Water and Wastewater Engineering

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Lecture - 11

Coagulation and Flocculation (Contd…)

Last class we were discussing about Coagulation and Flocculation. We have seen that, what is the need of coagulation when we consider the removal of particles. In water, if you consider the solids, the size of the particles vary about six order of magnitudes. So if you want to go for mere settling it is very very difficult to remove al the particles present in the water whatever we are using for drinking purpose. So if you want to remove the rate of particle removal, what we have to do, we have to make the small particles come together and agglomerate and form bigger particles so that is the purpose of coagulation and flocculation.

So what we are doing in coagulation and flocculation is adding some chemicals which change the surface properties of the coagulant colloids and make them agglomerate together. And in coagulation the mechanism we can classify into four different categories; one is ironic layer compression, second one is adsorption and charged neutralization, third one is [s…..2:15] coagulation and fourth one is adsorption and inter particle bridging.

And we have seen that, how the particle concentration in the particle affect the coagulant dose. And we also found that it is very very difficult to find out the optimum coagulant dose theoretically. So, if you want to find out the dose you go for laboratory experiments using a jar test which simulates the field conditions of coagulation, flocculation and settling then based upon that one we can find out the optimum coagulant dose. So today we are going to discuss what is the effect of alkalinity in coagulation and we will see what all are the different types of water available and how the dose of coagulants vary and how can we go about for the design of rapid mixing, slow mixing and what all are the factors to be remembered when we go for coagulation flocculation system design.

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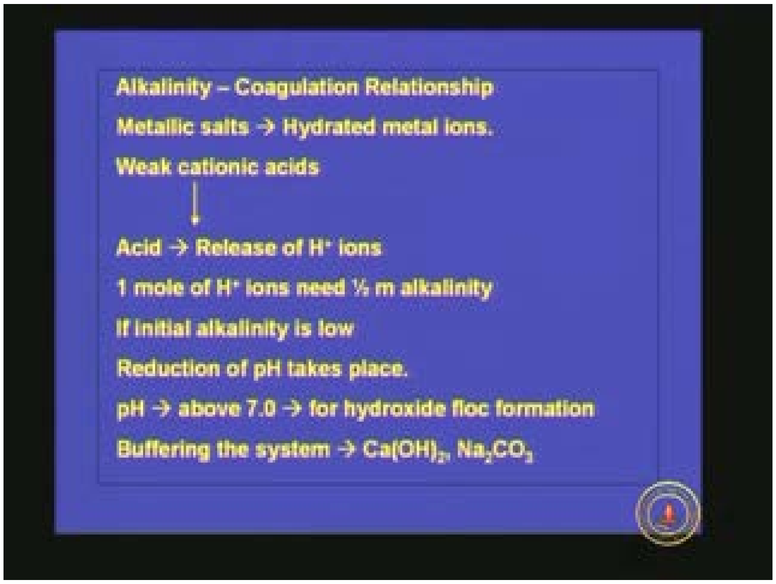

So alkalinity is very very important when we go for coagulation and flocculation because we have seen that in water treatment as coagulants we usually add alum or ferric chloride. These salts as soon as we add to the water they will be forming aqua metallic ions. So as a result what will happen hydrogen ions will be released to the system so the pH of the system will be coming down. But you know if you want to have a [s….3:45] floc aluminum hydroxide or ferric hydroxide should be formed, so for this one the pH should be either neutral or above neutral that means pH should be above 7. So if the pH is coming down by the addition of alum and if you want to maintain the pH within 7 or above the water should be having sufficient natural alkalinity. If sufficient natural alkalinity is not there what we have to do is we have to add alkalinity externally in the form of calcium hydroxide and sodium carbonate. So, in most of the treatment plants along with alum we add lime. The purpose is to provide enough alkalinity so that the coagulation flocculation process is effective. We will see what is the chemistry behind this one.

This is the reaction between alum and alkalinity. The alum whatever we are getting is hydrated alum it will be reacting with the natural alkalinity whatever is present in the water so it is in this form (Refer Slide Time: 5:03) and if natural alkalinity is already present in the water it will be coming like this and the products are 2 aluminum hydroxide plus 3 calcium sulphate plus 6 CO 2 plus 18 H 2 O. From this reaction it is very that for 1 mole of alum of aluminum sulphate we need 3 moles of calcium bicarbonate or 3 moles of alkalinity in the form of bicarbonate. So, if natural alkalinity is not present what will happen the reaction will not be possible because this is the compound (Refer Slide Time: 5:44) which is responsible for the sweep coagulation. Unless sufficient alkalinity is not there the formation of aluminum hydroxide will not be proper so your coagulation will not be effective.

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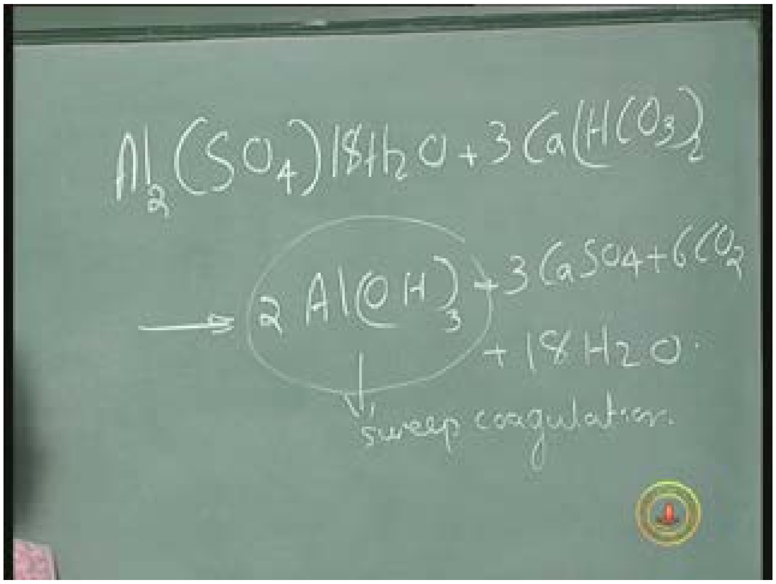

So what we have to do is if alkalinity is not there we have to add alkalinity externally. So this is what happens usually Al 2 SO 4 3 18 H 2 O we are adding alkalinity externally it is coming like this (Refer Slide Time: 6:23) this is nothing but lime and it reacts with water we get calcium hydroxide and the products will be the same 2 aluminum hydroxide plus 3 calcium sulfate plus 18 H 2 O so this is what is happening. We add alkalinity externally this is the external alkalinity 6:51). And we will see, these metal ions, when we add to water, because aluminum sulphate as soon as we add to water what will happen, aluminum ions and sulfate ions will be forming so these aluminum ions will be reacting with water and it will try to give aluminum hydroxide. Along with this one many other aqua metallic ions will be forming so here itself we can see h plus ions are released. So, if we want to neutralize this h plus ions that is why we need alkalinity.

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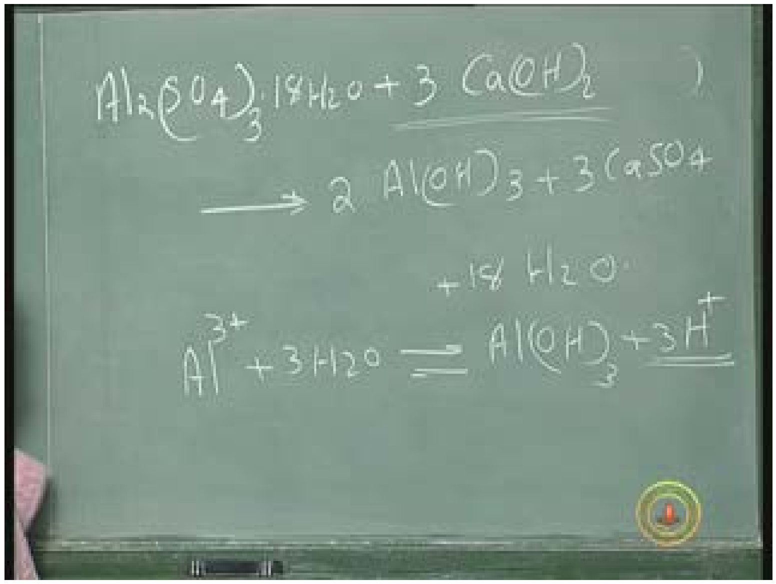

And one more point is that if you take the residual aluminum concentration versus pH this is coming something like this pH 0. It is coming something like this (Refer Slide Time: 8:05) so if the pH is above 7 the optimum pH is around 7.2 at this point aluminum hydroxide is having minimum solubility. What does it mean? If the pH is either this side or this side the solubility of aluminum will be very very high so you will be having very high aluminum concentration in the system so that is also not preferable. So in that point of view also we have to maintain an optimum pH above 7. So because this is aluminum hydroxide solubility diagram so we can see that it is having an [um….8:40] nature that means the solubility of this compound increases if the pH decreases or if the pH increases. So that is why in coagulation and flocculation alkalinity plays a very very important role. That is what I have explained here also (Refer Slide Time: 8:59) so metallic salts creates hydrated metal ions and hydrated metal ions are acting as weak cationic acids. That means each aluminum atom each aluminum atom will be combining with six water molecules because water molecules will be acting as [l……9:16] and this [li……] will be dissociating and releasing hydrogen ions. So whenever these aqua metallic ions are formed hydrogen ions will be released and one mole of hydrogen ions needs half moles of alkalinity.

So, depending upon the hydrogen ions released or depending upon the compound produced we can find out what is the hydrogen ions released into the system. And then naturally whenever we add these types of salts there is a reduction of pH. So pH above is required for the formation of hydroxide floc. So buffering of the system is required and usually we do the buffering by using calcium hydroxide and sodium carbonate.

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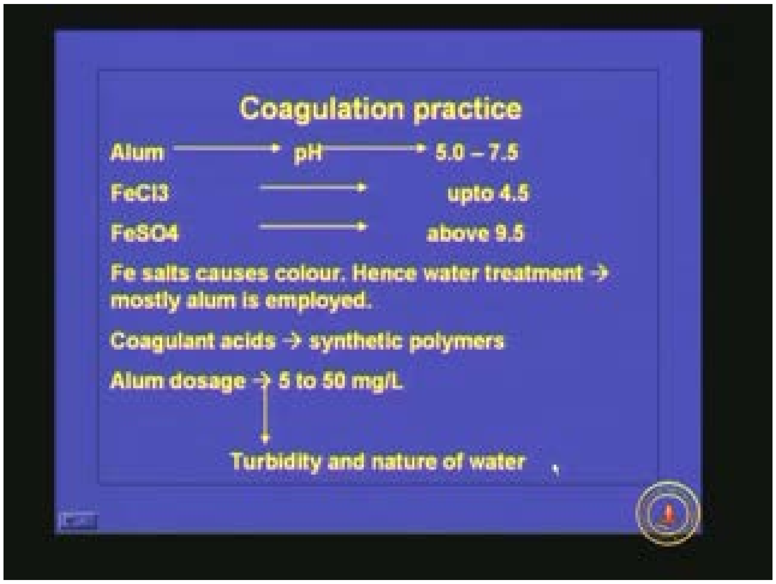

So if you want to see the optimum pH range of various coagulants we usually practice in water treatment plants here we can see alum the optimum pH is in the range of 5 to 7.5 but we always prefer a pH above 7 and for ferric chloride it is static from 4.5, 4.5 above it is able to work and ferrous sulfate or copper as it will work only for a pH above 9.5. And in water treatment last class also I have discussed in water treatment we prefer alum the reason is ferric sulfate causes color and moreover depending upon the conditions the overall the oxidation reduction potential of the system ferric can be reduced to ferrous and so on and so on so aluminum will not be undergoing any further reaction so we always prefer aluminum for alum for water treatment.

And usually in water treatment if you consider the optimum coagulant dose varies from 5 to 50 mg per liter and it depends upon again the turbidity and nature of water. Now we will see based upon the coagulation efficiency the natural water can be divided into for different categories. It is basically depending upon the turbidity of the water and alkalinity of the water because alkalinity is the parameter which decides the efficiency of the coagulation and we have discussed again how the turbidity or the concentration of the colloidal particles affect the coagulation in the last lecture.

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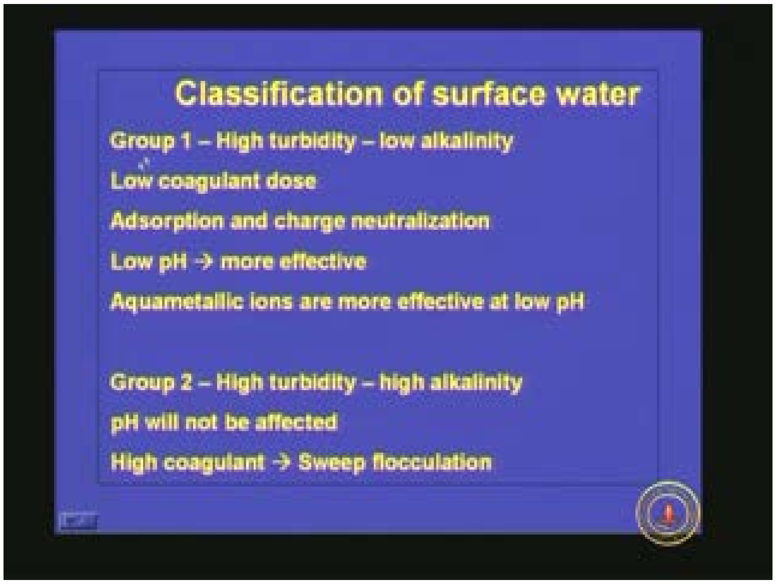

So in group 1 we consider high turbidity and low alkalinity water so here what happens the mechanism of coagulation will be adsorption and charged neutralization because at low alkalinity what will happen, when we add the coagulant to the water aqua metallic ions will be formed and it will be having positive charge. So positive charged ions are more preferred compared to non-charged or negatively charged ions. So these positively charged aqua metallic ions will be having high affinity towards the colloidal particles so they will be attaching to the colloidal particles and they will be neutralizing them. But if the pH is if the alkalinity is high what will happen the positive ions formed in the system will be low and adsorption and charged neutralization will not be effective. So, for adsorption and charged neutralization low pH is more effective so what will happen, here high turbidity is there, low alkalinity is there so adsorption and charged neutralization is taking place and because the turbidity is very very high once the particles are destabilized or the charge is neutralized there is high possibility of these particles to come together and agglomerate and settle down. So in this case the coagulant dose required is less compared to other cases.

Now we will see what is the group two type of water. Here we have high turbidity and high alkalinity. Since the alkalinity is very very high the pH will not be affected by the addition of coagulant to the water system so what will happen is the pH will be always in the higher side that means it is above neutral pH. So at high pH sweep coagulation sweep flocculation is the mechanism of turbidity removal. Why it is happening like this is at high pH or high alkalinity aqua metallic ions formation or aqua metallic ions will not be having high positive charge so adsorption and charged neutralization will not be so effective.

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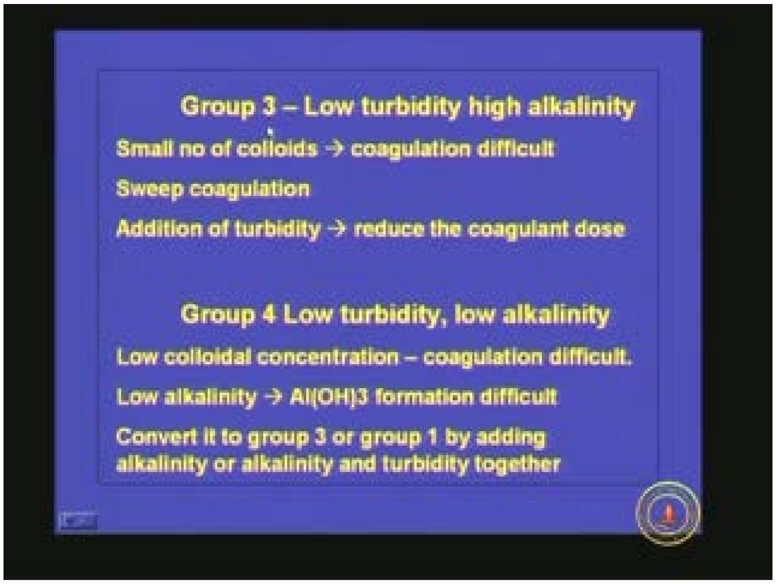

And now coming to group 3 water it is low turbidity and high alkalinity. Here also since high alkalinity is there the aluminum hydroxide floc formation will be very very effective. And since small number of colloids are present no other mechanism is going to work because the chance of inter particle collision is very very low. So the only mechanism which can work is sweep coagulation. So if you want to, so sweep coagulation we all know that the amount of coagulant required is very very high. So if you want to reduce the coagulant dose what we can do is add some turbidity externally because if more turbidity is there that turbid particles itself will be acting as nucleus for precipitation and precipitation will be more effective and in effect we can reduce the coagulant dose.

Now coming to the group 4 type of water low turbidity and low alkalinity. This is the worst type of water as far as coagulation and flocculation is considered. The reason is, low alkalinity. So this is not preferable for aluminum hydroxide formation because the pH is towards the lower side. And low turbidity, since the turbidity is very very low adsorption and charged neutralization will be effective because low alkalinity will be forming positive aqua metallic ions and particles will be getting destabilized but enough number of particles are not there so they will not be able to agglomerate and settle down. So the coagulant dose required will be very very high. So if you want to reduce the coagulant dose either we can convert this water to type 1 water or type 2 water. Type 1 water means by adding alkalinity or by adding turbidity or together. So, if you want high turbidity what will happen it will be high turbidity and low alkalinity so the coagulation mechanism will be adsorption and charged neutralization. So with less coagulant dose we can remove the turbidity. If you add both it will be converting to the type 2 water so high turbidity and high alkalinity so sweep coagulation will be working much much better.

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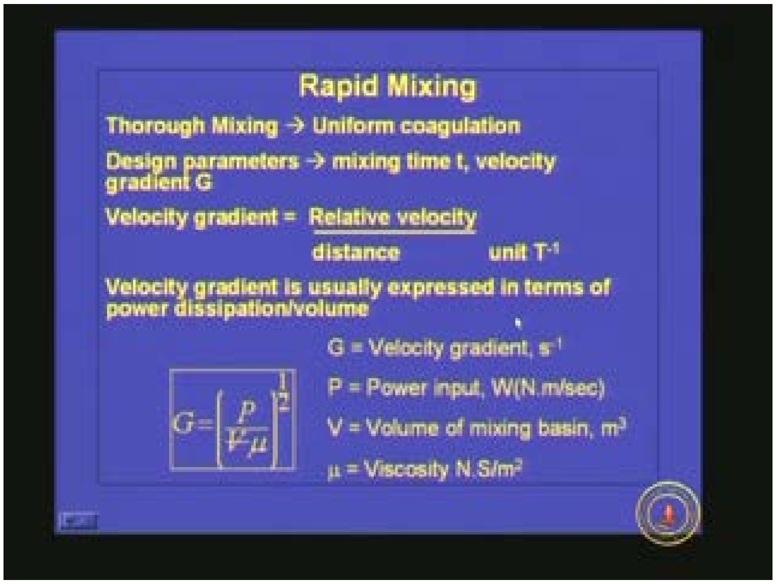

So now we will see, we have found out what is the optimum coagulant dose and we have also seen how we can change the optimum coagulant dose by adjusting the turbidity and alkalinity or by changing the mechanism of coagulation. But after the addition of coagulant we have to have a proper mixing of this chemical throughout the water volume. Generally all the particles will be having equal concentration of the chemical and once the particles are destabilized there should be some mechanism by which we can make them come together. So, rapid mixing and slow mixing are very very important in coagulation and flocculation. So thorough mixing is definitely very important for uniform coagulation and for thorough mixing the design parameter is velocity gradient and mixing time.

Velocity gradient is nothing but, if you want to find out the velocity gradient between two particles it is nothing but the relative velocity divided by what is the distance between them. For example, if two particles are there and if they have a relative velocity of 1 m per second and they are placed 10 m apart so the velocity gradient is nothing but 1 divided by 10 that means 0.01. And the time of velocity gradient is t minus 1. And velocity gradient is usually exposed in terms of power dissipated per unit volume or G we can express in this way G is equal to power divided by volume into mu raised to half where G is the velocity gradient exposed in terms of t inverse 1 and power in terms of watts that is nothing but Newton meter per second and volume (Refer Slide Time: 18:25) this is the volume of the mixing basin that much of power whatever we are supplying it is getting dissipated in that complete volume, the unit is meter cube and mu is the viscosity of water and the unit is Newton second per meter squared.

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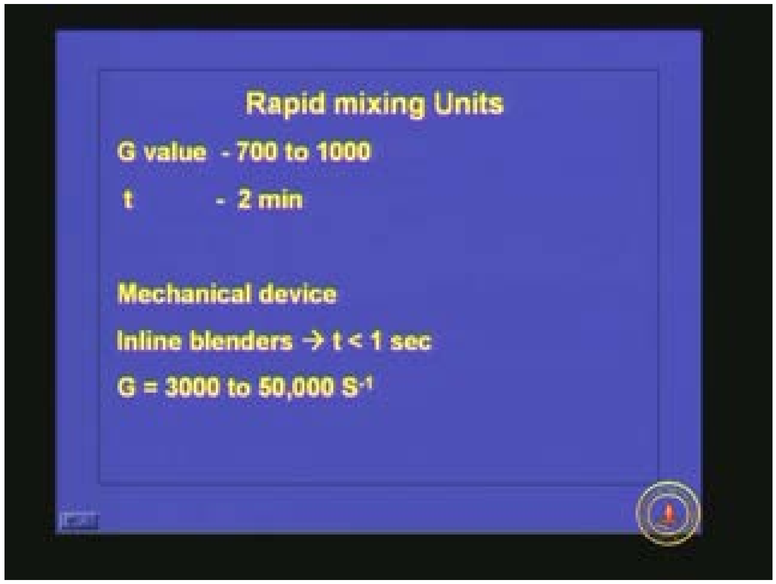

So usually for the design or rapid mixing unit we provide a G value of 700 to 1000. And usually the time varies from 1 to 2 minutes but there are inline mechanical blunders which works with very high G value so naturally the t will be very very less that means 1 second and here the G value varies from 3000 to 50000 per second. So once again the design parameter is nothing but G value and we have to be….. the G value for rapid mixing is 700 to 1000. In rapid mixing what is happening the chemical is completely mixing in the entire volume of liquid and it is helping in uniform coagulation.

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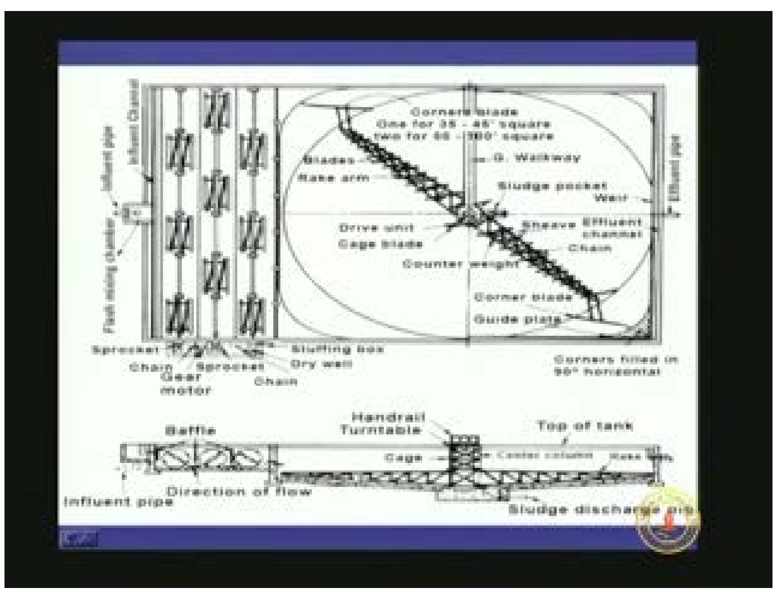

This is a picture of a coagulation flocculation unit. So we can see that this is the influent pipe and (Refer Slide Time: 19:49) this is the rapid mixing unit. The chemical is coming here and here one mixer is there and we can see that the size of this tank is very very small compared to this tank because the detention time required or the time we give for rapid mixing is only 1 to 2 minutes so naturally the volume required for the tank is very very less and this is the unit for slow mixing or flocculation and this is the clarifier or the sedimentation tank after flocculation. Big big flocs will be formed and that will be entering in the settling basin and it will be settling down, and this is the sludge removing mechanism where all the sludge will be removed and it will be taken away from the tank. This is the cross-sectional area (Refer Slide Time: 20:40) so we can see the influent pipe and baffles and this is the settling tank.

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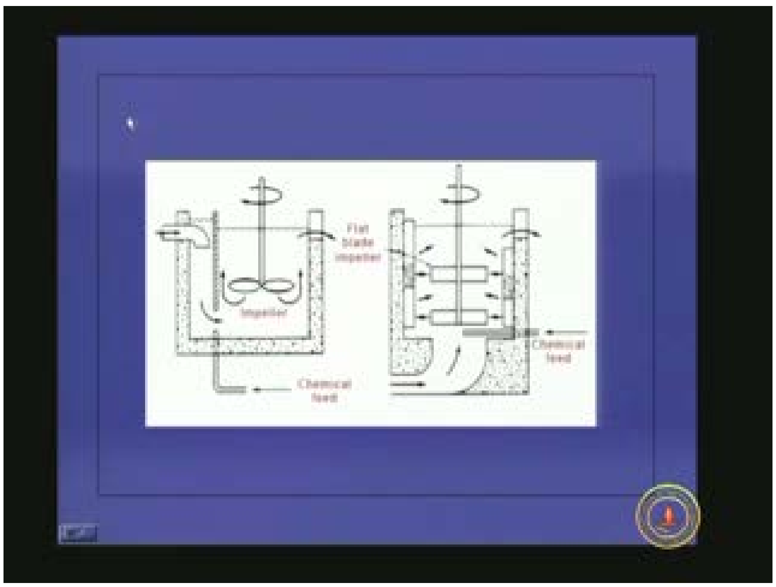

This is another type of rapid mixing unit. So we can see that this is the chemical feed and (Refer Slide Time: 20:55) this is the influent pipe, the influent pipe is coming here and this is the baffle wall to dissipate the incoming kinetic energy. Here the opening is very very less so naturally the velocity will be high so here we are adding the chemical so there itself the chemical is mixing with water and here another impeller is there which will be rotating at a very high speed so rapid mixing will be taking place and from here it is coming out to the flocculation unit.

This is yet another configuration (Refer Slide Time: 21:29) this is the inlet pipe and this is a baffle wall in both such baffles are there and this is the mixer and this is rotating in this direction. So what is happening, we can see the water flow direction, water is coming here and from here it is flowing towards this direction and again it will come back here, again another paddle is here and again it goes so complete and uniform mixing is taking place in this tank and the chemical feed is from here and it comes exactly at the center of the inlet pipe.

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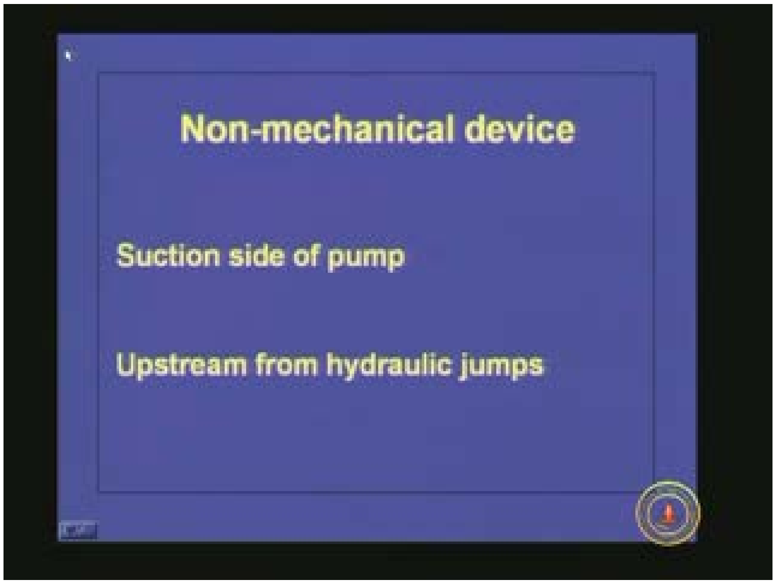

Whatever we have seen now those three units are mechanical units that means they are supplying power by mechanical means or through electricity or whatever and the unit is working but there are many non-mechanical devices which are used for rapid mixing. The advantage of this one is there is no maintenance cost and no energy requirement so it is more preferable but the only thing is if we design this one and construct it we cannot change the system it will be very very difficult.

The most commonly used non-mechanical devices are suction side of a pump. We know that the water will be sucked at such a high pressure so much of mixing will be taking place in the suction side of the pump so if you add your chemical there in the suction side of the pump what will happen, uniform mixing will be taking place.

Another one is upstream from the hydraulic jumps. If you provide the chemical dose just at the upstream side of the hydraulic jump then in the hydraulic jump the water in is super critical flow and it is changing to sub-critical flow. So whatever is the excess energy it is dissipating in this hydraulic jump. So if you provide or if you add the chemical just before the hydraulic jump then because of that jump thorough mixing is taking place and rapid mixing will be provided by this hydraulic jump. This is not hydraulic pump it is hydraulic jump itself.

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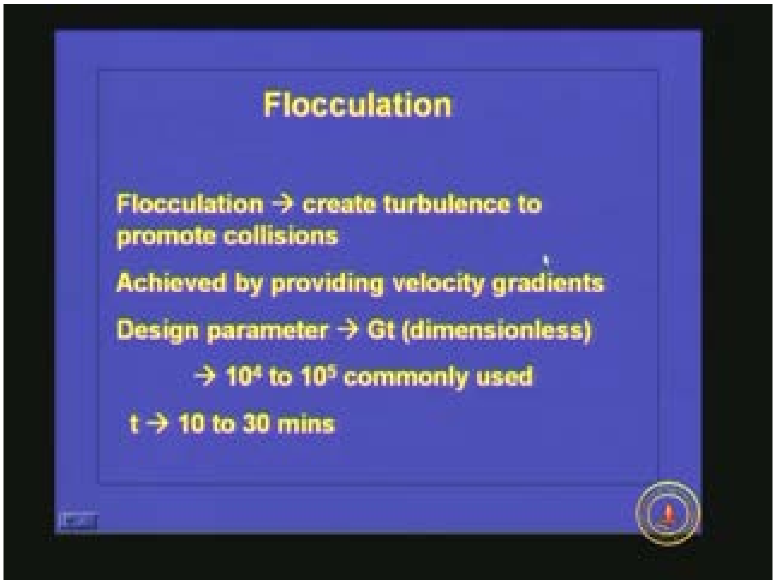

Now we come to flocculation. Rapid mixing is very simple, you have to provide a very rapid mixing for a short period of time to make sure that the chemical is mixed parallely and the coagulation is taking place uniformly. So as soon as this rapid mixing what will happen, the colloids whatever is present in the water will be destabilized because the chemical action will be taking place there. So once the particles are destabilized the next job we have to do is make them come together and agglomerate so that the flocs will be formed and the flocs if we can get large sizes of flocs the settling velocity will be much much higher and we can remove them effectively.

In flocculation what we do is, or the purpose of flocculation is nothing but create turbulence to promote collisions. Because if you provide turbulence and many particles are there which are already destabilized so what will happen, because of turbulence there are chances of these particles coming together and agglomerate. This is achieved by providing velocity gradient. Here also the design parameter is Gt (dimensionless parameter), here G is the velocity gradient and t is the time. And we can see that the Gt value varies from 10.4 to 10.5, this is the range we usually use in water treatment plants. And, the t value varies from 10 to 30 minutes but usually we provide a time in between 20 to 30 minutes.

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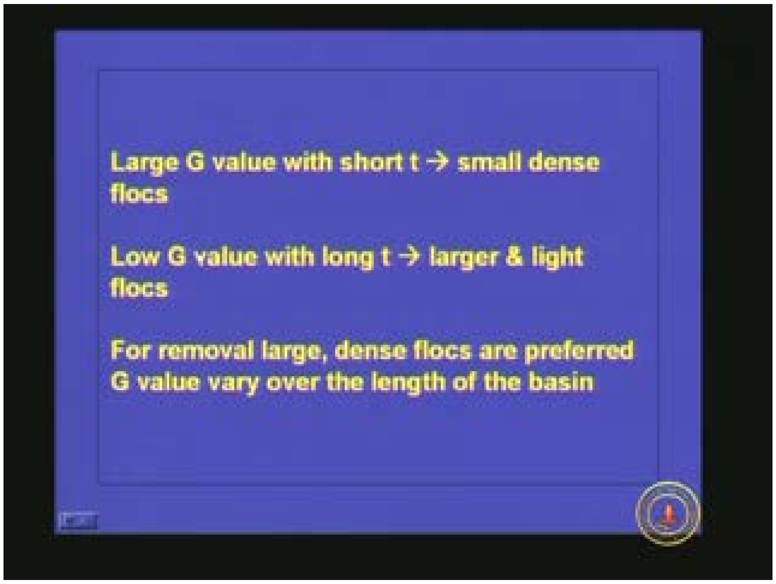

Depending upon the G value and the time we can make different types of flocs. If we provide large G value with short t we will be getting small but dense flocs. But if you provide low G value with long time, larger and larger but lighter flocs will be produced. So from this one it is very very clear that the G value and t decides the type of the flocs and we know if the density of the floc as well as the size of the floc are higher or more then naturally the settling will be very very high. So it is always advisable to go for a tapper G value or tapper Gt value. So initially if you provide a large G with short t what will happen, you will be getting small but very dense flocs.

Then for the next portion of your tank you provide low G with long t, then what will happen, these small dense flocs will be forming larger flocs so the flocculation will be much much effective, that is what I have written here. For removal large, dense flocs are preferred so it is always advisable to vary G value over the length of the basin.

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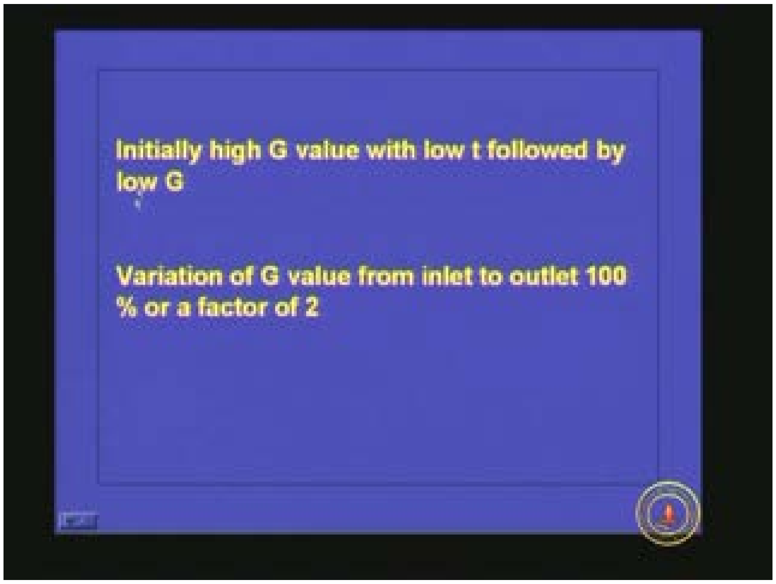

So how can we vary? Initially provide high G value with low t followed by low G value and variation of G value from inlet to outlet, if you want to get the best efficiency it is advisable to provide G value in such a way that the G value is varying 100 percentage from the inlet to outlet. That means the G value in the inlet, if you take the ratio of G value in the inlet to that of outlet if the factor is 2 then your efficiency is maximum.

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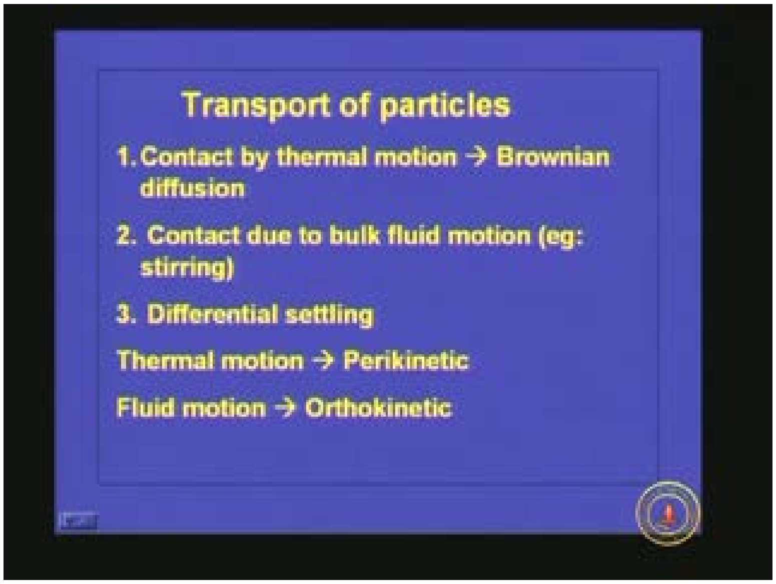

Now we will see what is the mechanism of this flocculation. So it is nothing but the transport of particles. Transport of particles, we have discussed earlier that coagulation and flocculation is the transport of particle and agglomeration of particle. Agglomeration of particle can take place only when they destabilize or they overcome the energy barrier, whatever we have seen in the last class. But once the energy barrier is overcome or the charge of the colloidal particles is destabilized then we have to make them come together, so that is the major role of flocculation. And this transport can be either by thermal motion that means Brownian diffusion or due to bulk fluid motion.

So in both the cases what is happening, a differential settling will be taking place so the chances of particle coming together is very very high. The flocculation which is caused because of thermal motion or Brownian diffusion is known as Perikinetic flocculation and the one which is caused by fluid motion or mechanical means it is known as Orthokinetic flocculation.

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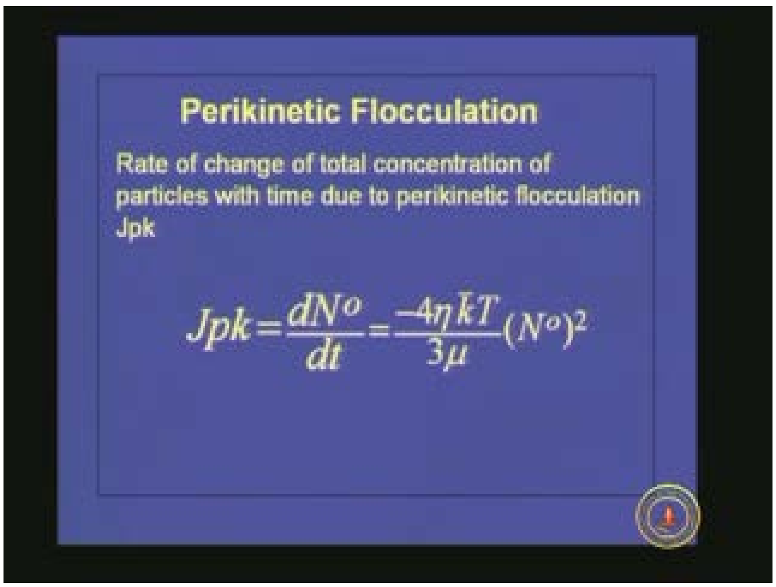

So if you want to find out the rate of change of total concentration of particles with time due to Perikinetic flocculation because whether it is Orthokinetic flocculation or Perikinetic flocculation our interest is to find out how the colloidal particle concentration is changing in the liquid. So, if you want to find out what us the rate of change of particles with respect to time by Perikinetic flocculation we can find out like this: (Refer Slide Time: 29:16) Jpk that means rate of change of particles due to Perikinetic flocculation and Perikinetic flocculation is nothing but the one caused by the Brownian movement that is equal to d N 0 by dt where N 0 is the number of particles present when t is equal to 0 and it is equal to minus 4 mu kT by 3 mu into N 0 square. So we will see what this one is.

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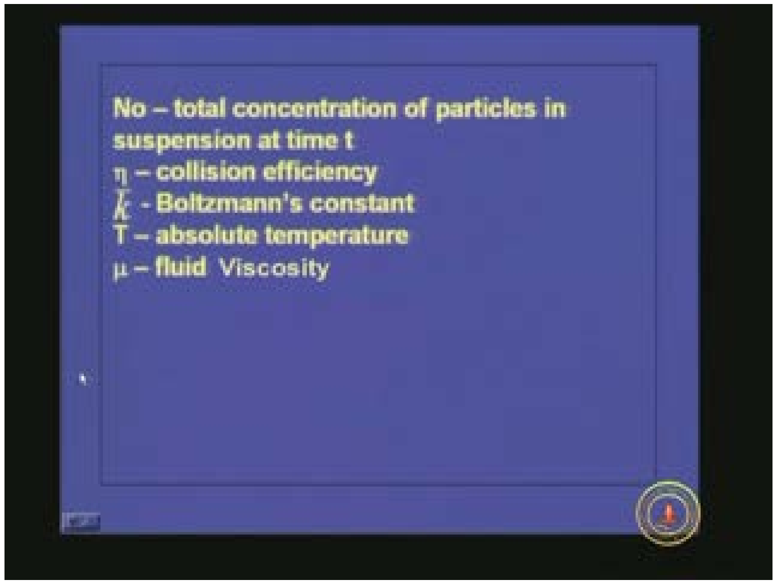

N 0 is the particle suspension at time t, this is epsilon that is the collision efficiency and k bar is Boltzmann's constant, t is the absolute temperature and mu is the fluid viscosity so it is a function of initial concentration and collision efficiency because we are assuming in most of the cases that once two particles are coming into contact the particles are agglomerating and they are getting removed from the system. But in most of the cases it may not be true. The efficiency of collision may not be hundred percent so that also we have to take into account. And k bar this is nothing but thermal diffusion it is depending upon Brownian motion that is why this Boltzmann constant is coming and fluid viscosity is very very important.

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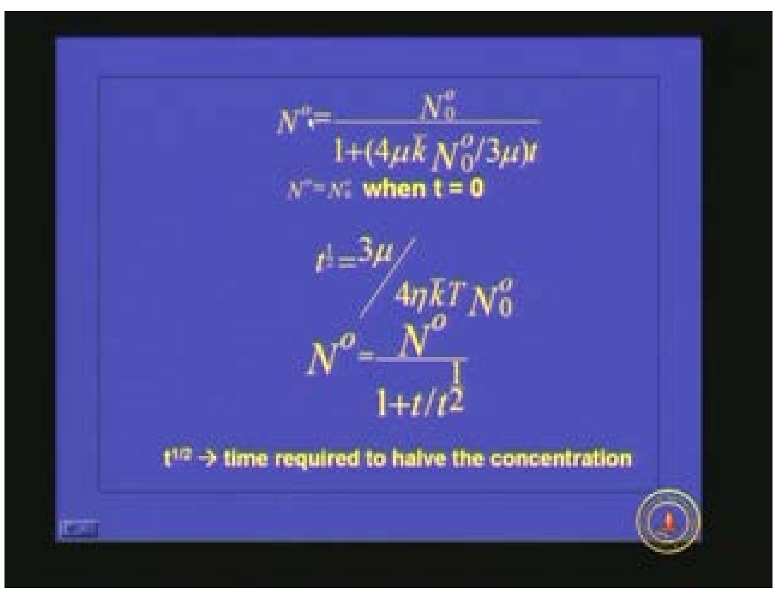

Therefore, the number of particles present in the system at any time can be found out using this formula; N 0 at t equal to 0 divided by 1 plus 4…. If you integrate the earlier equation then you will be getting this value; 1 plus 4 mu k bar into N 0 raised to 0 by 3 mu into t where t is the time. So at any time we can find out what is the number of particles present in the system.

Here N 0 is equal to N 0 power 0 when t is equal to 0. And we can find out from this formula what it the t half. That means if we want this N 0 equal to N 0 power 0 by 2. That means whatever was the initial concentration if you want to make it half or the half life of this one we can find out, this t half is nothing but 3 mu divided by 4 epsilon k bar T N 0 0. Or at t half we can find out what is the N 0 value. T half is nothing but the time required to half the concentration.

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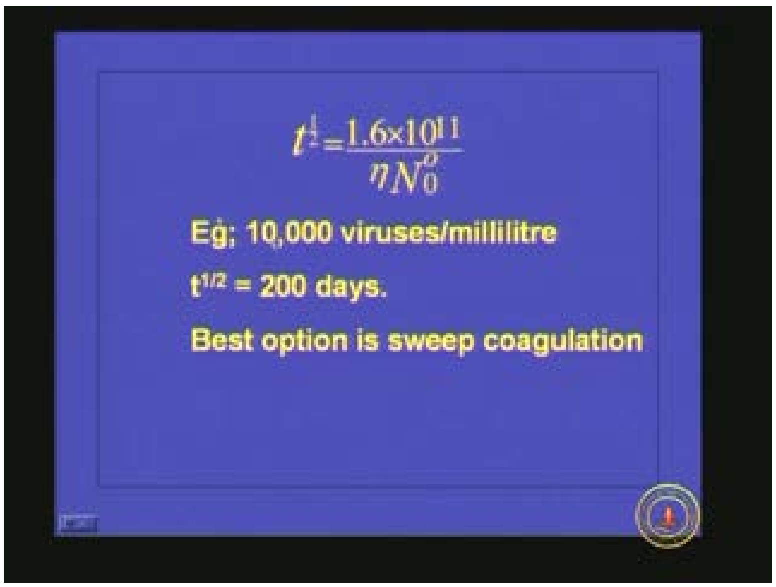

So if you want to find out, if you have virus in your system say initially 10000 viruses initially were present and if you use this formula we can find out that t half is around 200 days because you know that the diameter of the particle is very very less, if you put this one (Refer Slide Time: 32:19) here we can find out that how much time we have to provide for flocculation.

Now we will come to the Orthokinetic flocculation because Perikinetic flocculation we are not employing in water treatment plant because that will be happening automatically and the particle size which can be effectively removed by Perikinetic flocculation is very very small. So, coming to Orthokinetic flocculation the contact of particles in Orthokinetic flocculation is caused by fluid motion. That is why we are providing a mixture and providing a velocity gradient and because of this velocity gradient the particles are coming in contact. So we can find out the rate of change of particle concentration. This can be represented as Jok that means Jok because of the Orthokinetic flocculation the formula s nothing but minus 2 epsilon G bar the velocity gradient this is the (Refer Slide Time: 33:18) diameter of the particle N 0 the initial concentration of the particle by three.

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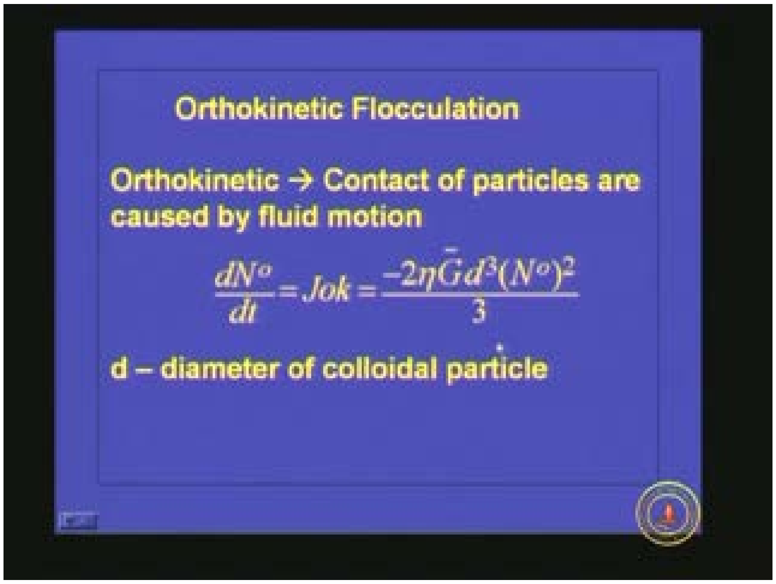

Now if you want to find out the ratio between Jok and Jpk we substitute both the equations and if we simplify we can get it like this mu into G bar d cube by 2 k bar T. So Orthokinetic flocculation is proportional to the velocity gradient and 3 power diameter whereas the Perikinetic flocculation is depending upon the temperature and the Boltzmann's constant. So for d equal to 1 mu and for a G bar or for a velocity gradient of 10 per second and temperature of 25 degree centigrade we can find out what is the ratio of Jok and Jpk.

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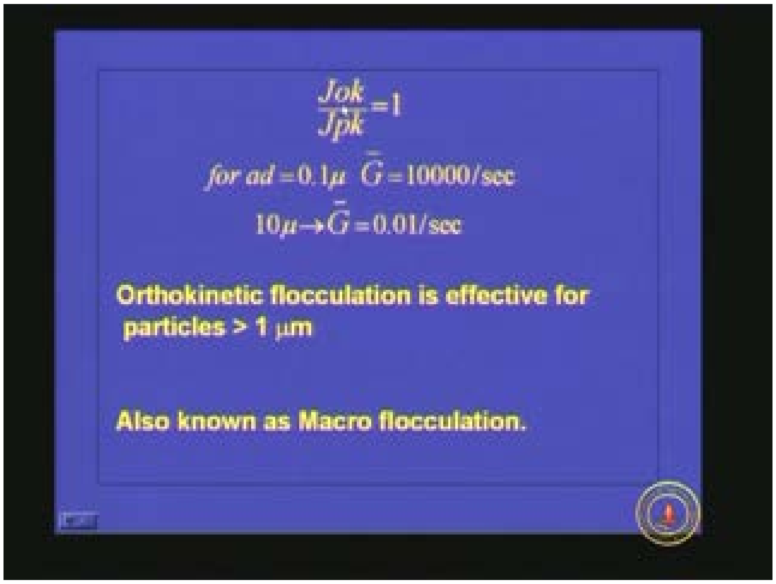

Or in other ways if you want to have a ratio Jok and Jpk that means the removal by Orthokinetic flocculation and Perikinetic flocculation are equal that is what this one represents. Then in

Orthokinetic flocculation we have to provide a G value of ten thousand seconds. If the particle size is around ten micrometer the G value we have to provide is 0.01 seconds. From this one we can make out that if the particle size is very very small Orthokinetic flocculation and Perikinetic flocculation are equally efficient and the G value we have to provide to get that efficiency is very very high.

But if the particle size is hundred times (35:02) that means it becomes 10n micrometers because this is the range of colloidal particles usually we find in water. So, if the particle diameter is around ten micrometer then the G value what we have to provide is not 1 per second. Or in other ways, we can tell that Orthokinetic flocculation is effective for particle greater than one micrometer. So, if you go for Orthokinetic flocculation the virus solution is there and we won't be able to remove it effectively. So, Orthokinetic flocculation is also known as Macro flocculation so it is also effective. As the size of the particle increases the flocculation efficiency also will be increasing whereas in Perikinetic flocculation if you have very very minute particles Perikinetic flocculation will be much effective.

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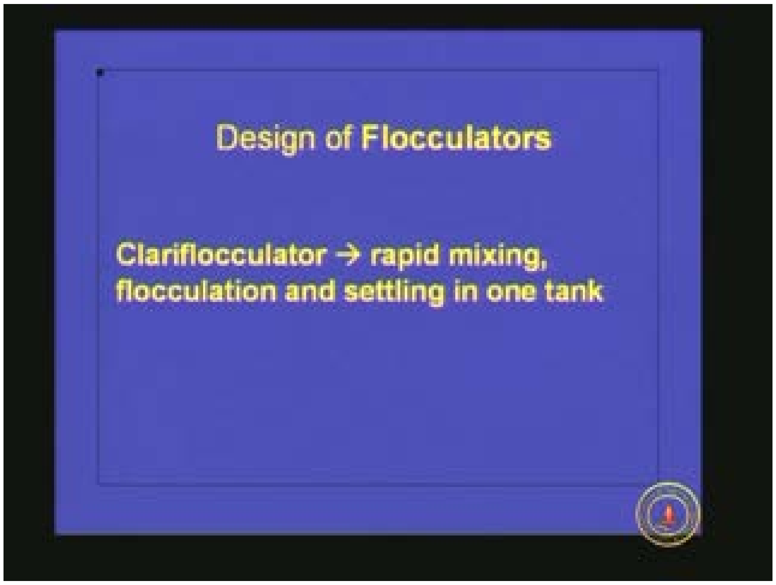

Now we will see how to design a flocculator. In a clariflocculator, clariflocculator is a unit commonly used in water treatment plants so in clariflocculator what is happening is rapid mixing, flocculation and settling is done in one tank so we are providing all the units in a single unit. That is what a clariflocculator is.

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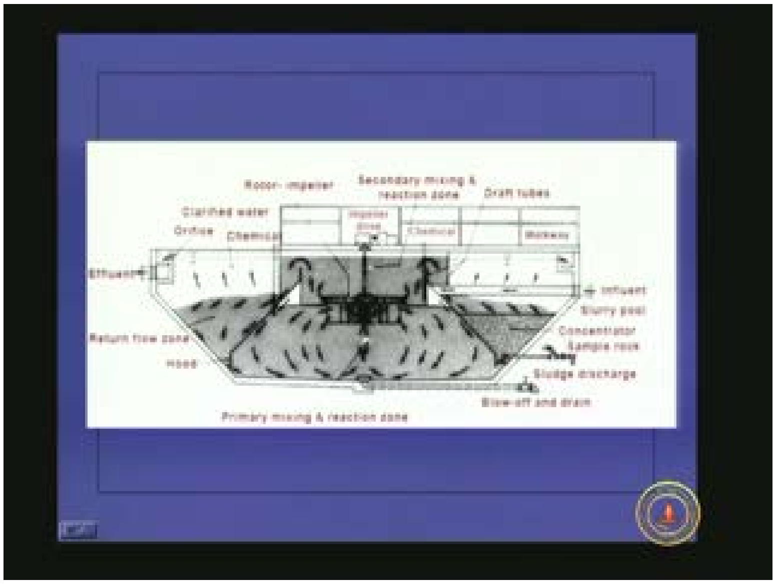

This is an example of a clariflocculator. Here we can see that chemical addition is taking place. This is the rapid mixing unit (Refer Slide Time: 36:37) and from here it is coming and here flocculation is taking place because of the turbulence or the velocity gradient and this is acting as a settling basin and we get clear water from here. This is the settling basin so clear effluent is coming and this is the sludge so whatever is settled it is going out.

In other ways, we can provide another type of a unit also. In the center, whatever is coming up, the inlet pipe itself will act as a rapid mixture and here we provide a flocculator and this entire chamber will be acting as clarifier or sedimentation tank.

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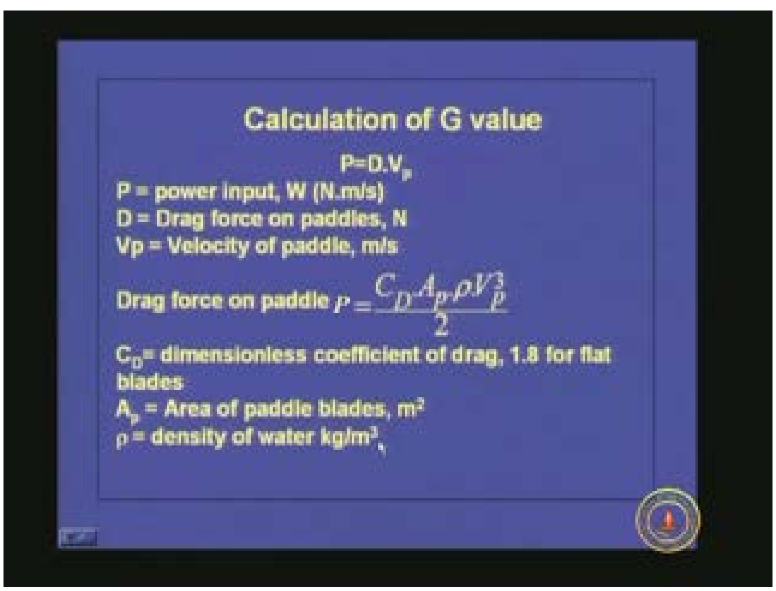

How can we design a flocculator or how can we find the G value?
We have seen that the design parameter of the flocculator is Gt where G is the velocity gradient and t is the time and we have also seen that the Gt value varies from 10 raised to 4 to 10 raised to 5. And we are providing the mixing by some mechanical means. That means we have paddles and motor and it will be rotating at a particular speed. So how can we design this unit? Since we have to provide sufficient G value and according to that we have to adjust the speed of the motor and sufficient area should be there for the paddles.

Now we will see the design parameters. The power can be calculated by using this formula: D into VP where P is the power input in watts, D is the drag force on paddles because we are rotating the paddles so when the paddle is rotating the trial force is acting on that one and because of that one the velocity gradient is created.

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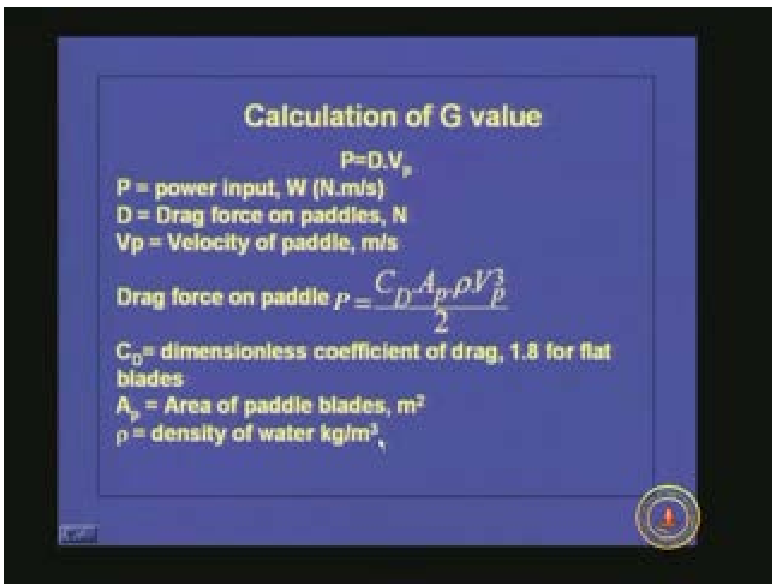

V p is the velocity of the paddle, the unit is meter per second. So the drag force on this paddle can be expressed using this formula: CD A p rho V p 3 by 2. CD is the drag force coefficient and A p is the cross-sectional area of the paddle and rho is the density of water and V p 3 is the velocity of the paddle. CD is a dimensionless coefficient of drag and usually we take it as a constant 1.8 for flat blade and A p is the area of paddle blades in meter square. Usually we won’t consider the thickness because the thickness will be very very negligible.

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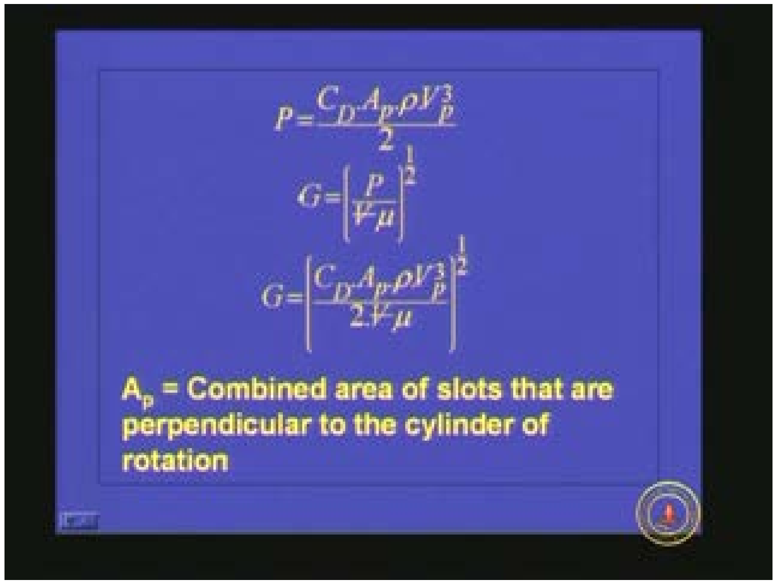

We have already seen that the velocity gradient is nothing but P by V mu raised to half. So G from this one we can calculate; G is CD A p rho V p 3 by 2 V mu whole raised to half. So A p is the combined area of slots that are perpendicular to the cylinder of rotation. That means if you have a flocculator the center shaft will be there and from that one the paddles will be there so we have to take the total area of all the slots that is moving in the water.

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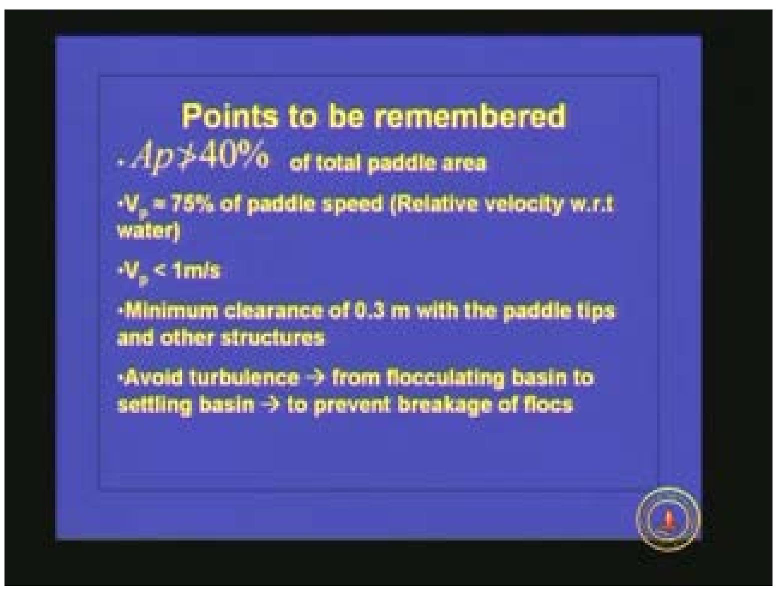

So, whenever we design a flocculator these are the points to be remembered. A p that means the area of cross-section of the paddle should be less than 40 percent of the total paddle area. So, whatever total area of paddle we are providing the cross-sectional area A p should be less than

40 percentage and V p we are taking the velocity of the paddle tip, the velocity of the paddle tip usually we take it as 75 percentage of the paddle speed. This is because we are considering the velocity of water there in the paddle tip because that is what is more important for us because that is what is creating the velocity gradient.

So what we usually find out is this V p whatever speed the paddle is rotating we take only 75 percent of the paddle speed. This is the relative velocity with respect to water and this V p should be always less than 1 m per second that is the design parameter and whenever we provide a paddle there should be a minimum clearance of 0.3 m with the paddle tip and other structures. Whether it is horizontal walls or vertical walls or whatever thing it is there should be a clearance of 0.3 meters and once the flocculation is over we are providing the G value and the water is remaining there for 20 to 30 minutes. And after the flocculation has occurred the water will be moving to the settling tank. So here we should be very very careful, we should avoid turbulence from the flocculating basin to the settling basin. If lot of turbulence is there then what will happen, it will break the already formed flocs so ultimately it will result in a poor performance of the carriflocculator. Thus, care should be taken to prevent the breakage of the flocs.

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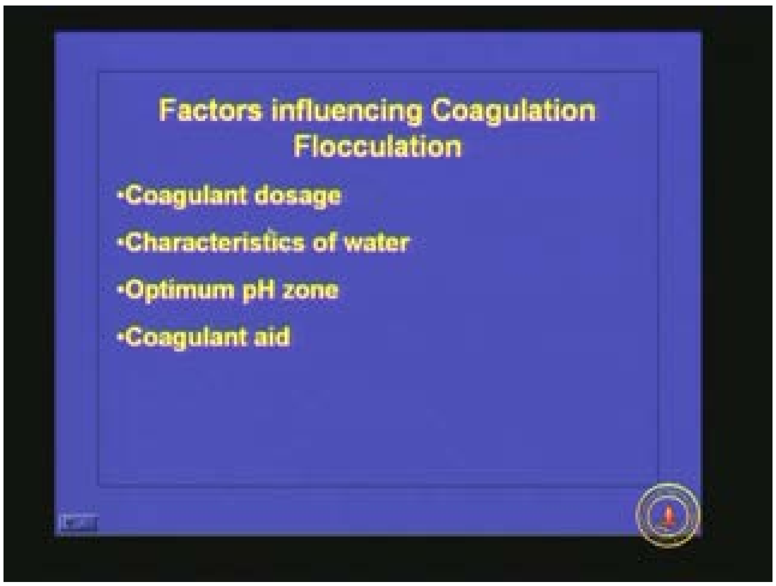

Now we will see what are the factors influencing the coagulation and flocculation. First one is coagulant dosage. Unless we destabilize the particle or unless we provide enough coagulant dose the particles are not going to be removed even whatever best way we design the rapid mixture and slow mixture or flocculating unit and your settler, because unless the particle's destabilization is done properly it is not going to agglomerate. Thus, the coagulant dose is very very important.

Next one is the characteristic of water, because we have seen that based upon coagulation and flocculation the water is classified into four categories: type 1, type 2, type 3 and type 4 based upon the concentration of turbid particles and alkalinity. So, depending upon the turbidity the ease or difficulty in treating the water will vary. If high turbidity and high alkalinity is there it is easy to remove by sweep coagulation or if high turbidity and low alkalinity is there then also it is easy because adsorption and charged neutralization is taking place but if the water is having low turbidity and low alkalinity it is the most difficult water to treat. Therefore, the characteristics of water is also very very important.

The next one is optimum pH zone. This we have discussed in detail. The precipitation of aluminum hydroxide is a function of pH because we will be getting maximum precipitation or the least solubility and the optimum pH will be around 7 to 7.5. So it is always advisable to maintain the optimum pH.

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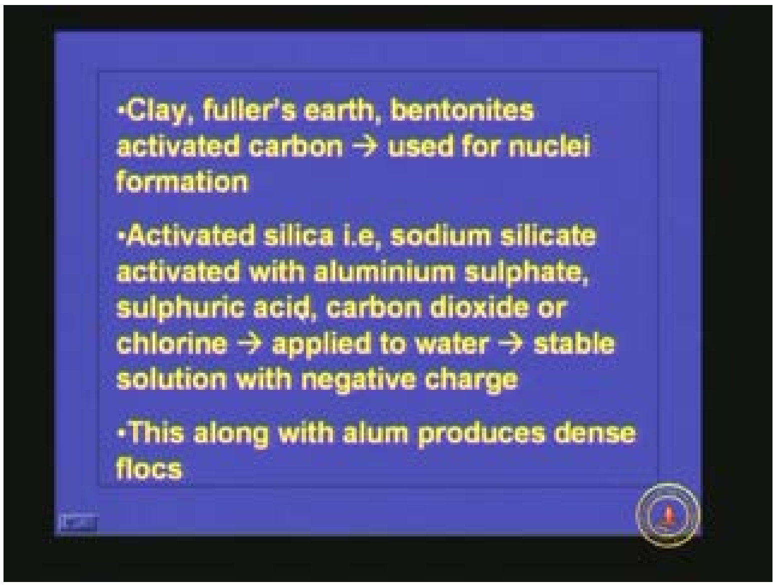

Coagulant aid: So this coagulant aid; what is a coagulant aid?
Along with the coagulant if you add some other substance which can enhance the coagulation that substance is known as coagulant aid. So what is happening here? So, if the turbidity is low but you have added enough coagulant dose so aluminum hydroxide is formed but the precipitation should take place isn't it, so into to increase the precipitation efficiency what we have to do, if you provide some nucleus the precipitation will be very very effective. So, if you add something similar to clay, fuller's earth, bentonites or activated carbon, this salt will be acting as nuclei so this nuclei will be helping the precipitation.

If you add this coagulant aids along with coagulants then the efficiency of the coagulation will be increased. And another one is if activated aluminum; if activated silica if you add that will also significantly improve the efficiency of coagulation and flocculation and activated silica is nothing but sodium silicate activated with aluminum sulphate or sulphuric acid or carbon dioxide or chlorine applied to water it forms a stable solution with negative charge. So this is a very good coagulant aid. So, if you add this one along with the coagulants the coagulation will be very very effective. So this helps to produce a very dense floc.

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And choice of coagulant we have already seen; but these are the different coagulants available: alum, ferrous sulphate or copperas, ferric chloride or chlorinated copperas and natural polymers. Natural polymers we have already discussed, we can use the seeds of certain plants; one is Moringa Oleifera or drumstick seeds. It is a very good natural polymer and it is also having disinfection properties, disinfection efficiency. So, if we use those things we will be getting good coagulation and flocculation or good removal of turbid particle but only thing is these natural polymers when we use it the left overs will be causing some oxygen demand or since it is an organic matter the foul smell will come if you store the water for a long time.

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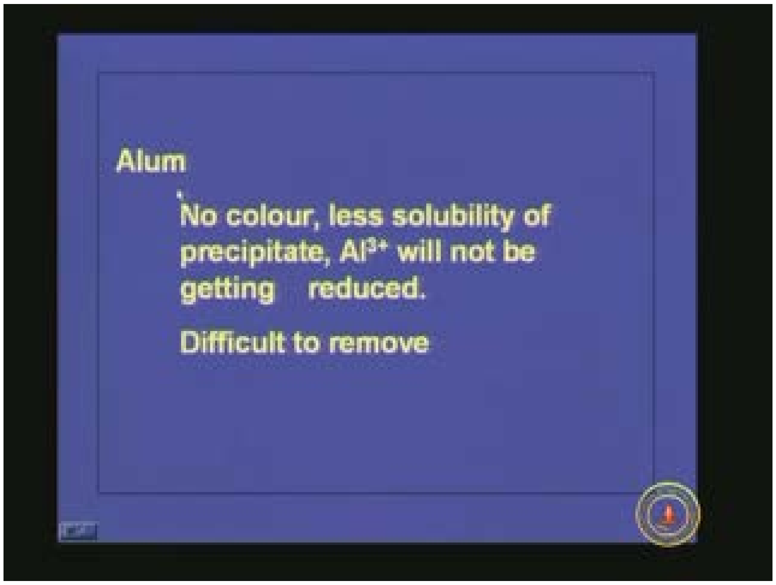

And in water treatment alum is preferred because there is no colour, less solubility of precipitate, and Al 3 plus will not be getting reduced but the disadvantage is aluminum hydroxide flocs are lighter than ferric chloride flocs so the removal is difficult.

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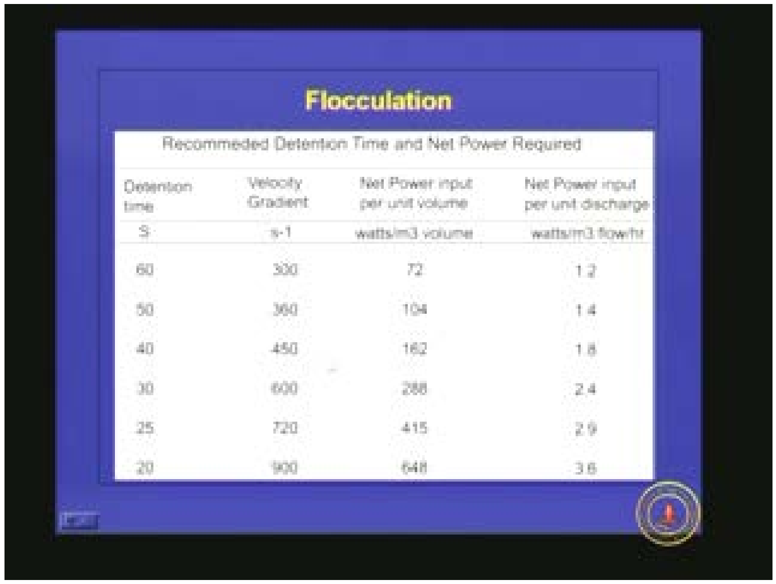

Detention time	Velocity Gradient	Net Power input per unit volume	Net Power input per unit discharge
S	s-1	watts/m3 volume	watts/m3 flow/hr
60	300	72	1.2
50	360	104	1.4
40	450	162	1.8
30	600	288	2.4
25	720	415	2.9
20	900	648	3.6

These are the recommended detention time and net power required given by the manual of water supply. So if the detention time is 60 then the velocity gradient is 300, net power input is 72 and this is the net power input per unit discharge and if the detention time is reducing then definitely the G value will be increasing.

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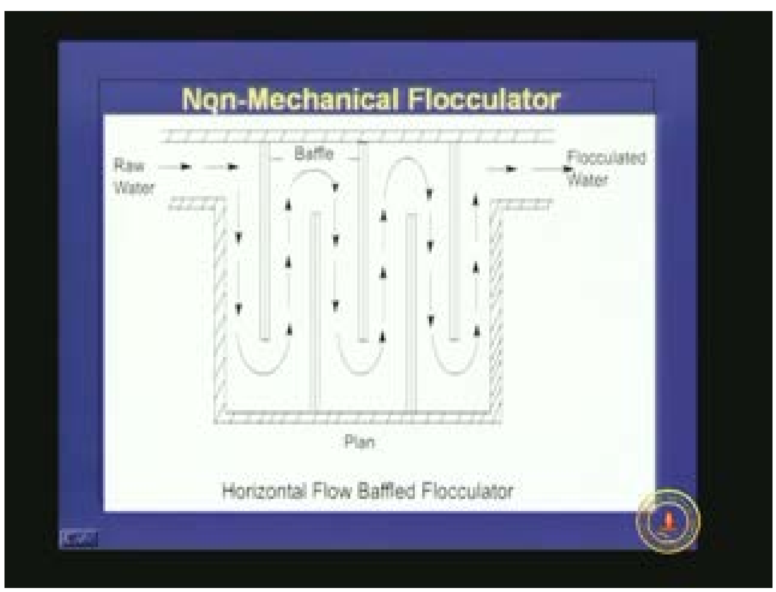

These are different types of non-mechanical flocculators. This is non-mechanical flocculator. So raw…… now we are not using…… we have discussed in rapid mixing we can go for mechanical device or non-mechanical device; same thing is valid in case of flocculator also; the G value or Gt value we can provide by mechanical means or non-mechanical means and here non-mechanical means the operational cost and maintenance cost will be very very less and, but the only disadvantage is it is very difficult to adjust according to the varied requirement. So sometimes the volume of water to be treated is very high or sometimes the volume of water to be treated is very less, in such cases the adjustment of these non-mechanical flocculators is very very difficult.

So this is an example of a non-mechanical flocculator. This is a horizontal flow baffled flocculator so raw water is entering here (Refer Slide Time: 48:10) and because of this baffles what is happening, the water cannot flow directly like this so it has to take a deviation in its direction so because of that one velocity gradient is created and the particles are agglomerating and the water is coming out here in the completely flocculated form.

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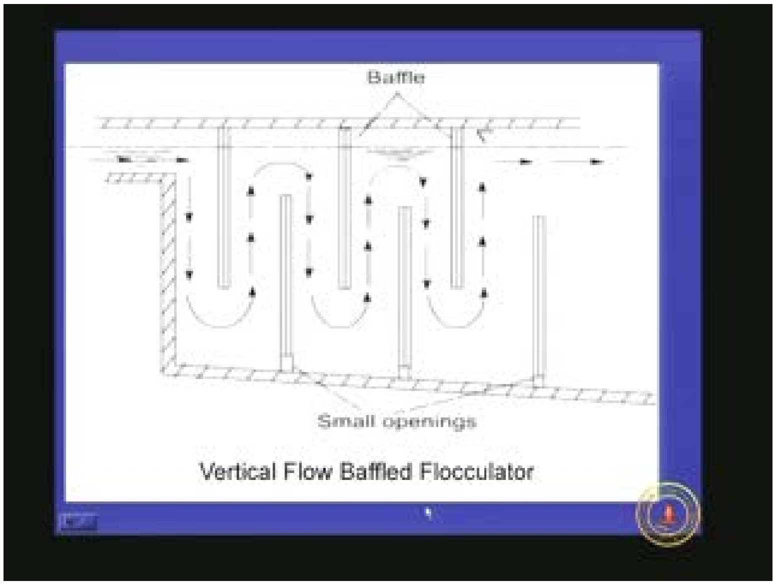

This is another one; vertical flow baffled flocculator and this (Refer Slide Time: 48:41) is a jet flocculator, the water is comuing here and rapid mixing is taking place here itself because chemical is coming along with the raw water and the jet here the mixing is taking place and it is coming out here.

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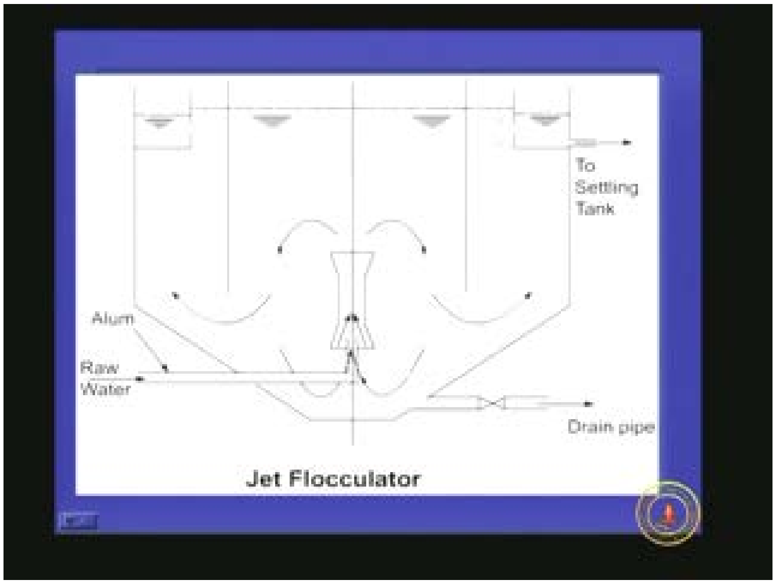

We can see baffles here and as it comes out there will be velocity gradient because the diameter of the tank is increasing with respect to this horizontal distance so the velocity will be varying and the velocity gradient will be created and this is the baffle (Refer Slide Time: 49:14) to avoid the short circuiting otherwise what will happen, everything will be going up and coming out through this outlet so these baffles help to provide more velocity gradient and avoid short circuiting.

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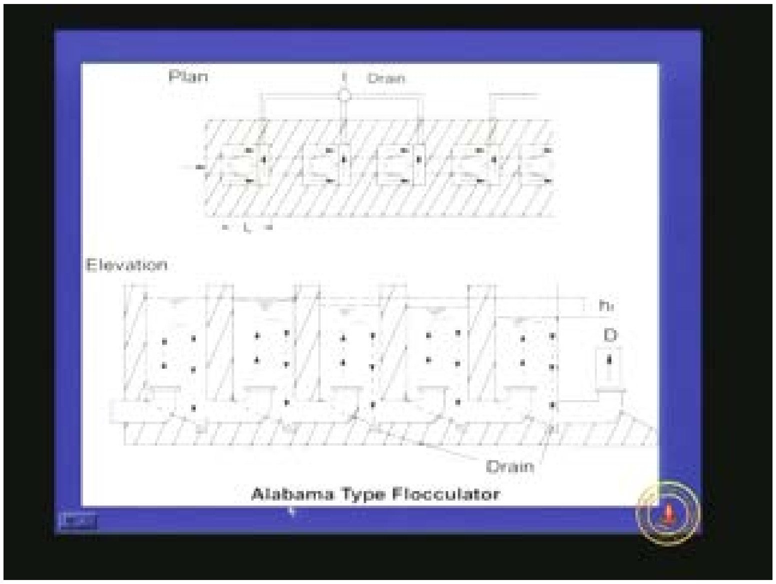

This is another type; Alabama type flocculator. Here what is happening is every chamber is having a separate inlet pipe. We can see here and the coming up like this and since it cannot go out through that one it is coming back (Refer Slide Time: 49:46) and this is the outlet or the tray, because of this one the velocity gradient will be created.

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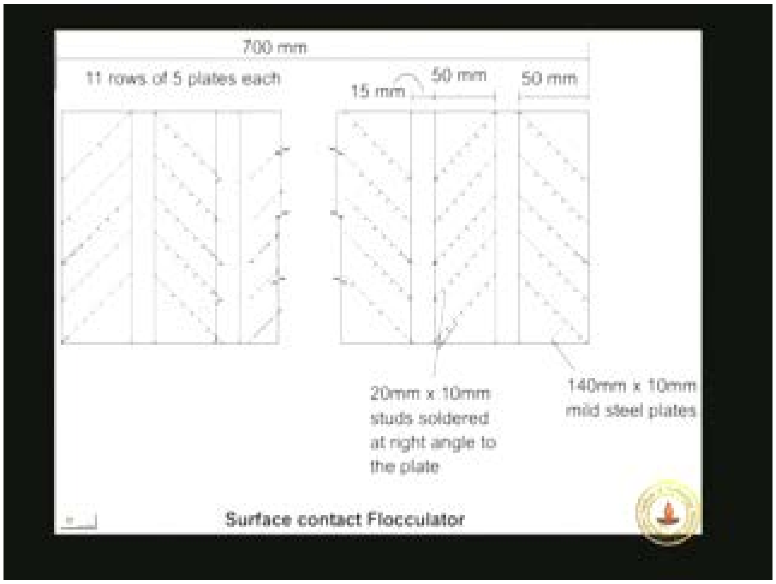

This is another type. Here also inclined plates are provided and that will be providing the velocity gradient and this is yet another type (Refer Slide Time: 50:03) the water is flowing like this and the sludge whatever is here…… and it has to pass through this one and that is creating enough velocity gradient.

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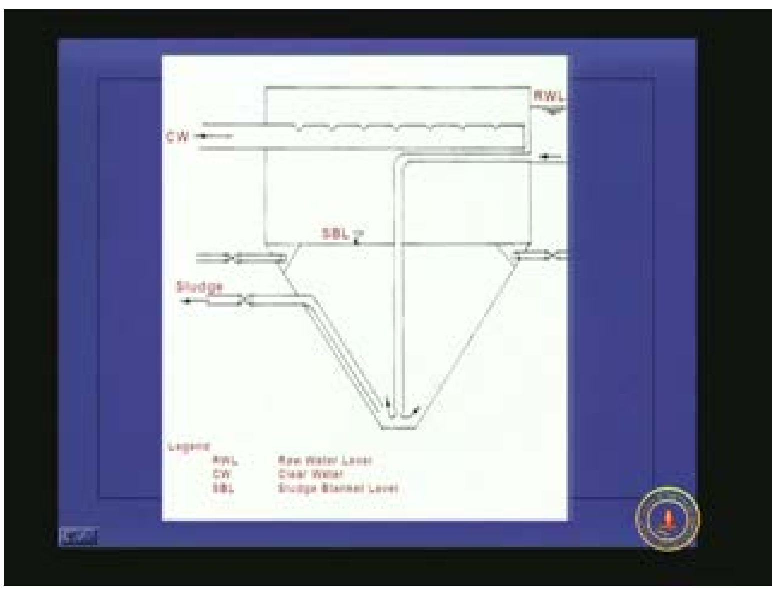

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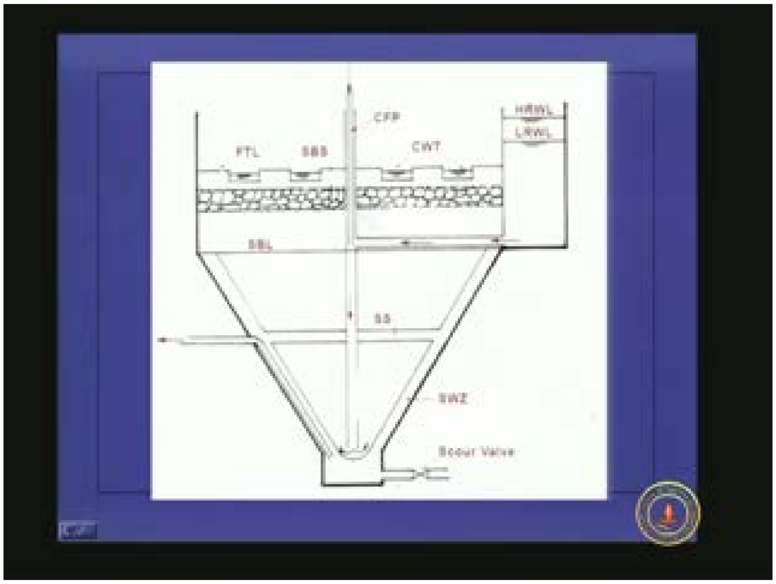

This is the modified type. Here we are providing the pebbles and all so that will be increasing the velocity gradient.

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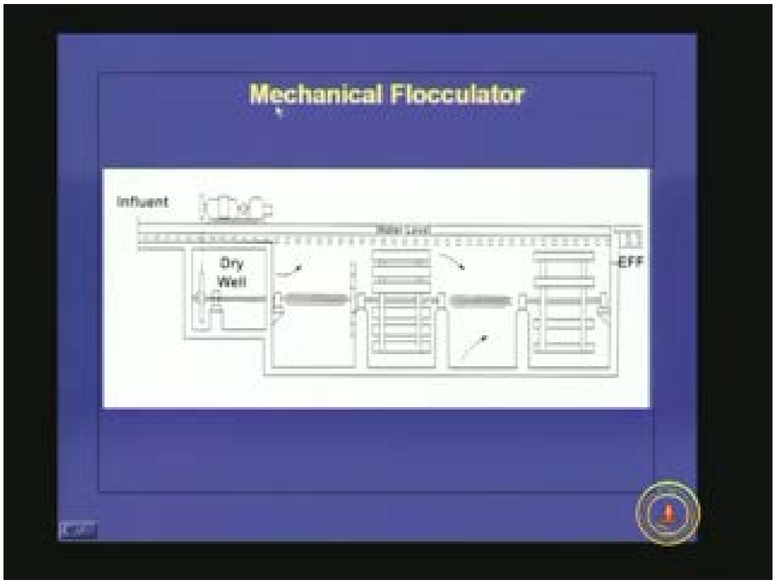

These are the examples of mechanical flocculators. So here what is happening, this is the paddle, this is the flow direction (Refer Slide Time: 50:32) influent is coming and this is the motor which is rotating the baffle the paddles so flow is coming here, it is entering through here and the paddles are here, the paddles will be rotating in this direction and different chambers and because of the paddle rotation it will be giving a velocity gradient and because of that one the flocculation will be taking place and this is the effluent pipe and this is the water level.

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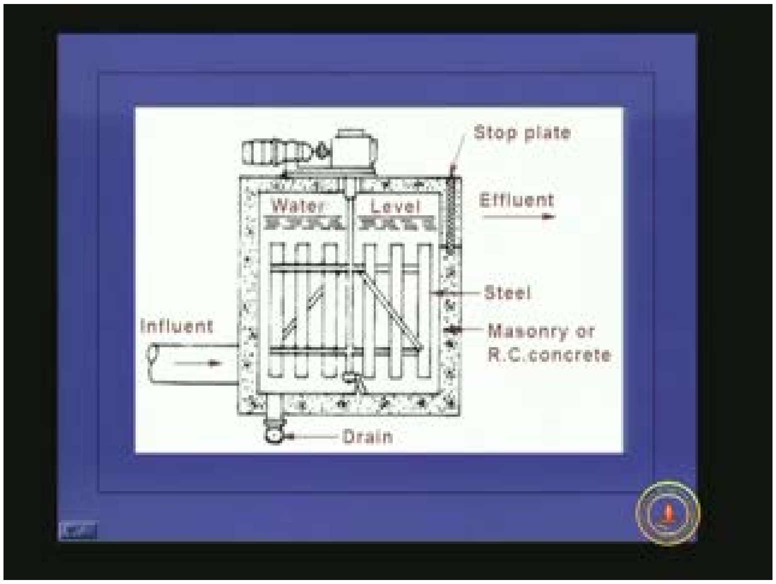

This is another type of mechanical flocculator. Earlier we have seen a mechanical flocculator where the paddle is rotating horizontally. Here the axis is in vertical direction so this will be rotating in this direction so influent is coming here and everything is getting mixed up thoroughly and flocculation is taking place inside the system and the treated or the flocculated water will be coming through this drain. So we have discussed about what is coagulation, what is flocculation and what are all the mechanisms of coagulation flocculation etc. So, using this information if you want to design a problem, I will just give some important points on how to do the design of a coagulation flocculation unit, what all are the important parameters we have to consider.

We have to treat 50000 m 3 per day of water and optimum coagulant dose dose is 40 mg per liter and GT value is 4 into 10 raised to 4 and temperature of water is 15 degree centigrade. So if you are asked to find out alum dose, tank dimension and paddle design I am not going to solve the problem completely I will just tell how to go around with this problem.

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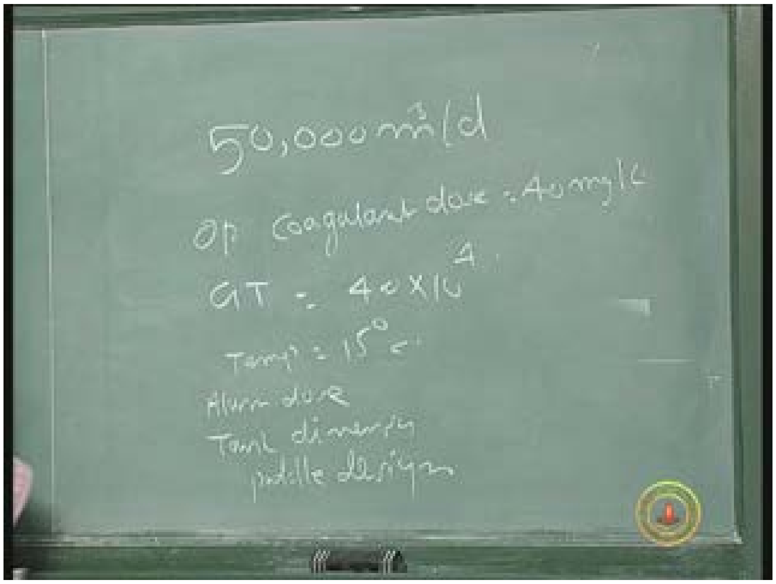

So how to find out the alum dose, alum dose is….this is, this is square milligrams per liter and your water supply requirement is 50000 m 3 per day so what we have to do, we have to find out what is the amount of alum required per […..53:12]. So you find out what is the total volume of water to be treated per month multiplied by this alum dose will give you the total alum requirement so it will be coming something like this: 0.04 kg into 50000 into 30, per month we have to find out so it will be equal to 60000 kg per month. So you have to find out what is the alum we have to use for water treatment for a city.

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Now we will find out what is the basin dimension. We know, Gt value is in the range of 10 raised to 4 to 10 raised to 5 and the design value is given as 4 into 10 raised to 4. So we can assume a G value and you know that t value varies from 10 to 30 minutes so we can assume a G value and check that the t value is coming within this limit. So assume 30 so you will be getting you will be getting a t value of 22.22 minutes.

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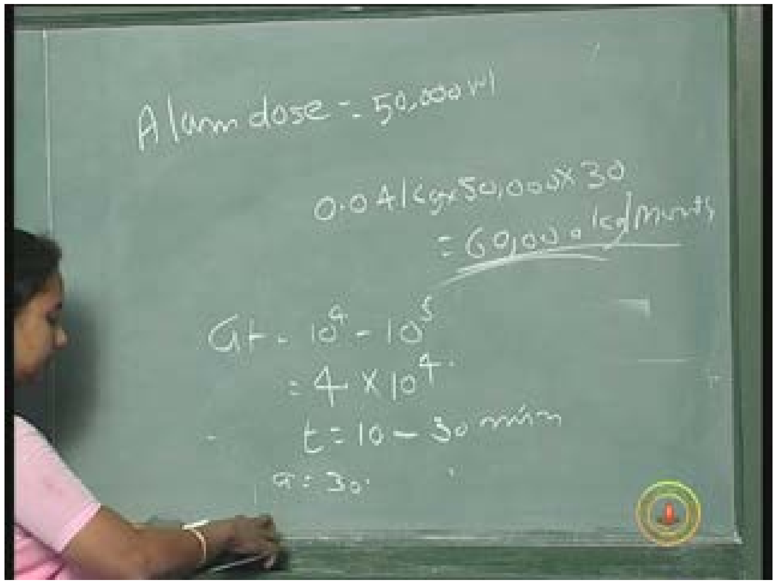

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Once you know the t value how you can do the tank volume. Volume is equal to Q into t. then we can design the paddles using this formula: P is equal to D into V p. this is the way how to design a rapid mixer in coagulation flocculation. So we will just see what all are the things we have discussed so far.

So we have seen what is the importance of coagulation flocculation, what are the different types of coagulants used for water treatment and what is the purpose of rapid mixing and what is the purpose of slow mixing and we have seen in detail what all are the mechanisms of coagulation that means ironic layer compression, adsorption and charged neutralization, then sweep coagulation, adsorption and inter-particle bridging. But as far as water treatment is considered ironic layer compression is not coming into picture at all because this is….. because the amount of alum or amount of coagulant we are adding is not sufficient enough to create that much of ironic strength. Then we have seen what are all the important points we have to be we have to be careful when we go for coagulation and flocculation.

System design: Because this is applicable for particles greater than one micrometer diameter. And flocc……. Rapid mixtures can either be mechanical units or non-mechanical units. Non-mechanical units are having very less operational and maintenance cost but the flexibility is very very less but coming to mechanical unit the operational and maintenance cost is there but we have more flexibility. But whenever we go for design it is advisable to go for a tapered velocity gradient provision; the reason is if you provide large G with small time you will be getting small dense flocs and low G with large time you will be getting large but………. means light flocs. So it is always advisable to go for tapered G value.