Physico-Chemical Processes for Wastewater Treatment

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Lecture – 28
Filtration - I

Good day everyone and welcome to these lectures on Wastewater Treatment by Physico-Chemical Methods. So, in the previous lectures we studied regarding the various unit operations starting with flow equalization, then followed by aeration then we studied the flocculation in coagulation in detail and thereafter we studied the sedimentation basin which is used for settling down all the particles which are either coagulated or flocculated and they may settle down. And in addition we actually sedimentation basin is always designed with respect to some target particle.

So, that target particle may be of some particular diameter and so, in the coagulation basin or in the settling basin, the particles below that target particle cannot be 100 percent or efficiently removed. So, those particles less than the target particle diameter will always be coming out of the effluent from the sedimentation basin.

Now, if the turbidity or the residual concentration of these target particles is not good enough, we have to still filter them out. So, there is a possibility that we have to use the filtration mechanism for the removal of these lesser size particles in the filtration units. So, we will today's from today we are going to start this filtration section, we will try to understand what is filtration, what are its basic mechanism, what are its basic theories that we must understand before designing actual filter. And we will continue with the filtration section today onwards.

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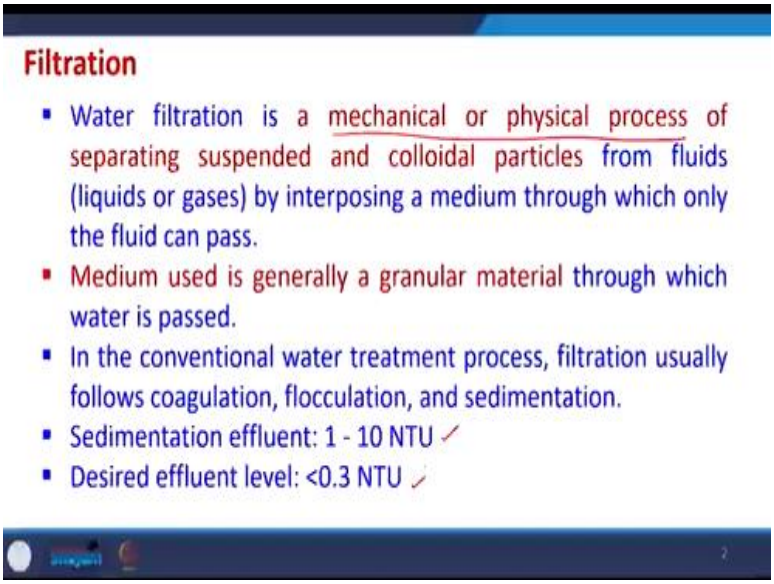

So, starting with the filtration, so, water filtration is like a mechanical or physical process of separating suspended or colloidal particles, which have not been removed in the settling stages from fluids (liquids or gases). So, filtration may used for gases also by interposing a medium through which only fluid can pass but other materials cannot pass.

So, this is the mechanism so, we provide a mechanical and physical process for removal so this is there, medium which is used is generally like a granular material through which the water is passed and the smaller size particles get trapped within the granular material or the whole of the bed etcetera, and we get treated water from the other side.

So, in the conventional water treatment process filtration is usually followed after the coagulation, flocculation and sedimentation basin, it may be used after the secondary treatment as well. So, there is a possibility of uses of the filtration mechanism at many places, if the sedimentation effluent is containing high amount of turbidity and it has to be reduced to less than 0.3 NTU then we have to use the filtration mechanism.

Filtration is also the common unit which is there in all the treatment units, small treatment units which are used in our homes or residences. So all the small treatment units which may imply ro, then absorption, then filtration so filter is very, very common. So we will try to understand the basics of the filtration in today's lecture.

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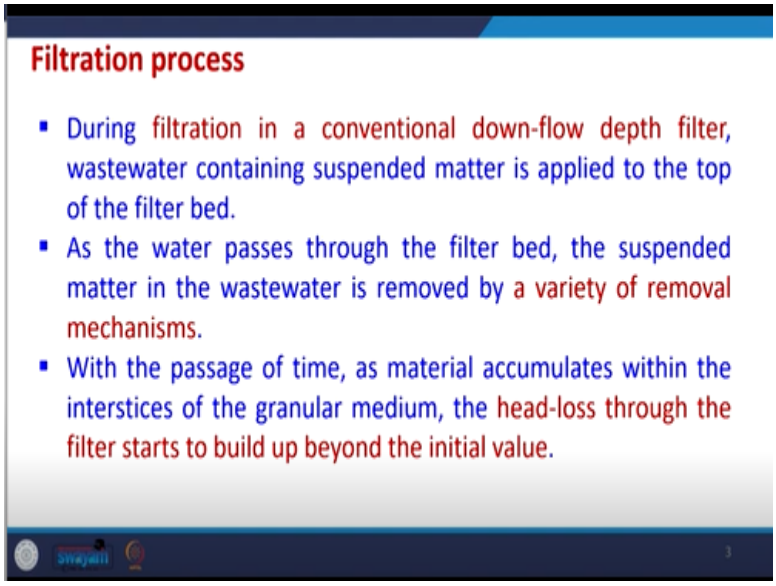

During filtration in a conventional down-flow depth filter, the wastewater containing suspended matter is applied at the top and it may flow to the bottom it may be vice versa also, we may allow the water to flow upwards. So it is also a possibility because we can avoid the channeling and other thing if the water flows upwards. As the water passes through the filter bed the suspended matter in the wastewater is removed by a variety of removal mechanisms.

So, a number of mechanisms are possible through which the wastewater gets removed and we are going to discuss them in the next slide so, this is there. And all these mechanisms work together to remove the suspended matter from the water and these mechanisms may work in different time domains.

So, it is also possible that initially some other mechanism may be working after some time the other mechanisms may also come into picture. So, with the passage of time as the material accumulates within the interstices of the granular medium the head-loss because more and more material is getting accumulated. So, head-loss through the filter starts to build up beyond the initial value and that means, we have to now backwash or clean the filter. So, there is a possibility of this.

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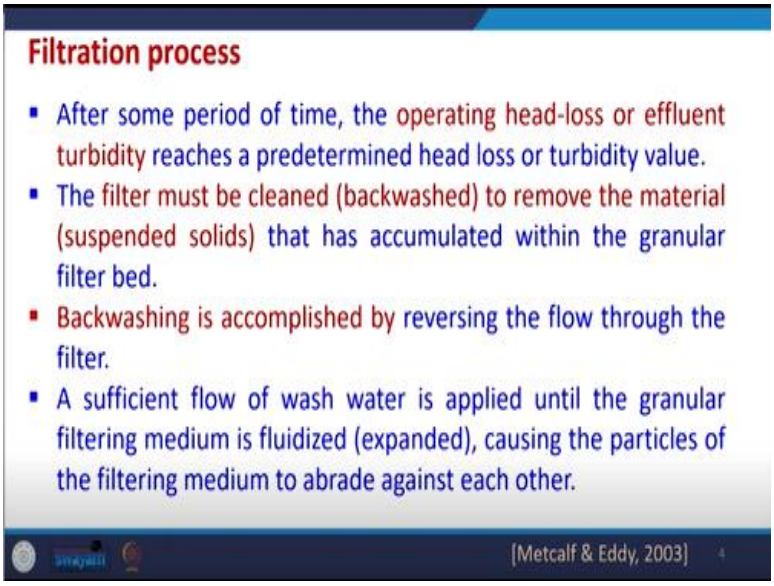

So, after some time the operating head-loss or effluent turbidity will reach a predetermined head-loss or turbidity value. So, under that condition, the filter must be cleaned. So, and that cleaning is done by backwashing to remove the material suspended solids that may have accumulated within the granular filter bed. The backwashing is very common and it is accomplished by reversing the flow through the filter.

So, we do it by using a cleaner water and certainly the amount of water which is used for backwashing is lesser, so, we get a backwash water, which contains high concentration of the suspended material and the concentration is high but the amount of water is low. A sufficient flow of wash water is applied until the granular filter medium is fluidized or expanded, causing the particles of the filtering medium to abrade against each other.

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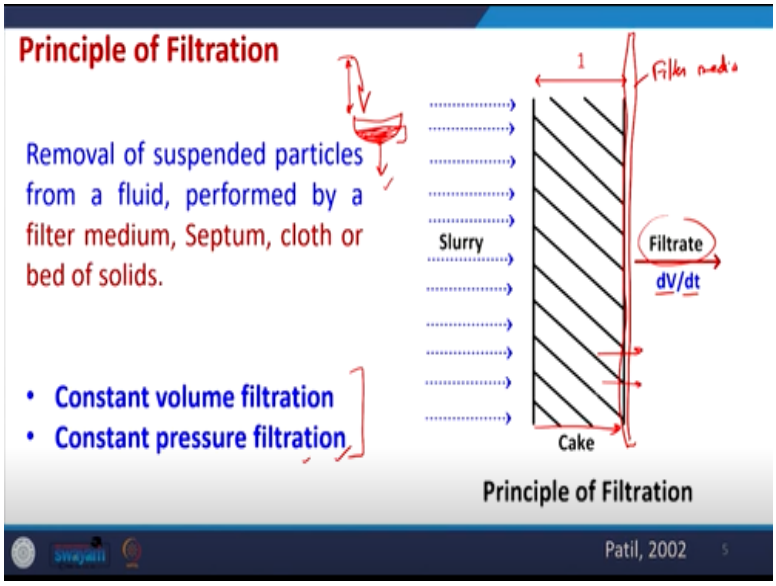

Now, there are certain principles of filtration and there are two types of filtration possible with respect to its operation. Now, removal of suspended particles from a fluid may be performed by a filter medium, septum, cloth or bed of solids. So, we see a filtration very commonly day to day in our life, in our homes we have a tea which we prepare using the tea leaves, now that tea is tea leaves are separated out of the tea in a simple filter, which is there. Similarly, for coffee we have a filter.

So, this separation is carried out in a simple like atmospheric filtration condition where the pressure is atmosphere, conditions are there, but how much above the filter we are pouring the tea that depends. So, how much about the filter suppose this is the filter which is there and where tea leaves are getting collected. So, how much above this we are pouring depending upon this velocity comes out and the depending upon that how much tea has accumulated here the amount of water which is coming out will be amount of tea which is coming out is known to us.

So, in the user filtration we have a slurry which is applied and the filtrate comes out. And there is some cake deposition which happens on the filter media initially only here we may consider that this is a simple filter media is this and above this, this cake deposition may have happened and what is the amount of volume we are getting per unit time. So, this is the rate of filtration that is there. So, there are two possibilities of filtration possible, one is called constant volume filtration and another is called constant pressure filtration.

So what is the difference? We will start with the constant pressure filtration first. In the constant pressure filtration the slurry which is being filtered it is being forced at a constant pressure. Now initially when only filter media is there and there is no cake, so this slurry can easily go out. So the amount of filtrate that we are getting will be higher, but as the cake starts depositing on the filter media, so the amount of filtrate that we get becomes less. So, that means, with constant pressure filtration, the volume which is coming out decreases with increase in time and after some time it will reach some steady state value or virtually decrease.

So, that means, the cake resistance is increasing the same is there same is the thing when we observe when we are filtering the tea. So, initially this filter does not contain any tea leaves. So, we can easily filter out lot of tea, but when the tea gets tea leaves get collected here. So, we have filter, filter cake resistance which comes, so we have cake resistance which is there.

Now, many times we may have seen that we pour the start pouring the liquid from upwards so, that the pressure increases and we have more amount of tea which can be filtered per unit time. So, this is constant, with pressure filtration, the volume of filtration per unit time becomes lesser and lesser with time until unless we remove the cake then second is the constant volume filtration under that condition we require the same amount of volume to be filtered per unit time.

So, under that condition, what we have to do is that we have to go on increasing the pressure as the cake deposition happens. So, we will have to increase the pressure continuously so, that the volume filtered is constant. So, these are the two basic types of operations which are possible.

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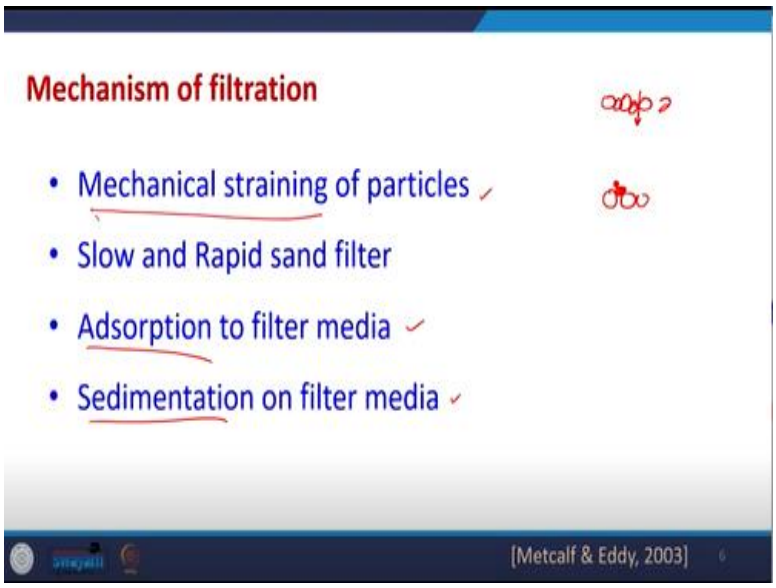

Now, how, what are the mechanisms of filtration on the filter media as well as on the cake? So, at this we are going to understand here. So, mechanism, mechanical straining of the particles this is the first thing. So, we have beds of granular material. So, in this we have some space which is there. So, what is the porosity and what is the pore size. So, anything any suspended material, which is having pore size, particle size more than the pore size will always get trapped. So, it cannot go through now, so, this is the first mechanism which is called as a mechanical staining of the particle.

Now, in addition to that, after some time what will happen suppose this is the pore now, on this a particle of the suspended particle got deposited or it got filtered out. So, that means the actual pore size has further decrease. So, after some time a smaller particle will also get trapped here on the same. So, that means, with time we can filter out smaller size particles also within the trap within the pores which are there in the porous media. So, that is possible. So, this is another mechanism which is there it will come into the mechanical straining itself, but still it is possible.

Now, in the slow and rapid sand filtration, these two mechanisms operate very well then, adsorption also may occur, these granular materials may contain some pore size themselves. So, in the pore size pores also these materials may go the suspended particulate matter, suspended matter may go and adsorption may occur of the suspended matter inside the filter media.

So, this is another mechanism and because the velocities the sedimentation is also very common, because the anything can very well settled down within this filter media. So, sedimentation, adsorption, mechanically straining these are the common mechanism by which the removal occurs during the filtration.

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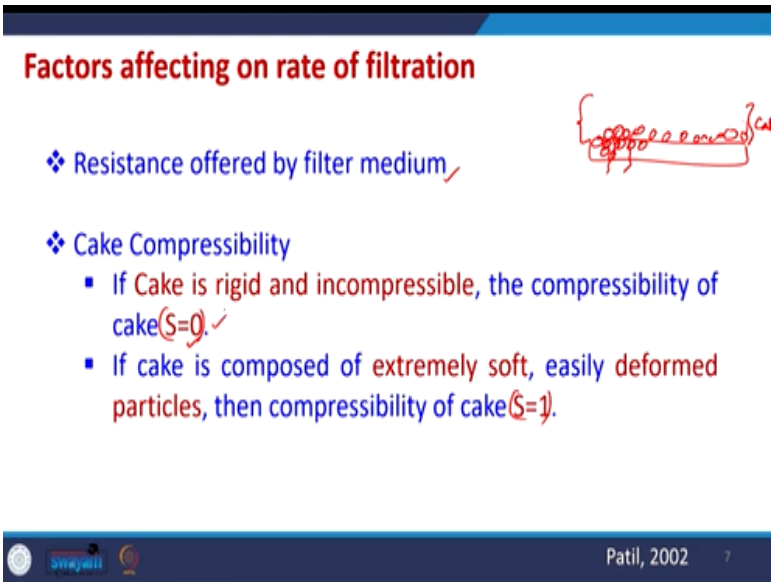

Now, what are the factors which affect the rate of filtration? So, first and foremost is the resistance which is offered by the filter media. So, we have a filter media on filter media suppose, this is the filter media and the filter media is having different granular materials and it is having some pores.

So, it will not allow very easy going up any suspended particulate matter though it will allow the water to percolate through it. So, resistance offered by the filter medium is the key factor which affects the rate of filtration and selection of proper filter medium is one of the important considerations in the design of any filtration unit.

Now, the cake after some time the suspended particulate matter will start collecting at the top and so, these, this is called as cake. So, all these will get connected. So, what is the cake properties, they are compressible, whether they are incompressible depending upon that there are these cake itself will offer some resistance. So, resistance offered by the cake is another parameter and within that cake compressibility is a parameter if cake is resist incompressible, then the there is a parameter which is called as S.

So, the compressibility of cake is taken as 0. So, under that condition S is 0, if cake is composed of soft materials and which can be deformed easily then that cake will be compressible in nature. So, S is equal to 1 is also possible in the extreme condition. So, but S is equal to 0 is common value and which is taken in the.

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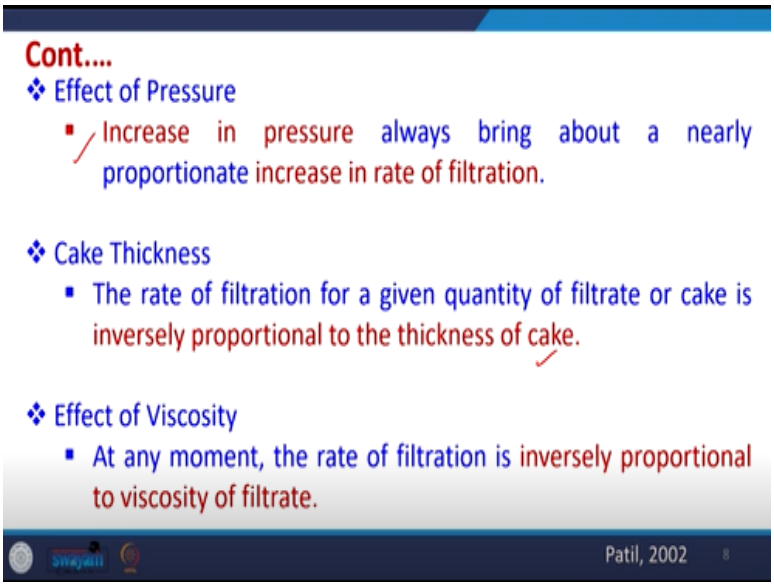

Then effect of pressure already we have studied generally we want the same volume of filtrate to come out per unit time. Now, because of the cake which gets deposited, the head-loss increases. So, that means, we should increase the pressure with time to bring a proportionate increase in the rate of filtration. So, effect of pressure is very common. So, for getting the same amount of same rate of filtration, most often will have to increase the pressure with respect to time until unless back washing is done.

The cake thickness the rate of filtration for a given quantity of filtrate or cake is inversely proportional to the thickness of the cake. So, as the cake thickness goes on increasing, the rate of filtration goes on decreasing. So, as the rate of filtration goes on decreasing, we will have to increase the pressure so, that the rate of filtration becomes the same as whatever is the desirable?

So, this is cake thickness is important parameter and its resistance is important parameter after that the effect of viscosity at any moment the rate of filtration is inversely proportional to the viscosity of the filtrate. So, this will find out in the rate equation the filtration equation which is

given. So, if any liquid is viscous, the rate of filtration will be lower, if it is less viscous, the rate of filtration will be higher.

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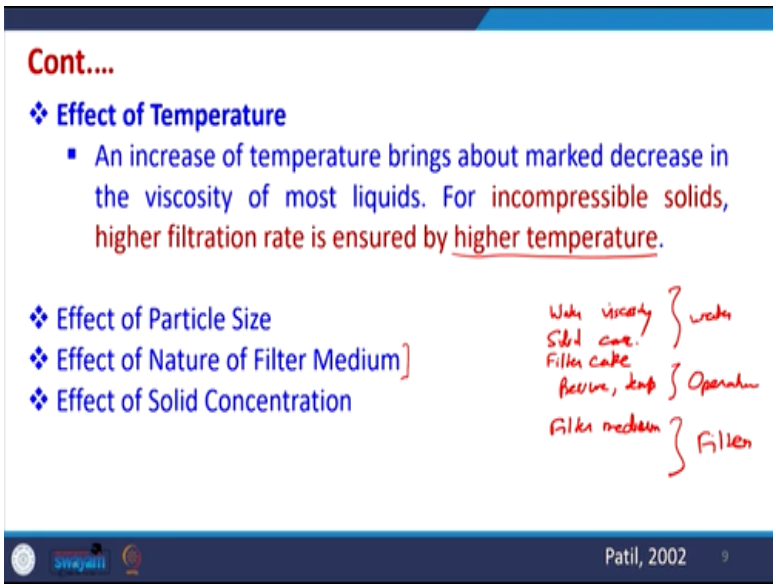

Now, similarly, temperature also affects the rate of filtration and increase of temperature will decrease the viscosity of most liquids and also for incompressible solids high rate filtration rate can be ensured at a much higher temperature. So, this is possible for both this is related to compressibility of the solids also all the cake and also with respect to viscosity of the liquid. So, high temperature generally helps in the increasing the filtration rate.

Similarly, the size of the particles, the nature of the filter medium, its various characteristics, the amount of solid which is present in the slurry, so, all these parameters affect the rate of filtration if the amount of solid is very high, the rate of filtration will drop very quickly and if the solid concentration is less the rate of filtration may continue to be on higher side. So, for the same amount of water to be treated, the amount of solid concentration in the water is very, very important parameter along with the filter design parameters.

So, there are few things, among all these effects there are a few things which are related to water. There are few things which are related to filter and there are few operational parameters that we can vary. So, with respect to water, the water viscosity is important parameter. Then the solid concentration is important parameter with respect to water so these are with respect to water. Similarly, with respect to filter and also the filter cake which gets formed from the water.

So, that is also important, then we have filter medium which affects the selection of the filter itself so filter is among the filter properties the filter medium is very important and in between we can vary the pressure. Pressure, temperature, all those things so, these are the operational parameters. So, all these things affect the rate of filtration.

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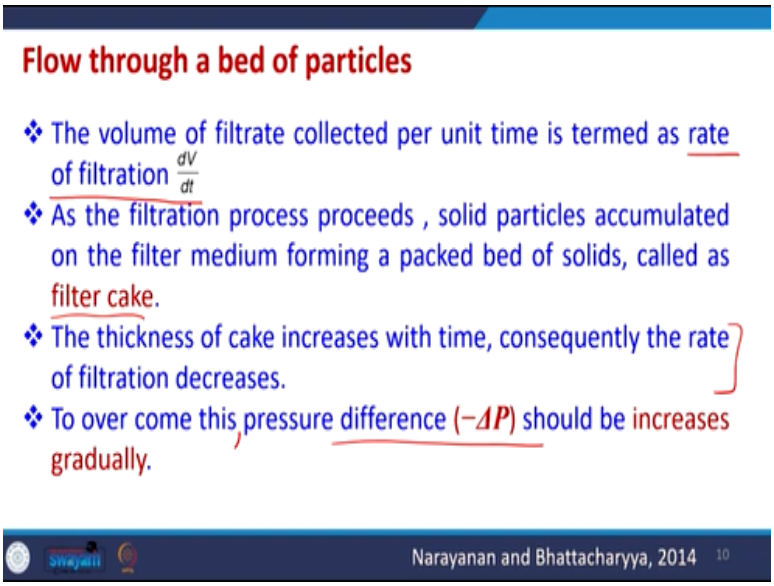

Now, this rate of filtration actually is filtration is like flow of through a bed of particles. So, there are theories which are related to flow through bed of particles that becomes very important so volume of filtrate collected per unit time it is termed as the rate of filtration. So, this is dv by dt as the filtration proceeds the solid particles accumulated on the filter medium form a packed bed of solids called as filter bed. So, in the later stages the water flows through this packed bed.

So, it is like the theory is related to flow through a bed of particle becomes very important in the filtration this is so, this is one of the first theories that we should understand for understanding the filtration. So, thickness of the cake increases with time and consequently the rate of filtration decreases. So, to overcome this pressure difference should be increased for obtaining the same rate of filtration. So, flow through bed of particle is very, very important parameters.

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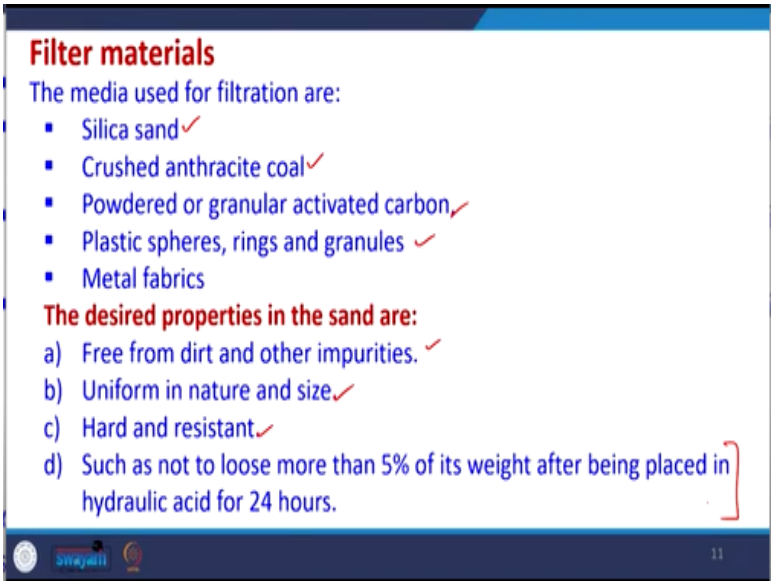

And now, within this what is the filter materials which are commonly used in the filtration. So, the different types of media which is very common in the filtration in particular in water treatment they include silica sand, crushed anthracite coal is also very common, sometimes we have layers of these also. So, we may have three layer filter media, two layer filter media, depending upon the requirement and other things.

Then we have powdered or granular activated carbon where adsorption may also occur along with the filtration. Then there are different types of plastic materials which may be spheres, rings, granules, etcetera which may be used as filter media, there is possibility of using metallic materials including metal fabrics also as the filter media. So, the good thing is some of them are they can be easily backwashed they retain all the property with some of them, they are cheaper, but they cannot be used multiple number of times.

So, all these considerations are given in properly selecting a filter media. So, what are the desired properties that we look in any sand or filter media? So, these are listed here, they should be, initially it should be free from any dirt and other impurities, it is better if the filter media is uniform in nature and size. So, this is one of important properties. Another thing is that it should be hard and resistance. So, suppose the filter media is such that we have to filter a water which is highly acidic in nature. So, if it is not chemically resistive, then it will cause some problem.

So, these consideration that it should be hard, it should be chemically resistive, it may be thermally resistive also. So, these are important considerations in the selection of the filter media. And there is another important consideration that this filter media should not lose more of its weight after backwashing or otherwise. So, like consideration is that they should not lose more than 5 percent of its weight after being placed in the hydraulic acid for 24 hours. So, this is like a test for chemical checking. So, this is how we can cross-check and cross-check whether we can use this filter media or not.

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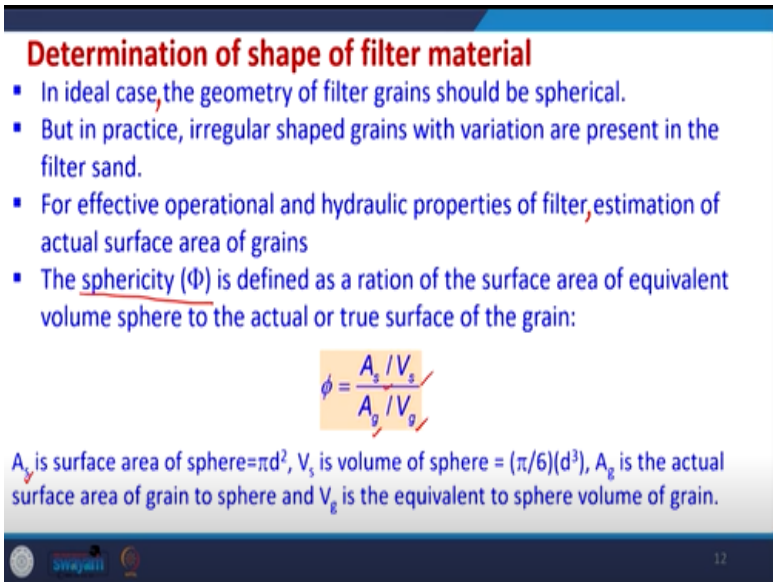

Now, there is important consideration which is used to determine the shape of the filter particle whether it is spherical in nature or some other shape. So, in the ideal case the geometry of the filter cake should be spherical, but in practice irregular shaped grains with variations are present in the filter sand.

For effective operational and hydraulic properties of the filter, estimation of the actual surface area of the grains is very important. So, what is done is that, we find out the sphericity first, and it is defined as the ratio of the surface area of the equivalent volume surface to the actual or true surface of the grain.

So, we try to find out so, we can see the surface area of the sphere and the volume of the sphere and similarly, for actual surface area of the grain with respect to air and similarly the equivalent volume of the grain, so that is there. So, we try to find out and from this definition, we can find

out sphericity and using this we can find out the surface area also. In addition to that the voidage which is created inside the packed bed, that is also very important. So, we will try to learn the voidage and other things in the next lecture, but before that, we will solve one very simple question and before ending the lecture.

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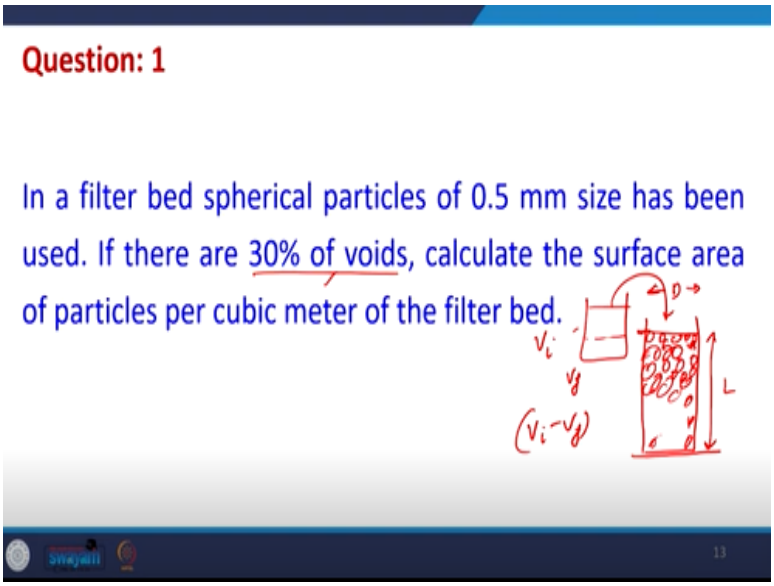

So, in a filter bed spherical particles of 0.5 millimetre size have been used and if there are 30 percent of the voids, so, the calculation of voids is very important. Calculate the surface area the particle per cubic meter of the filter bed. So, what is the surface area that has been generated because of the 30 percent of the void?

Now, the question is that, sometimes it may be asked that how we calculate the void. So, this is very simple techniques are used, one of the technique that can be used is that, suppose, we have the filter media, so, what we do is that, we will take a column, fill the filter media all throughout up to a certain length.

So, suppose this is the length and we filter it and try to pack it as it will be there in the actual condition. So, this whole packing will be done. So, porosity basically means, trying to know that what is the volume in between these particles with respect to total volume, so, that is the voidage which is there or porosity and that can be, we can calculate the volume of voidage by suppose, what we do is that this is closed we take some beaker or something or any bucket in which we have water and that water will be, sorry, that water will be poured in this column.

So, until less we see and we initially measure the volume of the, this water in this bucket and after pouring we pour the water till we have, we can see the water up to this. So, from, we can see and now, we measure the final volume in this bucket. So, the volume of water which has been lost, it can be used for calculating that what is the volume, which is there inside the bed.

Now, we know the total volume of the bed as well because we know the diameter of the bed as well as we know the length of the bed. So, we have the total volume of the bed is known to us, we have amount of, from the amount of water that we have poured inside the column that gives the voidage. The voidage is very important we can always calculate it easily.

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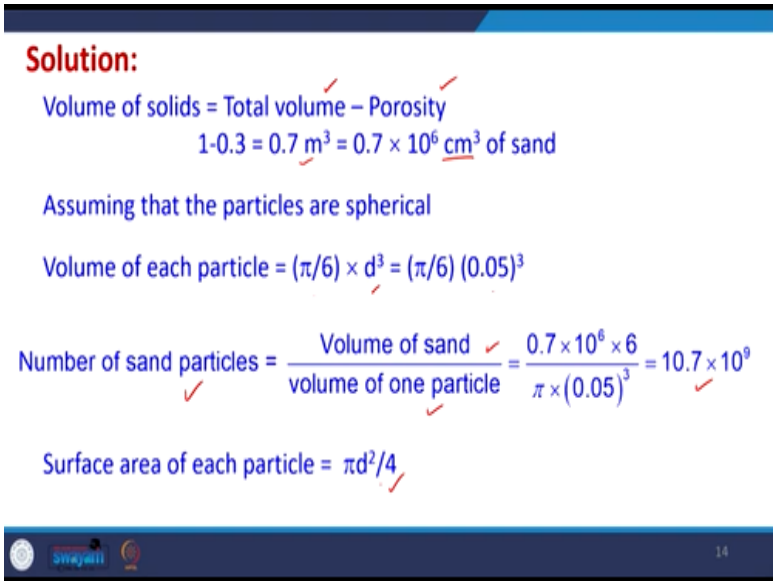

Now, in this question, we have to calculate the surface area of the particles per cubic meter of the filter bed. So volume of solid is like total volume minus porosity. So, it is 0.7 meter cube and we have converted into centimeter cube of sand here assuming that the particles are spherical, so volume of each particle will be pi by 6 d cube and this is the size which is average size which has been given, so size also can be calculated, average size can be calculated via different methods.

So this is not within the scope of this lecture otherwise, we could have discussed that also, you can refer to many places where you can read how to calculate the size of the particle, then the number of sand particles will be there, volume of sand divided by the volume of one particle, so we find that, the number of sand particles are 10.7 into 10 raise to 9. Now surface area of each particle is like this pi d square by 4 we can easily calculate.

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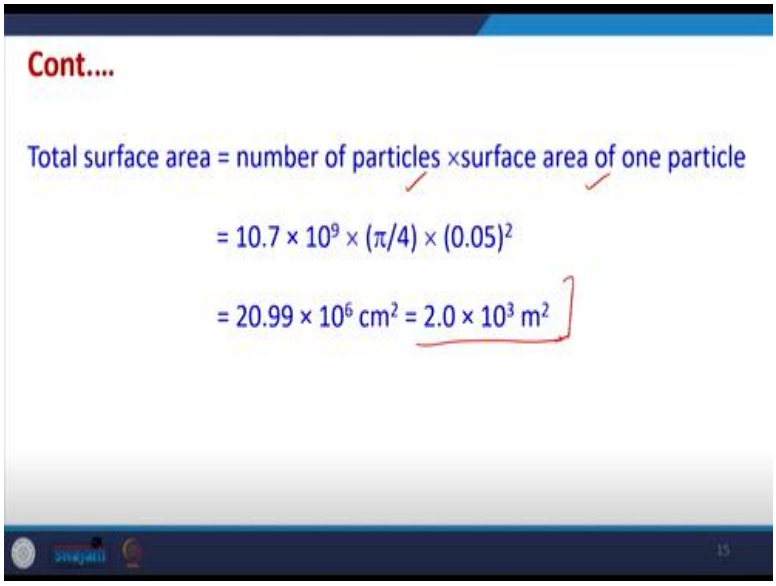

So total surface area is number of particles into surface area of one particle so we can know that this is the surface area which is there 2 into 10 raise to 3 meter square per cubic meter of this particle if they are packed, so this way we can calculate the total surface area including the voidage because we know that voidage will be there in the actual packed bed condition. So this is the initial start of the design thing this is very important consideration in designing the filter bed. So we will continue to use these information.

In the next class we will try to learn the theories which are related to filter flow through the porous media, then how we can perform some calculations with respect to there is one filtration equation that is used for performing lot of calculation with respect to filtration so and after that we will try to learn different types of filters so this is we are going to continue, today will end the lecture here itself. So, thank you very much.