Fundamentals of Environmental Pollution and Control
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Lecture No. # 17
Wastewater Treatment (continued)

Okay good morning, I mean we start this class with the wastewater treatment that we have been talking about say the primary wastewater treatment where I was said that we only use some physical means, we only use some physical means. It contain a number of methods I have discuss some of you, some of that say you know this oxidation point being one then say trickling filter being another then we have discussed about this… Yes, so particularly these three that we have discussed some of these three. These together forms you know the primary treatment methods where the mostly the physical process is used.

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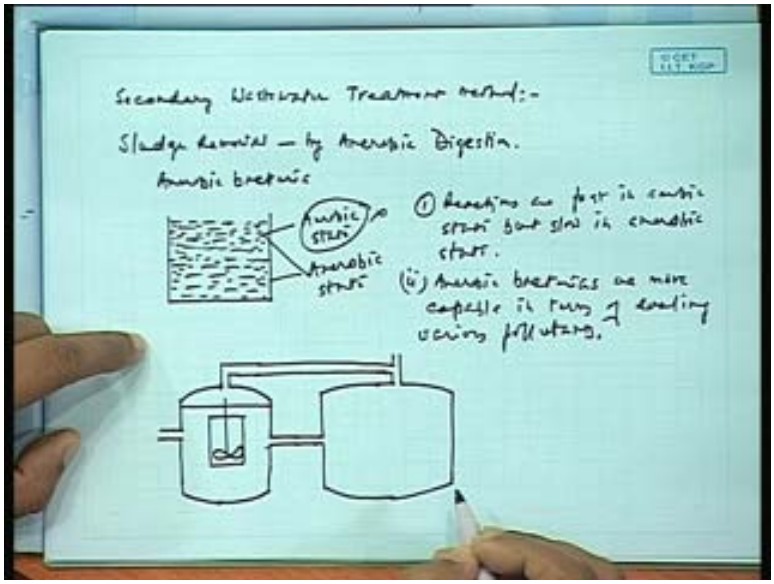

We'll come back come to this secondary treatment, secondary, secondary wastewater treatment method perhaps you know most, most commonly used is this kind of treatment method where there is a certain objective of wastewater sludge removal or pollutant removal from the wastewater stream, from the wastewater stream. So, we'll discuss about one very important thing that is one and very important process what is known as sludge removal, sludge removal and the process is known as by anaerobic digestion, most commonly used for you know civic waste treatment. This has an importance you know this is because you know the, for very important reason this is that you know this the participation of anaerobic bacteria, anaerobic bacteria.

Let me explain you few of few things about this aerobic, anaerobic bacteria is you see this comparing to this, this is mostly the anaerobic bacteria which carries out this which is a basically carries out about the digestion that means you know much of the material, much of the material would be actually absorbed by digested by this microbes, by the mostly the bacteria's, see these

are anaerobic bacteria's. See, what happens is if you observe this you know in the, in any stream of water, suppose if we just consider a particular stream of water, we consider that you know there are if you see this fluid like this okay if you see that you know there are lot of sludges on this at the bottom. Say, the mostly if you can think of say any various food items or things like that where if you keep that for longer time, if you keep that for longer time, you'll find that the sludge is settled I mean any kind of substance. The sludge is the thickened a solid substances which are in a mixture, which are essentially in a mixture.

So, here you can see here what we observe here in such cases that here if there would be a larger oxygen supply, there would be a larger oxygen supply. So, you know here it would be the stage, the state at it is, it can be considered as aerobic state, aerobic state and these here oxygen would be largely depleted and there would be very little oxygen here because of two things, one is the high concentration of this, larger high concentration of solid material and the secondly, secondly essentially there is so much of organic activity here, so much of activity that would be here in this space. So, here you would find that the oxygen would be mostly depleted. So, it does can be considered to be anaerobic, anaerobic state, anaerobic state. The essentially there's the situation is, situation is the fine line, this fine line is extremely sensitive where actually anaerobic bacteria and this aerobic bacteria actually differentiate between two, between themselves in two regions.

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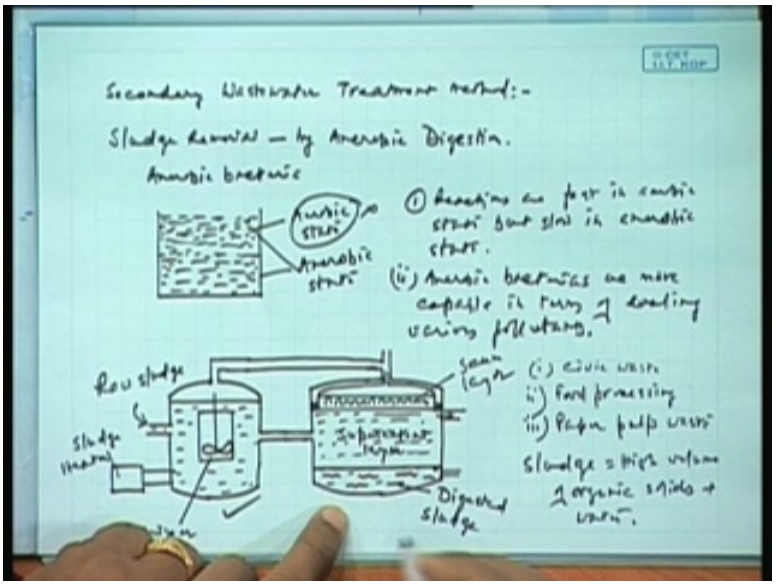

See, in a natural system there is a tremendous competitiveness, tremendous competitiveness in the sense that you know in the places where anaerobic bacteria's generally survive the bacteria's, aerobic bacteria's will not be able to survive. In the other case in the aerobic state where there is an aerobic bacteria's mostly survive, anaerobic bacteria might not find it suitable to colonize there. So, this particularly, so what we can see, we see an interesting area where now what happens is when this sludge when this sludge is you know up to the brim, you can see this sludge is up to the brim, we can observe you know in many cases like you know civic waste, civic waste whether the sludge is very high, the sludge level is very high. This anaerobic state, the anaerobic column may all together not exist, altogether may not exist.

So, you can see this aerobic state being completely eliminated and the whole state being is under anaerobic, anaerobic state. Either a few interesting thing about this, mostly aerobic bacteria you know aerobic zone, the reactions are generally speedier, faster reactions take place. On the other hand in anaerobic state, in the anaerobic state the reactions are slow, reactions are very, very slow and but one important thing about this anaerobic state of anaerobic bacteria is that you know one important as I have said the reactions, reactions are fast in aerobic state but slow, but slow in anaerobic state.

Secondly, however this anaerobic bacteria's, anaerobic bacteria's, anaerobic bacteria's are more capable in terms of dealing with various pollutants. Anaerobic bacteria's are more capable in terms of, in terms of various in terms of reducing various pollutants in terms of, in terms of reducing various pollutants. So, here this if you can just see this, what we observed now is you know in a anaerobic digester that we have been discussing about, let me explain a few on this you know what is the set up looks like. The setup is somewhat like this. This is a two stage process, this is a two stage process with you know feed backs and with the flow coming in, going out like this. So, here we see this. This is what is a typical anaerobic digester. It's a two phase, it's a two phase process, this two phase process you can see observe this, all right. So, here there would be a stirrer. See, this is here it is says, goes to another tank. I'll discuss this process, here it goes to another tank where okay if you just see this, there will be… Excuse me. So, this is can see this sludge heater, sludge heater this is where this, this, the raw sludge is coming in, raw sludge is coming in and this is, this is digested sludge, digested sludge, this is supernatant layer, okay.

So, this is supernatant out, so you can see this here. We observe this is something like this, let me go out little fast here say this here as you can see this is the raw sludge is coming in okay, this is the raw sludge is can be you can think of say one the typical sludges that you can say that the civic waste, civic waste is one then say food processing, food processing waste. Then many other kind of you know particularly the pulp waste say paper pulp, all this you know particularly related to various industries where they can be used. A sludge is essentially if you can understand, this is high, high volume of, high volume of solids, organic solids, organic solids plus water, plus water. This is what is a sludge, this is what would be a sludge, generally a thick sludge that would be. So, this sludge is coming in from here, so the sludge is coming in from here the sludge is coming in from here, this is particularly the sludge heater is there, the role of the sludge heater is to heat the raw sludge.

Heating means you know as it heats to a certain level say you know particularly in cold countries or in a situations where this, the particularly the sludge is generally low in temperature, sludge has a low temperature, the reactivity, the reactions take place is at a lower rate. So, as a result of that say that there would be a larger tanks necessary and things like that. So, here what we generally try to do is we try to heat this sludge, we try to heat this sludge as a result of which the microbial activity increases. So, here in our country you know situation like in our countries mostly this may not be necessary at times, this may not be necessary at times but here at this as you can see in a cold countries particularly, heating the sludge is a requirement just for to increase the microbial activity.

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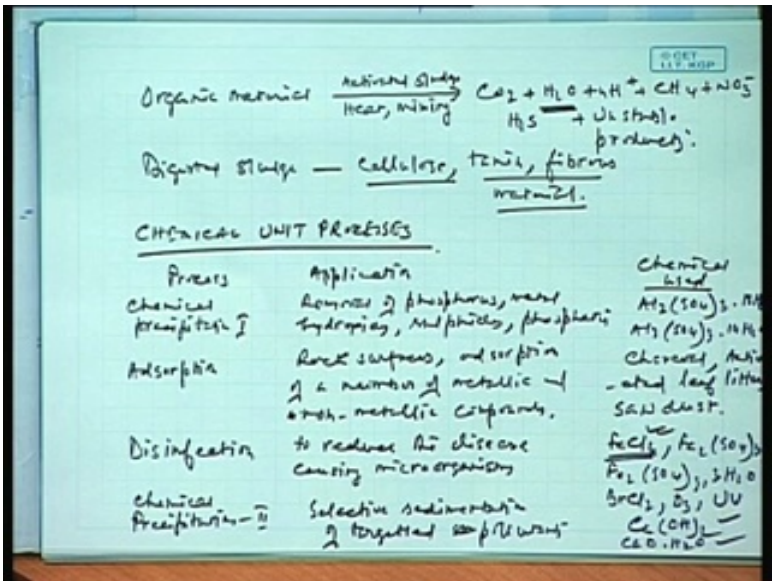

So, what happens now is, what happens now is this particular, this particular in the particular treatment system, in this particular treatment system, the first of all the is the mostly all this material this organic material, organic material, organic material in the, in the presence of you know in can write in the presence of oxygen or without you see in heat with this, with the heat and with the mixing, with heat mixing and some say activated sludge, activated sludge, activated sludge all this organic material would be mostly forming a number of… It also adds to the acidity, apart from that, apart from that this carbon hydrate this is CH 4 that we generally observe here in this case in an methane forming substances and some some unstable products this will begin to form, this will begin to form and you can see this as the reaction takes place here in the first column, here in the first column say the one column, the column that we have done here this one, as this one comes to convert the organic material slowly begins to convert into water, slowly begin to form into a carbon dioxide, water, CH 4, CH 2 you can find H 2 S also forming, say nitrogen is a large body of say NO, NO 3. So, here this conversion begins to take place.

As a result of this, as a result of all this, as a result of all this is, this from the first tank to the second one, the concentration of water begins to increase, concentration of water begins to increase because much of the water that is produced would be transferred into as a supernatant layer in this. And as a result of, as a result of this reaction, as a result of this reaction a scum layer would be developed, a scum layer would be developed here the scum layer.

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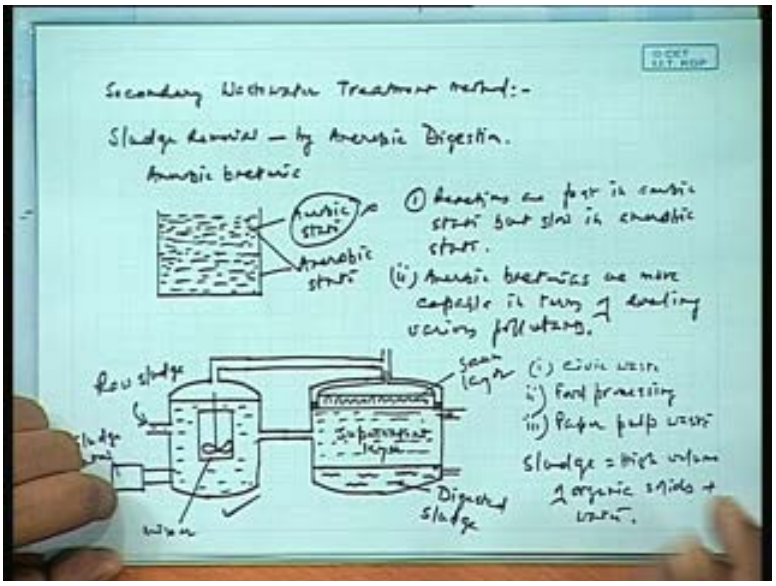

You have seen that you know particularly say if you have observed a part of sweet making or any other processes you will find this scum coming up on the top which they continuously remove. Have you seen this, this in a, in a you know milk you know or in a sweet making process there'll be a scum, white scum coming up on the top that is what is the scum. This is the scum layer continuously being formed in such cases continuously being formed and you can find that you know a certain amount of digested sludge, this digested sludge this, this is what is you know this is particularly most of this material here is unreacted substances, unreacted substances or say the substances which cannot be readily, readily converted into, converted into say carbon dioxide, water or hydrogen ion like this.

The most of this the digested sludge would be, what would be this digested sludge? The digested sludge would be mostly the cellulose, mostly the cellulose material, cellulose material you'll find tanninate, you'll find tannin and a certain you know certain you can find you know other fibrous materials, fibrous material. So, this remains, this requires a longer time to decompose, I have time and again emphasized that is the carbohydrates, the essentially the carbohydrates which are readily oxidized and readily treated you know they can be treated very fast but well these most of these substances like cellulose, tannin, other fibrous materials would be formed, would not react, would not react, these fibers would complete remain and they would settle down as a digested sludge.

Sometime a part of the digested sludge may be reverted back to the first tank. The reason is activated sludge, the consideration that I said in the last class why activated sludge is required, so this activated sludge may be recycled back. So, this is what is called the, this is what is called this sludge removal by anaerobic digestion. Even one can see this complete digestion taking place here as a result of which the raw sludge, a substantial amount of raw sludge, raw sludge will be removed, the substantial amount of the solid tractions in the sludge would be removed and be converted into liquid fraction. And as a result of that this would be, most of this material would be without much of, much of carbohydrates, without much of carbohydrates and they

would be whatever they would contain, mostly contain most of this higher organic substances, higher organic substances like cellulose, tannin, fibrous materials or any other hydrocarbons that you can think of which are not volatile which are generally solid which you have, which may be liquid or solid form remain in the digested sludge, all right.

See, this is, this is one kind of sludge removal that you know is generally is of a great importance. So this, this comes you know why I have discussed this is, this process, this kind of processes are becoming very important nowadays. Microbial digestion is the, in a new area of research in wastewater engineering as well as in environmental science. We are, we are more and more dealing with this substances, with these organisms to create situation by which you know natural means can be employed to for remediation, natural means can be employed for remediation of most of this substances.

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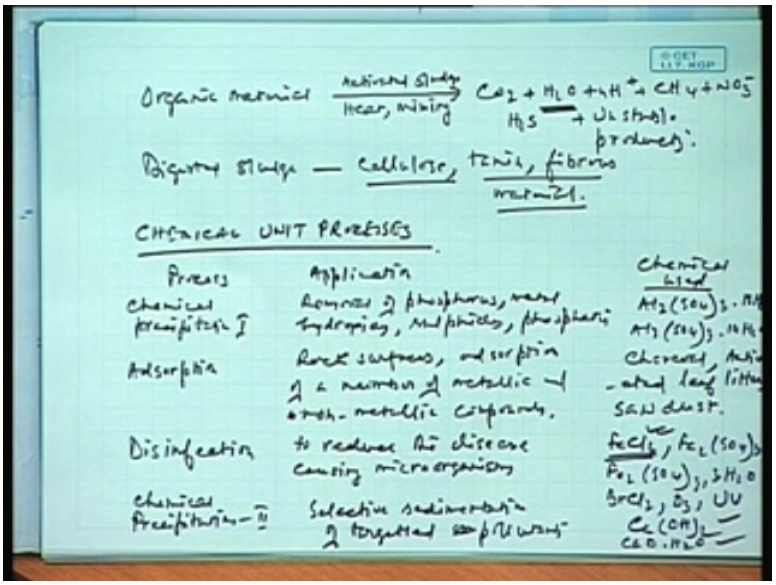

So, here you know the second, the very important other you know the chemical unit processes. The next is this say is a major heading chemical unit processes, processes, chemical unit processes where we would be generally using, we would be generally using some kind of method or treatment for method on treatment for say treating the waste, treating the waste. The process you know just let me make some differentiation here application, process and application where you can process where you can use this, this is the, this is say process is chemical precipitation is, chemical precipitation say removal of, removal of phosphorous, removal of phosphorous then removal of metal hydroxides, metal hydroxides, metal hydroxides and metal hydroxides, phosphorous, metal hydroxide then sulphides.

So, removal of phosphorous means removal of phosphates also just to say that the phosphates. Phosphates are the sources of phosphates as you can see many of this phosphates are coming through the fertilizers, detergents or detergents are a major sources of phosphates nowadays and the chemical used, chemical used for this purpose is, chemical used for this purpose is one of them is alum. So, here this is alum is Al 2 So 4 3 18 H 2 O or you can see this Al 2 So 4 3 14 H 2

O. This is the combination that we generally observe say this chemical precipitation adsorption, adsorption, the adsorption is the methods for adsorption is this is, this is also a very important area now, this is lot of materials are being now used for adsorption. Say this particularly the adsorption are this the rock surfaces, broken rock surfaces that we have observed you know particularly in the trickling filter rock surfaces say the nowadays a lot of substances are being used say this for particularly say the adsorption of rock surfaces, say adsorption of this particularly what we do is adsorption of, adsorption of say a number of metallic and nonmetallic, adsorption of a number of metallic and nonmetallic compounds, material that are being used are interesting array of materials are now being used say you know one of them is charcoal that I have said. Charcoal is one very important area of where adsorptions are being, being thought of say this activated, activated leaf litter. We are, we have done a number of experimentation on this, this activated leaf litter.

We can observe you know particularly this phenolic adsorptions, phenols can be activated leaf litter. Leaf litter is the leaf that falls off from the tree, this remains as a very good substance I mean it's you know generally mostly those things are burnt but these substances are rich in cellulose and rich in you know high surface area and this makes a very good component, this makes a very good material for adsorption, particularly a number of material can be adsorbed in the, in the, in the activated leaf litter, activated saw dust, saw dust all these things are being used for adsorption nowadays. Some materials so you know you just try to understand this as a process you, you would be a mostly the polluted wastewater you might require to do some preprocessing like you know a size may be classifying to a size may be important.

You run a particular stream of water over these surfaces, over these surfaces and design the process in such a manner that they remain in contact for a long time. As a result of that this most of this material will have a very high surface area and they will be mostly porous also. So, as a result of that many of the substances will have a natural affinity to remain attracted, natural affinity to remain attracted with the surfaces and as a result of that the concentration of a particular pollutant begins to reduce okay. This is the adsorption process, this is the adsorption process, those are material that I have already explained what are these things we generally use. One we also use disinfection, disinfection where we generally, we generally do not particularly try to remove any material instead of that, instead of that we generally want to exterminate or kill some of these, some of the microorganisms.

Say you know this is to reduce the application, to reduce the disease causing, disease causing, disease causing microorganisms, disease causing microorganisms, this is a disease causing microorganisms. There are some microorganisms I have discussed in the water pollution, the type of pollutants in water. So, the disease causing microorganisms like which are say which are generally related to water hygiene, water sanitation all this you know we have discussed earlier in this water treatment, water pollutants. So, these are mostly the famous ones that we generally know is at ferric, ferric chloride, ferric chloride then this is ferric sulphate also used as chemical precipitation, also used in Fe 2 So 4 3, ferric chloride this is then then you can say that Fe 2 So 4, Fe 2 So 4 3, 3 H 2 O and another very, very important and greatly used, this is greatly used is calcium hydroxide, this is not sorry calcium hydroxide comes for precipitation.

So, disinfectants that we can generally find this disinfectants being used, particularly the chlorine there are certain bromides also are being used say this bromine chloride BrCl 2 right bromine chloride then ozone is also used, ozone is also used say UV is also used, disinfect UV and you know particularly in a various kind of substances that generally we use and another very important part you know we should also discuss about this, about this chemical precipitation. Let us this is one you write chemical precipitation, chemical precipitation, chemical precipitation two, this is almost the same only thing you know just because I didn't write it there, so let me write it here. This is a mostly the purpose remains the same, purpose remains the same selective, selective sedimentation of targeted, targeted substances, targeted pollutants calcium hydroxide, calcium hydroxide or you can write it as CaO H 2 O, CaO H 2 O. This is being is a very popularly used, this is very popularly used. So, this is the chemical unit processes that are generally used for different purposes of this particularly in dealing with the wastewater and for dealing with this, the process of using these chemicals, using mostly these chemicals. Let us further discuss on some of those things you know what are the standard reactions that are generally involved in.

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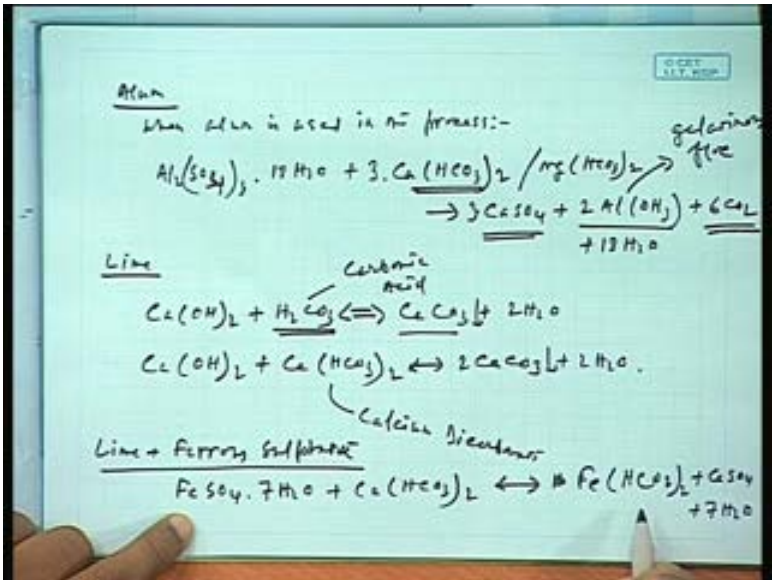

See use of alum, alum that we have used, alum that I have generally used, alum that we have known Al 2 So 4 3 to 18 H 2 O, this this the reactions generally when an alum is used in the process the intervening reactions are very important of great importance to us, Al 2 So 4 sorry Al 2 So 4 3 and 18 H 2 O forming with say 3, this is forming 3 CaSo 4. This aluminum hydroxide, this aluminum hydroxide, this aluminum hydroxide is used as a floc, you know this is a gelatinous substance, gelatinous is a basically a gelatinous floc that would be settled slowly that settle slowly when this you can find that you know much of this you know is and also you know part of this carbonate is becoming, this carbonate is essentially targeting the carbonate, the bicarbonate, the bicarbonate being converted into broken into calcium sulphate and carbon dioxide.

So, you know as a result of that the dissolution of bicarbonate taking place, so alum actually this is the alum by which you know you can see the gelatinous floc which is a result of a precipitation here and what we are trying to remove is calcium bicarbonate. So, this calcium bicarbonate and this magnesium bicarbonate this is also you know you can see this, the same is can be for magnesium bicarbonate also which is greatly you can see this, this all related to the hardness of water. So, reduction of hardness of water by using alum, reduction of hardness of water by using alum, the typical process is like this, the typical process is like this. And another very important thing is that about lime. I will discuss about the other general purpose of this processes but you know let me just explain you what are the reaction involved. The lime is a, when the lime is added you see this lime is added, this is lime plus you know is H 2 CO 3 as there is a forming of this. This is calcium carbonate, calcium carbonate plus 2 H 2 O forming here or is Ca another reactions that we generally observe is Ca OH 2 plus Ca 2 CaCO 3 plus 2 H 2 O. Say here also you say is a carbonate reduction process is a basically, the particularly the mostly this you know mostly this the carbonic acid hub bound carbonic acid, this is carbonic acid and this is calcium bicarbonate as you know calcium bicarbonate.

So, as a result of this you know this calcium carbonate, this is begins to precipitate, calcium carbonate begins to precipitate. So, these are, this is of the typical, typical methods, typical processes that are used sometimes was used lime plus lime plus ferrous sulphate lime plus ferrous sulphates, this lime plus ferrous sulphate the usual, this is an usual method of bicarbonate removal. So, here we can find it Fe CaSo 4 plus 7 H 2 O, this is ferrous sulphate that ferrous sulphate that we have said the ferrous sulphate is also used as a disinfectant plus calcium bicarbonate, calcium bicarbonate forming ferrous bicarbonate this, this is when this ferrous bicarbonate then further this ferrous bicarbonate then further reacts with, this ferrous bicarbonate then further reacts with…

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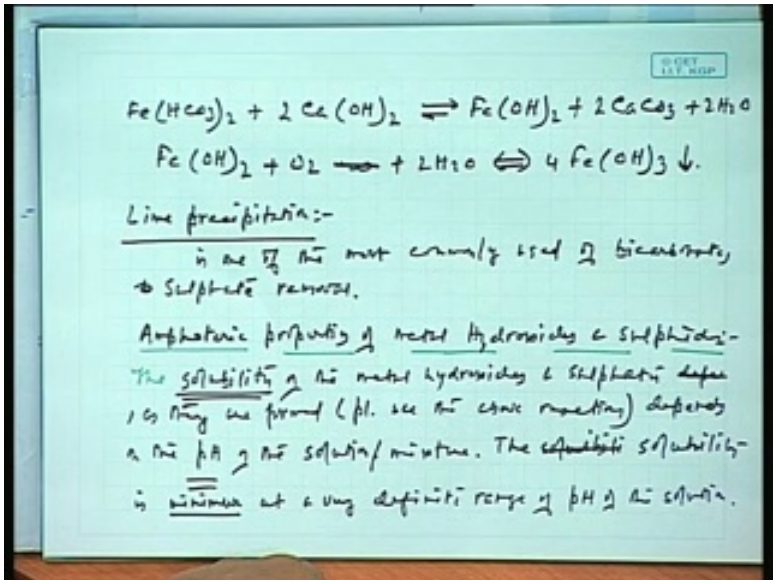

This is what begins to precipitate, this is what begins to precipitate, this is also lime and ferrous sulphates when are being used together we can see how it can reduce this, the bicarbonate

alkalinity in water, right. So, this is just you know the method of, method of lime, the method of precipitation that we generally use in cases like this. So this, we'll consider that you know you see here in cases like say the requirement of lime and oxygen like this. So, these are the standard reactions that generally form in the chemical precipitation process. We would more discuss about, we would more discuss about the lime precipitation. This is because the lime precipitation is becoming, lime precipitation is of absolute importance and the major, it's a major method of secondary treatment. So, we would just bring lime precipitation here.

As we have already said that discussion here this lime precipitation that we generally observe in such cases, the lime precipitation remains, the lime precipitation is one of most commonly used, commonly used method of, method of bicarbonate, bicarbonate, hydroxide, bicarbonate and sulphate removal. Sulphate also you know we have discussed about we have seen you know mostly about the sulphate removal. I'll discuss about that. What happens here is one very important thing is, this is the one important property that is what is known as amphoteric, amphoteric, amphoteric properties, properties of metal hydroxides and sulphides.

This is a, it's of great importance, see please underline this amphoteric properties of metal hydroxides and sulphides. What happens is, what happens is the solubility, the solubility, the solubility, the solubility of the metal hydroxides and sulphates, metal hydroxides and sulphates depend sulphates as they are formed. Please, see the above reactions, please see the above reactions, you know as these hydroxides are formed, the solubility of metal hydroxides and sulphates as they are formed depends on the pH of the solution or pH of the solution or the mixture. This is what is important, one is this calcium hydroxides, most of this calcium hydroxides or say you know magnesium hydroxides even say then other metallic hydroxides, other metallic hydroxides they, when they are formed many of them are perfectly soluble in water is perfectly soluble in a medium of water where there is water is the major medium.

Now what happens is they are soluble, they are soluble only in a particular pH range, in a particular pH range. What is observed is the amphoteric property here it what is generally observed is the amphoteric the solubility, the solubility, the solubility, the solubility, the solubility is minimum at a very definite range of pH of the solution, pH of the solution I think the acidity or alkalinity of the solution okay. The solubility is minimum at a very definite range of pH of the solution.

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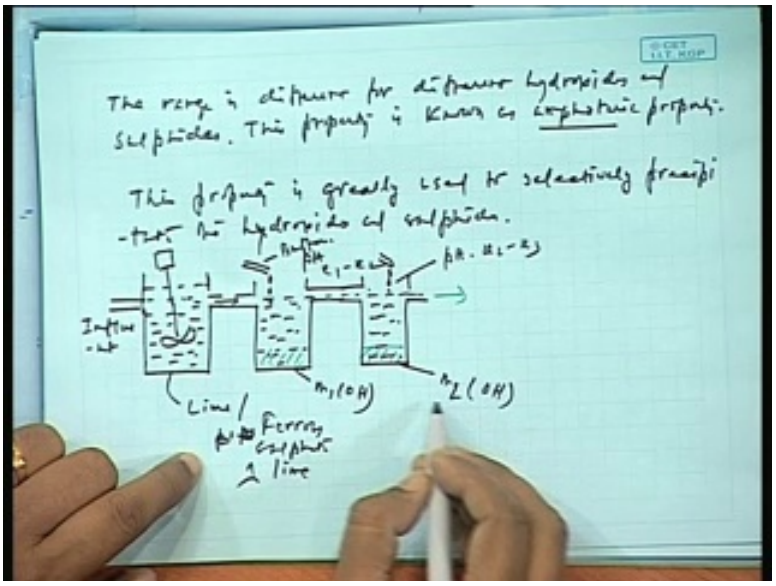

This is, so this range is understandably, this range is the range is different for, different hydroxides, hydroxides, different hydroxides and sulphides. This property is known as amphoteric, amphoteric, amphoteric property. This is, this property is greatly used, this property is greatly used to selectively, to selectively precipitate, this property is greatly used to selectively precipitate the hydroxides and sulphides, this property is greatly used to selectively precipitate the hydroxides and sulphides, remember this. So, what we see is this is something like this. If you just see the pattern here, if you just observe the pattern here what we are trying to do is we'll try to find a mixing chamber, we'll find a mixer here okay.

So, this is where this is, it is this is the stream the influent, the influent, this influent, this influent is where this we are mixing with say either, either lime or ferrous sulphate or lime, lime or say ferrous sulphate of lime, ferrous sulphate, ferrous sulphate of lime, all right. Now, this is now when it is going from one place to another this is going from one place to another, what we try to do is this particular this liquid we would try to control the pH here, we would try to control the pH here say at a particular range say pH we are finding pH, we are keeping between x 1 and x 2, pH we are measuring keeping between x 1 and x 2.

So what happens is here we would have it is this is by how it is, how it is could be done, by mixing of, by mixing say by mixing buffer, buffer. So, we will use the, we use the buffer to control pH. So, if we are mixing the buffer to control pH, we would find a, we would find a selective deposition of a particular hydroxide or sulphide okay. The next is, so next the stream continues, the stream continues we carry out the stream, we use the same process, we process the same process say here we generally maintain say similarly we maintain a particular we are particularly maintaining another pH, another pH by using the buffer as we have used in this case, we are using this buffer here, this buffer, using this buffer we are maintaining the say pH between say x 2 and x 3, okay.

Now, we can selectively precipitate another, another particular hydroxide. So, this is the use, this is, this is the process you know which is of, so here this can continue, this can continue, this process can continue, what is what we are trying to do is, what we are trying to do precisely is after this, after the water has been mixed with, after the water has been mixed with lime or and lime or lime and ferrous sulphate here in this case so, as soon as that have forms the hydroxides would be formed, different hydroxides would be formed. These different hydroxides would be selectively precipitated. What we would try to do is, we would try to maintain the pH, the range of the pH at which the solubility of a particular metallic hydroxides or sulphate is minimum. If it is minimum then only it would come out of the body of the water, it would try to settle out, this would begin to precipitate so it's okay.

So, this is what we are selectively precipitating a particular say M 1 OH 2 OH right, this one is M 1 M 2 OH a particular, a particular, a particular kind of hydroxides, particular hydroxides are being selectively separated. This has a great importance, this particularly this can be only be achieved by the use of this amphoteric property. The amphoteric property suggests that at a particular range of pH, at a particular range of pH if we can maintain the pH at that level, the solubility of the metal hydroxides or metal sulphides would be minimum and this would be different for different metal hydroxides, metal sulphides okay and that is how you would selectively precipitate all this substances, okay. Lime precipitation is a very greatly used process you know it's all most all major chemical treatment methods, the much more than 90% of the chemical treatment methods wherever and however it is done lime is used. So, lime as a method this is a very common method, very cheap method, very simple method to work with but you know planned performance and other things are certainly a matter of concern because you know the scaling it begins to reduce the effectivity of this treatment. However, it is quite common method, it is a method. It's okay, we'll stop here, we'll take out, we'll begin the class again and we'll start see how we can do it again, how can we look forward to this.

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Well, we are explaining about the chemical treatment of mine waste wastewater in general and we are discussing about the amphoteric property of most of this metal hydroxides and sulphides. We have also observed that you know that in situations like where in a solution, in a solution all this metal hydroxides and sulphides generally show a particular preference of pH when they are their precipitation rate is high, precipitation rate is highest for them and also to observe that that you know they show a minimum solubility in water at a particular pH. This particular property of this metal hydroxides, metallic hydroxides and sulphides are greatly used in chemical treatment. I have also discussed you know the procedure essentially is like this. I have given you a

particular idea about how this you know the plans can be designed, in plans can be design in with that in mind. Let me explain you a little bit on this.

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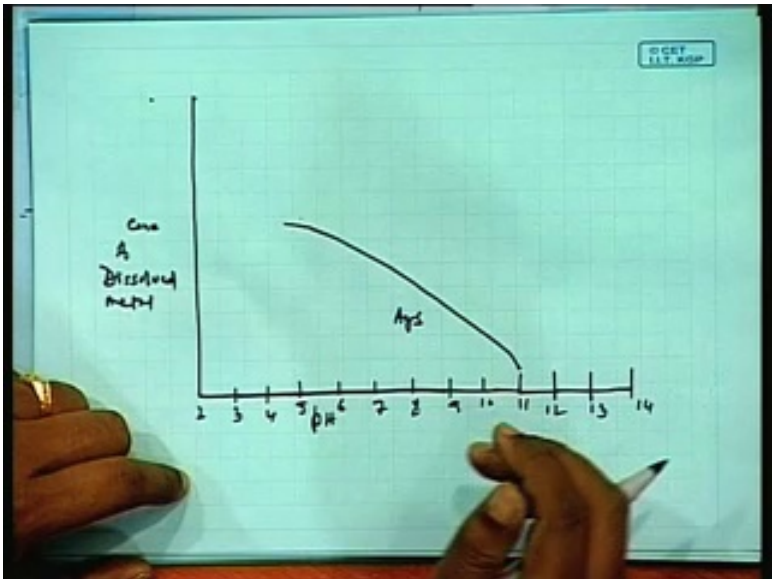

Let me explain you a little bit on this. Say you know here if you just observe this amphoteric property in a graphical form, this is how it looks like say concentration of dissolved metal, concentration of dissolved metal and if you observe this, if you observe this you know in terms of pH here we also consider the pH 2 3 4 5 6 7 8 9 10 11 12 12 13 and say 14. So, here okay, so what we observe the pH in which the water can remain. See, here what is important here is this to observe here is say at about 11 pH, at about 11 pH, this is the Ags, Ags, it has the Ags has, this is the Ags, this is a silver sulphides. So, we can find out here this you know this particularly you know has a minimum solubility here. So, what we are trying to do is suppose if we want to precipitate silver sulphide here, what you would try to do is just to maintain the pH at about 11, pH of the solution to be kept at about 11 so that…