Course Name: Industrial Wastewater Treatment

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Lecture 4: Coagulation, Precipitation and Heavy Metal Removal

So, welcome back. We are in module 5, lecture 4 and we are talking about coagulation, precipitation and heavy metal removal. So, the concepts covered in this lecture will be on the chemical precipitation of the phosphorus in the wastewater. So, we will be covering the phosphorus present in the wastewater, in what forms the phosphorus is present in the wastewater. Similarly, we will talk about the chemistry for the phosphate precipitation. We will talk about the phosphate precipitation with calcium, aluminum and iron. We will talk about the various strategies which are involved for the phosphorus removal. We will talk about the phosphorus removal using metal salts and polymers. Then we will talk about the phosphorus removal with effluent filtration. And then lastly, we will talk about the estimation of the sludge quantities from the phosphorus precipitation.

So, the phosphorus appears in the wastewater as phosphates. So, it may present as orthophosphates which contains a single molecule of phosphorus like for example, phosphoric acid is there. So, these orthophosphates they are generally soluble in water, and they can be easily quantified. Whereas the condensed phosphate which are the long chain compound where we can see that we can have more than one atom of phosphorus is involved. So, they can be linear, or they can be in a cyclic form.

So, as they occur, so they are termed as pyro, meta and polyphosphates. Similarly, we can have organically bound phosphates which are present in the wastewater. So, phosphate is a constituent of soil, and it is macronutrient which is required for the growth of the plants. So, this is very very essential for the fertility of the soil and that is why it may be added as a fertilizer if it is required the phosphate concentration in the soil is less than the desired value. So, we add the phosphate fertilizers to it.

Similarly, the phosphate may also be present in the animal waste that is why it will be present in the municipal wastewater. So, the phosphate that goes into the soil it gets adsorbed into the soil. So, it will not be infiltrated into the groundwater neither the water can take away the phosphorus from the soil directly to the water bodies. But the erosion of the soil and later the surface runoff may lead to the contamination of the water bodies. So, phosphorus is also found as a builder in the detergent that we use.

So, phosphate detergent they contain lot of phosphate. Similarly, the phosphate is also used as tri-sodium phosphate for the boiler water conditioning for the softening of the boiler water. So, some of the industries affluent may also contain lot of phosphates into it. Though the phosphate is non-toxic, and it does not have any adverse impact on the human health as well as the health of the organism, but there can be indirect threat to the environment in the form of eutrophication. So, the water quality can deteriorate by the eutrophication.

Eutrophication means that the trophic levels of the water bodies become very high because of which the algae they can bloom, and this leads to the eutrophication process. So, the optimal ratio of the carbon nitrogen phosphorous that is required by the diatoms or the algae. So, it is given by the Redfield ratio, and it is nearly 106 is to 16 is to 1 in molar terms and it is 41.1 is to 7.23 is to 1 when it is expressed in milligrams or milligrams per liter.

So, we can see here that the phosphorous is the least constituent which is required by the algae. So, this becomes the limiting nutrient in the surface water, and we all know that the natural sources of the phosphorous may be limited in the environment. So, if we are adding anthropogenically the phosphorous by means of phosphate fertilizers or by means of the phosphate detergent. So, we are adding phosphorous into the water, and which fulfills the demand of the algae, and this alga basically can grow in such a water where the phosphorous is added in form of either phosphate fertilizers or by basically as a wastewater if the wastewater is going into the water. So, it may lead to the bloom of the algae.

If the phosphate is greater than 0.2 milligram per liter. So, it can also interfere with the water treatment processes. So, it will lead to the interference in the chemical coagulation of the turbidity. So, what does the organization has given the permissible phosphorous concentration in the drinking water to be around 0.1 milligram per liter. Similarly, the allowable phosphorous in the natural waters it should not exceed 0.2 milligrams per liter whereas in the wastewater it should not be more than 10 milligrams per liter. So, chemical precipitation can be used for the phosphorous removal and here we can see that the removal of the phosphorous from the wastewater it involves the incorporation of the phosphate which is soluble in water into the suspended solids and later on these suspended solids can be removed. So, these phosphates can be incorporated either in the biological solids for example, we are having bacteria which is called cyanobacteria.

So, they can uptake the phosphate higher than the level which is required for the metabolism. So, that is also known as luxurious uptake of the phosphate and that is how these biological solids later, they can settle down or they can also be removed from the wastewater by means of the chemical precipitations. So, here we are talking of the chemical precipitation method. So, if we add the salts of multivalent metal ions, so they can lead to the sparingly soluble phosphates or they can lead to the precipitation of the phosphate which are present in the wastewater. So, generally we use the multivalent metal ions like calcium or aluminum or ferric salts.

So, they are used for the precipitation of phosphate in the wastewater. Polymers can also be used in conjunction with alum or lime. So, they can also aid to the flocculation of the wastewater. So, they can basically cause the inter particle bridging as we have already discussed about the polymers, they can contribute to the inter particle bridging of the particles and they can help in the formation of the floc and later on as the floc grows. So, these flocs can settle down easily in the sedimentation tanks.

So, the chemistry of the phosphate precipitation with calcium and with aluminum iron. So, these two are of different types. So, that is why we will consider the precipitation with calcium and precipitation with aluminum and iron separately. So, first of all we will talk about the phosphate precipitation by using calcium. So, calcium we generally used in form of lime that is calcium hydroxide.

So, if the natural bicarbonate alkalinity is present, so that will react with the lime that we are adding and then the calcium which is present in the lime, so that will precipitate out as calcium carbonate. So, this means that as soon as the lime is added to the water, so first it will react with the alkalinity which is present and then it will precipitate as calcium carbonate. So, when the pH of the wastewater it increases beyond 10 as we are adding lime, so the pH of the water will increase. So, when it increases beyond 10 and when the excess calcium is present after encountering the natural bicarbonate alkalinity, so then the calcium will react with phosphate, and it will form a precipitate of hydroxyl apatite. For example, you can see here that 10 calcium ions plus 6 phosphate ions plus 2 of hydroxide ions, so they form together, and they form an insoluble compound or precipitate that is known as hydroxyl apatite.

So, phosphate precipitation with calcium, so the quantities of the lime which is required for the precipitation of the phosphate is independent of the phosphate concentration because it will depend primarily on the alkalinity of the wastewater. So, we can see here that the curve between the alkalinity versus the lime dose, so if we see here as the alkalinity of the water increases the lime dose also increases. So, the quantity of the lime that we want to add so that we can precipitate phosphorus in the wastewater, so it is nearly 1.4 to 1.5 times the alkalinity which is expressed as calcium carbonate.

So, as the pH values increases a lot when we are adding calcium, so that is why it is not feasible that we use lime during the co-precipitation. Co-precipitation means that if we are adding the lime during the secondary processes of the wastewater treatment, so it may not be feasible because of high pH values it may hamper the biological process that is causing the treatment of the wastewater. So that is why it is very essential that we go for the pH adjustment, or we should neutralize the wastewater before we take that wastewater which we have treated with lime, so that the phosphate can be removed for its safe disposal or if we are taking the wastewater for the subsequent treatment. So, we need to neutralize the water, we need to reduce the pH of the water, and the pH adjustment has to be carried out, so that further processes can be carried out. So, here the recarbonation with carbon dioxide can be used for the lowering the pH values.

Now the precipitation with aluminum salts as well as iron salts can also take place and we can see that there can be a simple reaction like the aluminum ions can react with the phosphates and they can form the phosphate precipitates here, right, as well as there may be some acidity that will be generated. Similarly, the ferric ions they can react with phosphates, and they can form ferric phosphates, and these ferric phosphates again can settle down and it also increases the acidity of the wastewater. These reactions will depend upon the number of competing reactions and their equilibrium constants that are taking place side by side. For example, the salts they also can react with the alkalinity, right. So, they also can lead to the formation of the aluminum hydroxide or ferric hydroxides.

So, these reactions we have already discussed in the previous classes. So, these processes may also interfere with the phosphate precipitation. Similarly, there can be the effects of the alkalinity, right and similarly we know that the pH is a very very important factor when we are talking about the precipitation. So, at optimum pH only this aluminum phosphate or the ferric phosphate may precipitate. So, it will depend upon the pH value also whether the phosphate is in solubilized form, or it will occur in the precipitated form and similarly it will depend upon the trace elements and the ligands which are present in the wastewater.

So, this will also complicate the process. So, we can estimate amount of the dosage required for the aluminum salts or for the ferric salts directly by using these equations because there can be a number of competing reactions which will also take place side by side and these reactions cannot be used directly for the calculations of the chemical dosages. So, when we need to find out that what dose needs to be added. So, for a particular base water we can find out the doses through a bench scale test or we can also go for some time the full-scale test especially when we are using polymers. So, we need to determine that what optimum dose is required so that we can precipitate the phosphate at the fullest.

So, the concentration of the soluble phosphate in equilibrium with the insoluble aluminum phosphate and ferric phosphate. So, it is represented in figure 2 and this is showing you that the pH value versus the log molar soluble phosphorous concentrations on the y-axis. So, we can see that the solubility of the phosphates it decreases slowly and slowly and at a certain pH value it is the lowest and then again, the solubility may increase. So, it is because the aluminum phosphate is getting precipitated out and at a certain pH value for example you can see here that nearly 5.5 or so the precipitation of the phosphate is the highest and similarly it also again increases at the lower pH values and at the higher pH values because of certain mixed complex poly-nutrient species formed which are shown by this white area.

So similarly, here also the ferric salts when they are added, so ferric phosphates will precipitate out and this also is having the lowest solubility of the phosphate at a certain pH value which is nearly 4.5. So, we have to maintain these pH values so that we can get the maximum removal of phosphate by the chemical precipitation when we are using these types of salts. Now, we will talk about the strategies for the phosphorous removal during the wastewater treatment. So, there can be different locations at which these chemicals can be added so that the phosphorous can be removed during the wastewater treatment.

For example, we can have the pre-precipitation method, we can have the co-precipitation method, and we can have the post-precipitation method. So, pre-precipitation means that when we are adding the chemical to the raw wastewater that is when we are adding the chemicals before the primary sedimentation facilities, so this is known as the pre-sedimentation process. The phosphate is removed by precipitation, and it is removed along with the primary sludge. Co-precipitation means that when we are adding the chemicals in the secondary treatment processes. For example, we can add the chemicals to the effluent from the primary sedimentation facilities, we can also add the chemical in the mixed liquor that is in the activated sludge process, and we can also add the chemicals in the effluent which is coming out from the biological process just before the secondary sedimentation tank.

So, here in this case the phosphate is precipitated along with the biological sludge. The post-precipitation method means when we are adding the chemicals after in the effluent which is coming out from the secondary sedimentation facilities and then it is removed later on by providing other sedimentation facilities because after the secondary sedimentation tank, there is no other sedimentation facilities which are available. So, in that case we have to provide a subsequent sedimentation tank so these precipitates can be removed, or we have to provide certain effluent filters. So, we can see here that this picture depicts the various strategies for the phosphorus removal. So, we can see here that figure A is showing that the chemical addition is being done in the raw wastewater and the primary sedimentation tank is used for the precipitation of the phosphate and the insoluble phosphate is coming out from the primary sedimentation tank sludge.

The figure B is showing that the chemicals can be added before or after the aeration tank in the activated sludge process and this is known as the co-precipitation method and similarly, we can see here that figure C is showing that the chemicals are being added after the secondary sedimentation tank or in the effluent which is coming out from the secondary sedimentation tank. So, in this case we have to provide an extra sedimentation tank where the phosphate precipitates can be settled out and it can be removed. So, then we can have conditions where we can add the chemicals at various locations. For example, we can see here that we are adding the chemicals before the primary sedimentation tank, we are adding the chemicals before the secondary settling tank, we are adding the chemicals after the secondary settling tank. So, here we can get the insoluble phosphorus at different locations because of the addition of the chemicals.

So, then we can also use a single filter when we are using the multipoint addition of the chemicals. So, here we can use filter which can remove the insoluble phosphorus from the effluents. Similarly, we can also use a two-stage filters where we are using two filtration units, and the insoluble phosphorus can be removed from here. So, there are number of factors which will affect the choice of the chemicals which we want to use for the phosphorus removal. So, for example, it will depend upon the influent phosphorus level, and it will also depend upon what is the level of the phosphorus that we want in the effluent.

So, based on that we can choose that which chemical will be the best and can remove the phosphorus to that desired level. So, it will also depend upon the wastewater solids as these solids will also interfere with the phosphate removal process as these suspended solids may also be removed during the coagulation process when we are adding the metal salts to it. Similarly, alkalinity will also play a very important role during the phosphate removal. The chemical cost is also an important factor and similarly the reliability of the chemical supply that whether the chemicals are readily available. So, this will also impact the treatment plant facilities.

Similarly, a large amount of sludge will be generated because of addition of these chemicals. So, we should have proper sludge handling facilities at the treatment plants, and we should also look for the ultimate disposal methods which will be used so that we can dispose of the sludge which is enriched with the phosphate. And similarly, we have to also look that whether the chemical which we are using it is compatible with the other treatment processes especially the biological processes. So, the phosphorus can be removed by using metal salts and polymers and the Ortho phosphorus is the species of the phosphate which can be easily removed rather than the polyphosphates and organic phosphates because the orthophosphate is highly soluble in water and then it can interact with the metal salts and the polymers easily and that is why they can basically be precipitated out as the phosphate's precipitates. That is why it is also very important that if we are using this aluminum salts or iron salts if we are using it after the secondary treatment process then it becomes more effective as the organic phosphates and the polyphosphates.

So, they are transformed into orthophosphates till that process. So, now the improved settling which happens when we are adding these salts so it will basically also lead to the settling formation of the flocs and settling of these precipitates. So, this will not only improve the settling, but it will also improve the nitrogen removal. However, ammonia removal may be minimal if we are having high BOD values so in that case ammonia removal is inhibited. So, but if the chemical additions to the primary sedimentation tank or primary facilities so if they are reducing the BOD loadings then it can enhance the nitrification process.

So, metal salt addition can be done to the primary sedimentation tank so when we are adding this metal salts to the primary sedimentation tank it reacts with the soluble orthophosphates, and it can precipitate out. So, whereas the organic phosphates and polyphosphates they may also be removed by some complex reactions, or they can get adsorbed onto the floc particles they can be removed. So, primary sludge will contain lot of things for example it will contain the insoluble phosphorus as well as it will also contain some amount of BOD and TSS which is also removed when we are adding chemicals to the primary sedimentation tank. But when we are using the primary sedimentation tank, we require adequate rapid mixing and flocculation facilities so that whenever we are mixing these chemicals so they should basically form they should react with the orthophosphates, and they also basically should form flocs. So, these facilities have to be provided upstream of the primary facilities.

So, we have to provide certain separate basins either if we are not having those basins in the existing facilities or we have to modify the existing facilities so that the rapid mixing as well as the floc formation can take place. And we can also go for the polymer addition so that the inter-particle bridging may take place and because of which the settling may be enhanced. So, when we are using low alkylity water it is sometimes desired that we also add some base because when we are adding the metal salts so it may increase the acidity of the water and if the water is not having the buffering capacity or it is having very low alkalinity so in that case the pH may go down beyond the optimum range. So, that is why it is very very necessary that we add certain base to the base water so that the pH is always maintained between 5 to 7. Similarly, we should also try to maintain the metal salts to the phosphorus ratio so that the optimum remediation of the phosphate may take place.

For example, your table 1 shows us that if we are adding Aluminium to Phosphorus to a ratio of 1.4 is to 1 so we may get a reduction of nearly 75 percent whereas if this ratio is increased to 1.7 so it the 85 percent of the phosphate may be reduced and similarly when we increase this ratio to nearly 2.3 so this may lead to the reduction of 95 percent of phosphorus in the base water. So, similarly for the ferric salts also we can see that at a ratio of nearly 2.2 or 2.3 we can get around 90 percent removal of the phosphorus whereas at a ratio of as high as 4.5 we can get removal of nearly 99 percent. So exact application rate is to be decided by doing the online testing for example the characteristics of base water will change from various sources for example whether it is municipal wastewater, or we are talking about the industrial wastewater. So, it will depend upon the characteristics of that wastewater and how much phosphate we require to remove from the wastewater. So, depending upon that we have to decide what should be the exact dose, what should be the application rate so that we can remove the phosphates to the desired level.

So, we can also add the metal salts during the secondary treatment processes. For example, we can add the chemicals in the untreated wastewater which is coming out from the primary sedimentation tank we can also add it to the aeration tank, or we can also add it to the final clarifier influent channel that is before the secondary sedimentation tank. When we are using trickling filter so in that case, we may add these chemicals in the untreated wastewater as well as we can add the chemicals to the filter effluents, and we can also use multipoint additions also as we have discussed in the strategies for removal of the phosphate. So, the removal of the phosphorus in such cases may be a combination of precipitation, adsorption, exchange as well as agglomeration processes and the phosphate precipitates may be removed during the primary sludge or during the secondary sludge or it can take place from both when we are going for the multipoint additions. So, we know that the minimum solubility for the aluminum phosphates it occurs at around 6.3 whereas for the ferric phosphate it occurs at about 5.3. So, this means that if we are having the pH around 6.3 for aluminum phosphate and 5.3 for the ferric phosphate so it is best, but it has been found that for the practical application we can also keep the pH nearly 6.5 to 7 which also shows very good removal of the phosphate, and it also becomes compatible with most of the biological treatment processes. So generally, we do not use ferrous salts because the ferrous salts they will produce low phosphorus levels only at very very high pH values and we know that if we are using very high pH values then the wastewater has to be neutralized before it is taken to the biological processes. And similarly if we are having the low alkalinity waters or the waste water so in that case we can use sodium aluminate and alum or we can use ferric plus lime or we can use both also so that we can maintain the pH higher than 5.5. So, the chemicals that we are adding can lead to the improved settling as well as the low African VOD and it will also be enhanced if we are adding polymer also to the final clarifier. So, the dosages that is recommended it should be between 1 is to 3 for the metal line is to phosphorus in the molar ratio. So, when we are using the trickling filters or the extended aeration process for the active research process so the solids may not flocculate, and they may not settle down well in the secondary clarifier.

So, in that case we can add aluminum or iron salts which can cause the precipitation of the metallic hydroxides as well as the phosphates or it can basically precipitate both of them. So, in that case we can also add certain organic polymers also so it will also lead to the settlement of the colloidal particles also. For example, it will lead to the coagulation of the colloidal particles as you discussed previously and the coagulated colloids as well as the precipitates of the phosphates so they will settle down readily in the secondary clarifier and it can reduce the total suspended solids in the effluent, and it can also enhance the phosphorus removal from the wastewater. So, dosages of 1 to 3 metal line to phosphorus so this may lead to the removal of the phosphorus, and we may get secondary effluent which is having a phosphorus greater than 0.5 milligrams per liter. If we want to achieve the phosphorus levels below 0.5 milligrams per liter so, then we have to add either the higher metal salts or we have to use the filtration process so that the levels below 0.5 milligrams per liter can be maintained. So we should always try to add the polymers in the mixing zone where basically the rapid mixing is taking place or if we are adding to a clarifier then there is internally desecrated clarifier or we should basically go for a static or dynamic mixture before going it for the precipitation process and or we can also add the polymers to the aerated channel where the mixing may take place because we know that the mixing times is generally 10 to 30 seconds and we should try to keep a shorter mixing times by providing number of mixers and we should try to maintain the mixing times less than 10 seconds because the inefficient mixing or excessive mixing so they both will result in the poor settling and thickening characteristics of the sludge that will be generated because if we are having the insufficient mixing then it will lead to the entangling of the polymers on itself and it will not lead to the inter-particle bridging or if we are using the excessive mixing also so it will lead to the desorption of the flocs which are formed and because of which the flocs which may have the poor settling and thickening characteristics. So now the phosphorus can also be removed by using lime but the use of the lime is declining because of the two reasons that is we have to handle a large amount of sludge that is formed because the lime first of all will encounter the alkalinity and this will lead to the formation of the calcium carbonate before the phosphate precipitation takes place so that is why we have to handle a large amount of sludge and similarly there can be operation and maintenance problems which are associated with the handling, storage and feeding of the lime.

So, we have already talked about that when we are using lime so the dosage of the lime will depend upon the desired removal level for the phosphate as well as it will primarily depend upon the wastewater alkalinity. So, when we are using lime so it is traditionally used as a precipitant in the primary sedimentation tanks, or we can use it after the secondary treatment clarifications. It is never used during the secondary treatment processes because of the fact that the pH increases many folds and because of which the biological processes may be hampered. So, lime recalcination can be used where we are using lime in a large quantity so this can be used for the lime recovery processes. For example, the calcium carbonate sludge that is generated from the treatment so that may be thermally regenerated by putting the sludge to around 980 degrees centigrade and which will result in the evolution of the carbon dioxide, and which will basically result in the formation of lime again.

So, we can recover the lime by using the lime recalcination process and this lime can be reused again for the precipitation of the phosphate. So, when we are using lime for the wastewater treatment so it is very much required that the recombination should be done and pH adjustment or the pH adjustment of the wastewater should be done. So, when we are adding lime to the primary sedimentation tank we can go for low as well as high lime treatment and it can lead to the removal of phosphorous of nearly 65 to 80 percent and here the calcium and hydroxide so they can react with the Ortho phosphorus, and they can form insoluble hydroxyapatite, and we can get residual phosphorous of nearly 1 milligram per liter. So, when we are using a high lime system so in that case the pH has to be raised to about 11 as the pH is raised about 11 so we have to recarbonate it before we take it for the biological processes. As you know that in the active research process the pH should not exceed 9.5 or 10 because the higher pH values this way it can upset the biological process and during the trickling filter when we are using lime so the carbon dioxide generated so it may be sufficient to lower the pH so we may not require the carbonation. So, dosage in the low lime treatment it varies from 75 to 250 milligram per liter, and we get the value of nearly 8.5 to 9.5 and the calcium to magnesium ratio that needs to be maintained should be less than equal to 5 is to 1. So, we can see here that the lime it can be added to the waste stream after the biological treatment process so when we are using the lime after the secondary treatment so that we can remove the phosphorous and the total suspended solids so this process can be either single stage process or this process can be a double stage process.

So we can see here that the single stage process it involves the secondary effluent is taken to a rapid mix first of all where the mixing of the lime is done vigorously and then later on it is taken to the flocculator where the flocs are formed and these flocs are formed at slow RPM values and which leads to the formation of the flocs and the enlargement of the flocs in the flocculator and later on it is taken to a settler where the precipitates or the flocs which are generated so they settle down and this sludge is taken to the reuse facilities where we can regenerate the lime from here so if we are not having any recycling facilities or regeneration facilities so we can take the sludge to the disposal or we can then take it to the thickener where the excess water is removed from the sludge and we centrifuge it so that further the water that is there in the sludge it can be taken out and then we take it to a calciner where we provide very high temperatures where the carbon dioxide is evolved so that we can again get back the lime here and then the lime may be slick and it can be recycled again for the treatment process. So, after the settling the effluent is taken to a recarbonator because the pH values are very high and so we have to add carbon dioxide to it so that the pH can be brought to a low level, or the pH basically can be reduced and then we can pass it through a filter and finally after the filtration we can dispose of the treated water safely. In the two-stage process so during the first stage process we add the lime in large quantities so that we can raise the pH to nearly 11 so that it can precipitate the soluble phosphorous as well as the calcium phosphate which is also known as apatite and calcium carbonate precipitate will also be formed so they will act as an equivalent for the suspended solids removal also. So then the excess soluble calcium which goes into the second stage clarifier so there the calcium carbonate may further precipitate out and we add their carbon dioxide so that the pH may be reduced to nearly 10 and then basically we can remove the excess calcium which is left because of the high pH which was maintained during the first stage so that the precipitation of this calcium may be done and then after the precipitation of the calcium in the second stage we again go for the recarbonation process so that the pH may be reduced further. So, after this process we can remove the residual total suspended solids and phosphorous by using a multimedia filter also, but we have to also see that there is no excess calcium which is going to the filters otherwise it will lead to the cementation of the filter media.

So we can see here that this is a two-stage process where we are again having a rapid mix and then it is going to a flocculator then after that it goes to a settler and we are basically we maintain a very high pH and the sludge is generated from here similarly after this we reduce the pH and we take it to the second settling tank and after which where the pH is reduced to less than 10 and then again we take it to the recarbonator where again the pH is further reduced and after which we take it to the filter. So here we can see that the sludge that is getting generated from the two settlers here so they can be either taken to the recalcinator if we want to reuse the calcium or we want to recycle the calcium if we want to recycle the lime or we can take it for the disposal process. So, the phosphorous which is coming out along with the effluent so it can also be removed by using the effluent filtration. So, the chemical addition to the secondary effluent so that can also remove the phosphorous it can remove the metal ions it can remove the humic substances, and it can also improve the performance of the effluent filters. So the chemical addition if we are doing to the contact filtration process so it can be done when we want to discharge the water to the sensitive water body so where we want to maintain the low levels of the phosphorous and the water bodies in which we are distorting the water it is highly sensitive so in that case we can go for the chemical addition to the contact filtration process.

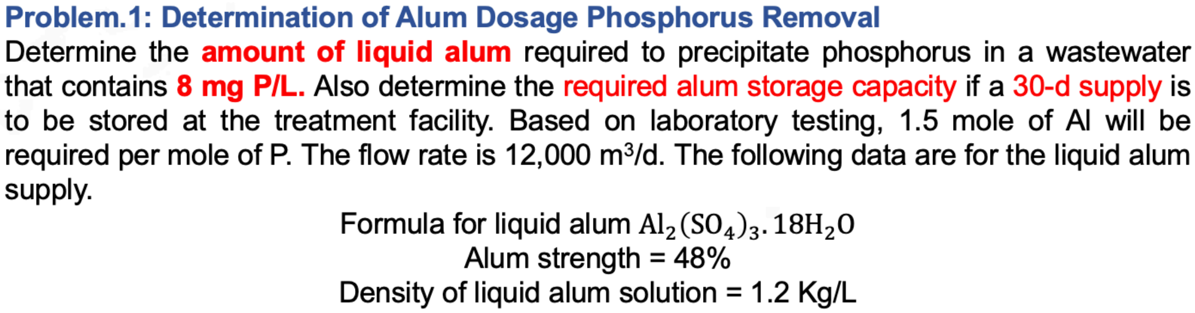
So, we can have two stage filtration processes here right so that we can maintain less than 0.02 milligrams per liter of phosphorous. So, when we are using two stage filtration processes so in that case the backwash water from the second filter, so it is taken back to the first filter where it enhances the flop formation and also basically enhances the influent waste ratio. So, the efficiency of the filters for the removal of the phosphate is enhanced in such a case. So now let us talk about the various advantages and disadvantages for the addition of the chemicals in various sections of the treatment plant so that the phosphate removal can occur.

So we can have the chemical addition at the primary stage which is applicable to most of the plants it will increase the BOD as well as the suspended solids removal it will also lead to the lowest degree of the metal leakage as we are adding the metals in the initial stages only which can be further removed during the later stages and similarly we can also recover the lime from in this process. The disadvantage of this process is that it is having the least efficient use of the metals, and the polymers may need to be added so that the flocculation may be enhanced. Similarly, the sludge is very very difficult to dewater in comparison to the primary sludge because now the sludge may contain the phosphates as well as it may also contains the suspended solids as well as some part of BOD. When we are adding the chemicals to the secondary process, so it occurs the lowest cost it is the lowest chemical dose is required and when we are adding the chemicals to the primary processes it has got improved stability of the activated sludge and polymers are not required in such cases. Whereas the over dose may also lead to low pH toxicity as the pH may be reduced because of the addition of the high doses when we are adding the metal salts and similarly when we are having the low alkalinity waste waters so in that case the pH control system may become necessary and we cannot use lime in this process because of the excessive pH as we already discussed and lot of inert solids so they are added to the mixed liquid volatile suspended solids and it will reduce the percentage of volatile solids in the sludge.

So, when we talk of the advanced precipitation that is when we are adding the chemicals after the secondary processes so it may lead to the lowest phosphorous effluent it is also having the most efficient metal salts used in such cases and here, we can also recover the lime if we are adding lime to the systems. But it may increase a high capital cost because we may require the further installations for the removal and settling of the precipitates for example, we may require the systems like for example, settling tanks we may also require the filters after this process and similarly this process may also lead to the highest metal leakage as we are adding the metal salts at the later stages. So advanced single and two stage filtrations so it can be combined with the removal of the suspended solids also so it may reduce the cost in such a way that it may also enhance the suspended solids removal. But we have to also bear the additional expenses when we are using two stage filtration process. So the chemical addition to the primary treatment so it may lead to the solving the overloading problems on the downstream of the biological system so it may reduce certain amount of BOD as well as may also reduce amount of total suspended solids so it will lead to the low organic loading in the further treatment units and similarly it may also allow the seasonal or we can say the year round nitrification process as some part of the BOD is removed during the primary sedimentation tank.

So, if we want to remove the BOD in the primary sedimentation by when we are adding the chemicals to it so it may be of the order of 50 to 60 percent and at which occurs at a pH of nearly 9.5. So, there can be number of reactions which happens and there can be number of the species of the precipitates that will be occurring when we are adding these salts or basically, we can say the lime to the wastewater. For example, when you are adding limes it can lead to the precipitation of hydroxyapatite similarly it can lead to the formation of magnesium hydroxide it can lead to the formation of calcium carbonate when you are adding the aluminum salts so it can lead to the formation of aluminum phosphates and aluminum hydroxides when we are adding the Fe3 salts so it can lead to the formation of ferric phosphate and ferric hydroxides. So now let us discuss a problem for determination of the alum dose which is required for the phosphorus removal.

For example, here we have to find out what is the amount of liquid alum.



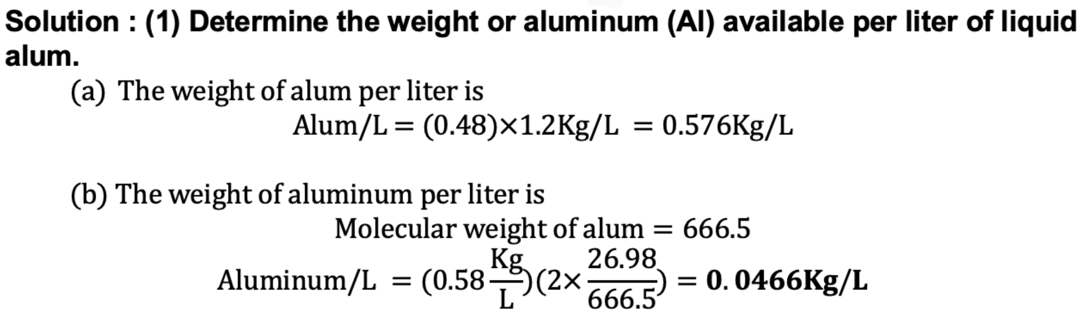
Problem.1: Determination of Alum Dosage Phosphorus Removal

Determine the **amount of liquid alum** required to precipitate phosphorus in a wastewater that contains **8 mg P/L.** Also determine the required alum storage capacity if a 30-d supply is to be stored at the treatment facility. Based on laboratory testing, 1.5 mole of Al will be required per mole of P. The flow rate is 12,000 m³/d. The following data are for the liquid alum supply.

Formula for liquid alum $\mathrm{Al_2(SO_4)_3.18H_2O}$

Alum strength = 48%

Density of liquid alum solution = 1.2 Kg/L



Solution : (1) Determine the weight or aluminum (Al) available per liter of liquid alum.

(a) The weight of alum per liter is

$$\mathrm{Alum/L} = (0.48)\times 1.2\mathrm{Kg/L} = 0.576\mathrm{Kg/L}$$

(b) The weight of aluminum per liter is

$$\text{Molecular weight of alum} = 666.5$$

$$\mathrm{Aluminum/L} = (0.58\frac{\mathrm{Kg}}{\mathrm{L}})(2\times\frac{26.98}{666.5}) = \mathbf{0.0466Kg/L}$$

(2) Determine the weight of Al required per unit weight of P

$$\text{(a) Theoretical dosage} = 1.0\ \text{mole Al per } 1.0\ \text{mole P}$$

$$\text{(b) Aluminum required} = 1.0\ \text{kg}\times(\text{mw}\frac{\text{Al}}{\text{mw}}\text{P})$$

$$= 1.0\ \text{kg}\times(26.98/30.97) = \mathbf{0.87\ Kg\ Al/kg}$$

(3) Determine the amount of alum required per kg P

$$\text{Alum dose} = 1.5\times\left(\frac{0.87\ \text{kg Al}}{1.0\ \text{kg P}}\right)\left(\frac{\text{L alum solution}}{0.0466\ \text{kg}}\right)$$

$$= \mathbf{28.0\ L\ alum\ solution/kg\ P}$$

(4) Determine the amount of alum solution required for wastewater/d

$$\text{Alum dose/d} = \frac{(12000\ \text{m}^3/\text{d})(8\ \text{g P/m}^3)(28.0\ \text{L alum/kg P})}{(10^3\text{g/kg})}$$

$$= \mathbf{2688\ L\ alum\ solution/d}$$

(5) Determine the amount of alum solution required per day.

$$\text{Storage capacity} = (2688\ \text{L alum solution/d})(30\text{d})$$

$$= \mathbf{80640\ L} = \mathbf{80.6\ m^3}$$

So, we stop here and thank you very much, so this is the reference that I have used for making this lecture and thank you.