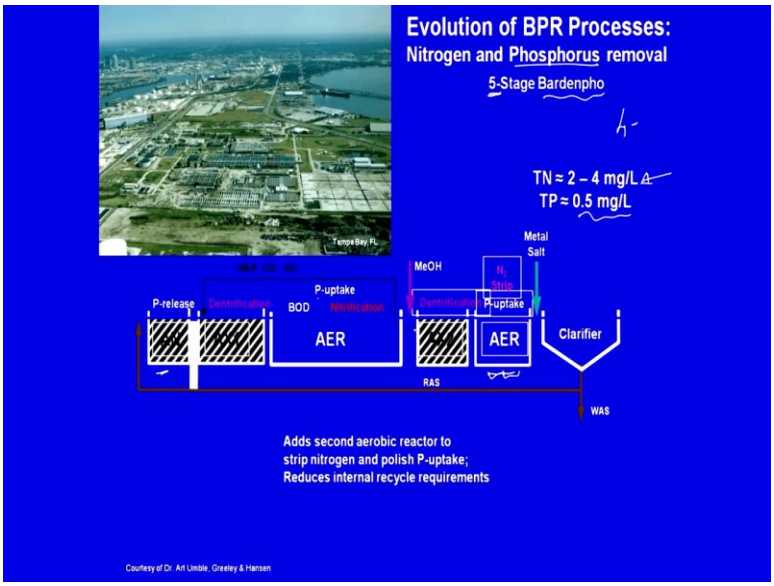

And then, the evolution of the BPR process earlier for the Nitrogen removal would look at four stages, but then for Nitrogen and phosphorus removal, we see a something called a five stage model Bardenpho process. So, let us look at what this is about it . Earlier I think this was our four stage Bardenpho process. We had a denitrification tank before aeration system or aeration tank and internal recycle.

And then we had another denitrification tank where it was endogenous respiration the cell mass itself is being used as a source of carbon or the electron donor and NO_3^- was the electron acceptor. And then you had the aeration to remove this remove your nitrogen from the system the nitrogen that is given out during the denitrification. You are you are supplying here to strip the nitrogen from the relevant system here.

And so here what do we see in the aeration system? Phosphorus uptake will take place because we are pumping here, some more Phosphorus uptake will take place in this area and by adding this anaerobic tank here, for the system to Experience stress and see to it that Phosphorus accumulate organisms thrive well, what do you need? You need alternating conditions of anaerobic and aerobic.

So , we have aerobic but now we need the anaerobic tank also. That is why it is called the five stage Bardenpho process. But here , rather than putting it up here, they are going to take the recycle much further there. Add second aerobic react to strip nitrogen and polish Phosphorus uptake. With more aeration more Phosphorus will be taken up reduces in, , internal recycle requirements.

So now, you see Phosphorus pretty good, total nitrogen also pretty good. , the whole thing is to understand that you need carbon source or electron donor and electron donor, you need an electron acceptor. That is for aeration and denitrification, . But for Phosphorus you need aerobic and anaerobic conditions. And that is how you try to play around so that you get the relevant optimum condition .

So metal salt, sometimes you add them for chemical precipitation of phosphorus. And you can add methanol if you want to increase the denitrification, but that depends on what is the residual carbon content here let us see.

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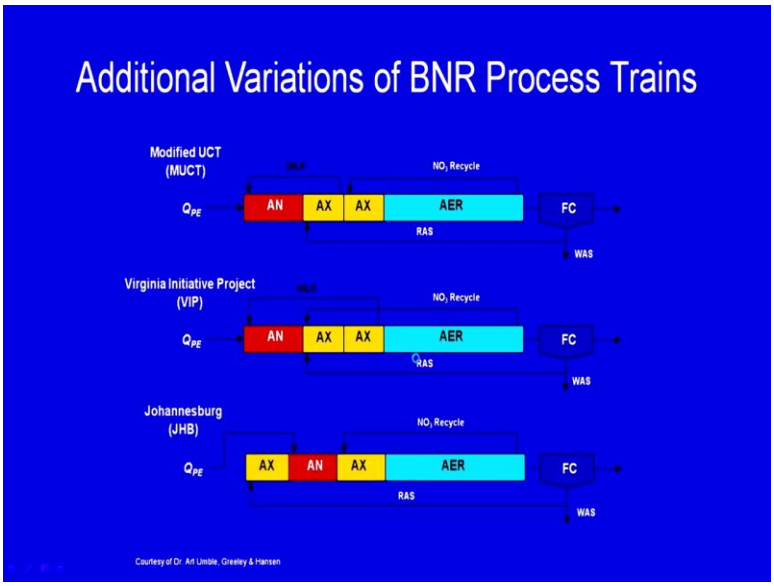

Additional, , variations of the BNR process, but maybe we will ask in the relevant Quiz or such but we will just have this information here so that this can be asked in the relevant quiz or the homework . Modified MUCT, Johannesburg , Aerobic, anoxic aerobics different variation but will not go into detail at this stage here.

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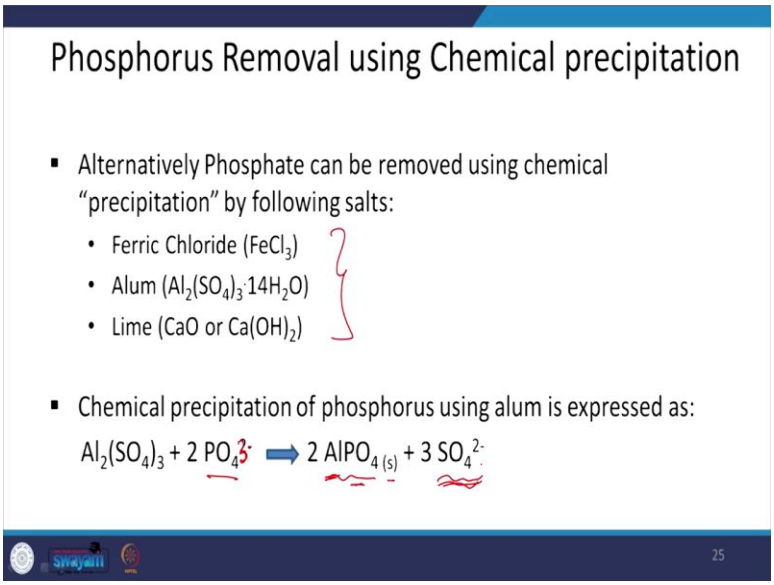

So, Phosphorus as we mentioned, can also be removed by the chemical precipitation. Precipitation meaning if I have a relevant compound that is dissolved with the relevant ligand or such I can see to it that the compound which is dissolved after reaching the certain threshold will precipitate out I am changing the phase. It is now not in the dissolved phase or activated phase.

It is more now in the solid phase by dissolving out , not dissolving out by precipitating out. So that is what we see. We have the event that you can add and you have the phosphate here. It is PO_3^- and then if there are any stocky metric issues, you can figure that out. So, Al_3^+. So, that is why you have this Aluminium, , Phosphorus cycle Aluminium.

Solid being formed with Aluminium and phosphate and that is how you can remove the Phosphorus. But in general, I know if you can get the biological process like that is better, because you are adding , TDS to your particular system? You do not want to add Total dissolved solids to your system, if you are looking at sustainability .

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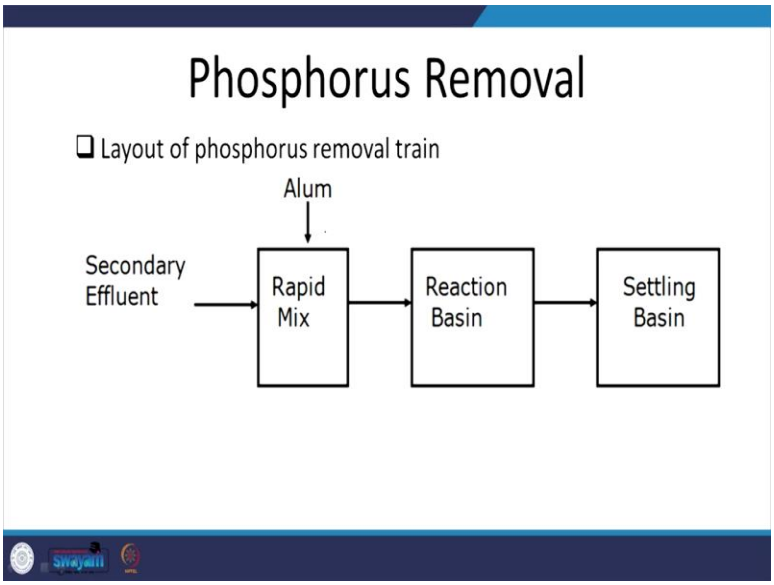

Let us do it . Phosphorus removal Rapid mix with along with alum, secondary affluent and then you can remove it and the usual reaction basin and settling basin, . But , depending on how well you are operating it or if you have old plant for which you do not have the space to , look at the removal of phosphorus by the biological process, then you can go for your chemical process, . So with that I am going to end today session, Thank you.