

**INDIAN INSTITUTE OF TECHNOLOGY ROORKEE**

**NPTEL**

**NPTEL ONLINE CERTIFICATION COURSE**

**Unit Operations of Particulate Matter**

**Lec- 06**

**Filtration and Batch Filtration (Part-01)**

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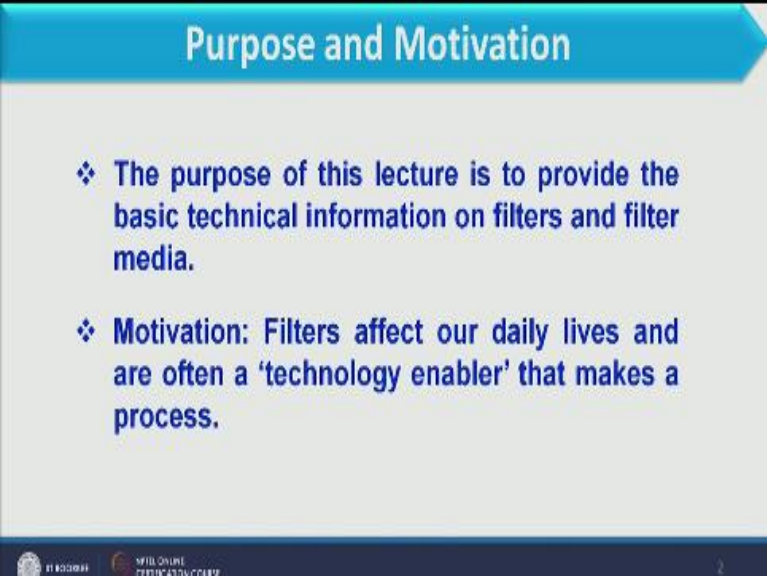
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Welcome to the second week of the course unit operations of particulate matter. This is the first lecture of week two and here we will introduce the concept of filtration. Now this particular topic that is filtration, we will cover in three different lectures, that is lecture 1, lecture 2, and lecture 3 where we will cover filtration as well as batch filtration. So in first lecture we will define the filtration, we will discuss the principles of filtration, and then we will cover the steps involved in filtration and different types of filtration.

In second lecture of this session we will describe the governing equations which are used to design the filtration equipment filtration unit. And in third lecture of this session we will discuss the examples, so that the concept of filtration and the calculation etc., for design of filtration unit can be illustrated. So let us start with the first lecture of week two which is on filtration.

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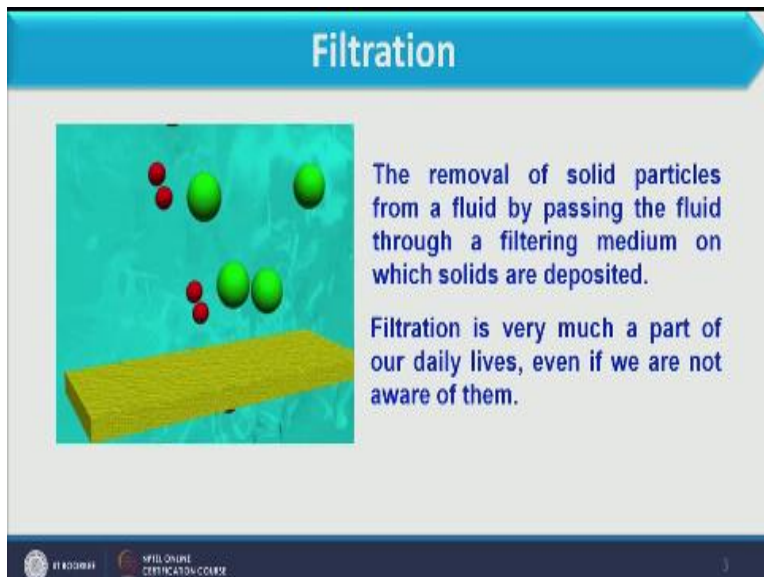
**Purpose and Motivation**

- ❖ The purpose of this lecture is to provide the basic technical information on filters and filter media.
- ❖ Motivation: Filters affect our daily lives and are often a 'technology enabler' that makes a process.

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Now what is the purpose and motivation of this lecture is, the purpose is to provide the basic technical information on the filters and filter media. So the purpose is to, we will define the filtration, we will discuss about the filters and filter media. Now what is the motivation behind it? The filtration if we consider filtration process we use in our day-to-day life whether we are aware with it or not, but we use it and how we will translate the concept of filtration which we use in our day-to-day life to the industrial scale that will be the motivation of this particular lecture.

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So what is filtration? If you see this particular figure what this image shows that here we have the filter media if you consider, and we have the solution over there, the solution is continuously coming over here, but the particle which are available in the solution if their size is greater than the pores of the media the solid will be deposited or it will not be filtered from this, it will not be penetrated through this. However, the particle which are lesser than they can penetrate, so that speaks about the concept of filtration.

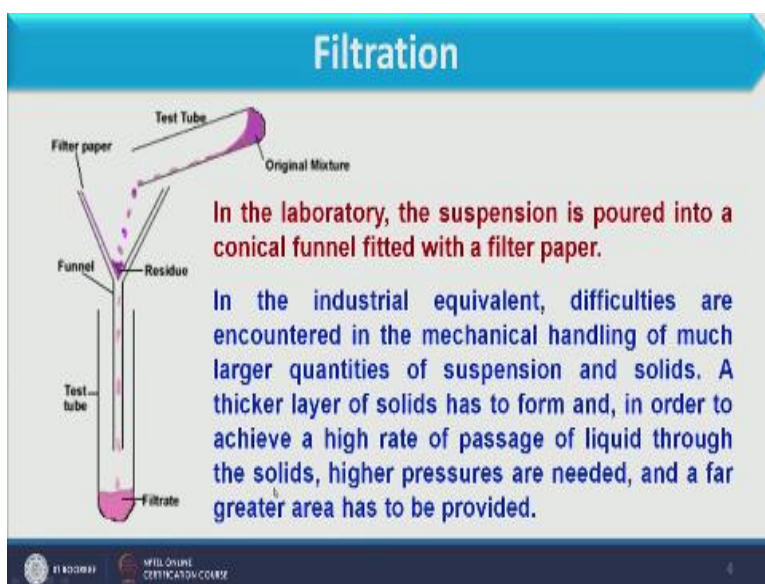
Now what is filtration is? Filtration can be defined as the removal of solid particles from a fluid by passing the fluid through a filtering media on which solids are deposited. So we have to filter the slurry, so that solid which is available in this that should be deposited on the filter media, and liquid which is available that should pass through the media. So that is basically the filtration. So filtration is very much a part of our daily life even if we are not aware of them.

Now to give an example of this when we carry out when -- in our day-to-day life what we do, I can say this that many of us have at least strain the tea which we prepare for us. So that is nothing but the filtration process, what we take, what we do in that we take the strainer and then we pass the tea through this, so the tea leaves which are available in the tea that will be collected

in the strainer and rest of the liquid will be passed through it. So that is nothing but the filtration itself.

So similarly in many other day-to-day activity we use filtration, but whether we are aware this or not, but we use the filtration. But the purpose of this lecture is how we will use this technique to design the process.

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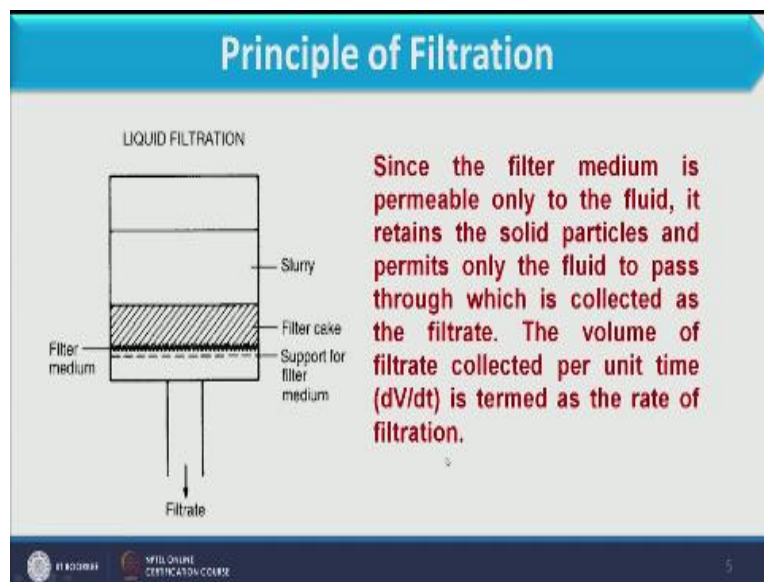
Further as we all have gone through the labs in school chemistry labs in school, so we all have use the filtration process. If you consider this image here we have the test tube and over this test tube we put the funnel, and inside the funnel we have the filter paper, then the mixture will be entered into this, so that the unwanted part or the solid which is available in the mixture that we will be collected in the filter and liquid is pass through this.

So in lab also we have use the concept of filtration, but obviously at very low scale. So in laboratory the suspension is poured into the conical funnel fitted with a filter paper. Now if we want to translate this concept to industrial purpose in a industrial equivalent difficulties are encountered in the mechanical handling of much larger quantities of suspension and solids. A

thicker layer of solids has to form and in order to achieve high rate of passage of liquid through the solids higher pressure are needed and a far greater area has to be provided.

So you see in lab scale in our day-to-day life we use filtration at very low scale. However, at industrial scale a significantly large area is required, and because of that media, sometime due to the accumulation of solid over the filter media the liquid will not pass through, so for that purpose we have to increase the pressure so that liquid should pass through the media. So all these complexities we have to consider in designing of filtration system for industrial process or industrial purpose. So here we have in this slide the principle of filtration.

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Now what is the principle of filtration? First of all we should see what are the different component in filtration system we have to consider, and these components are first of all we have to take the filter media through which slurry should pass, and then that filter media should be state over some about I say some support like if we consider the example of funnel also like in the previous slide we have discussed. So the funnel and inside this we put the filter media, so that funnel works as a support to the filter media.

# Principle of Filtration

As the filtration proceeds, solid particles accumulate on the filter medium forming a packed bed of solids, called filter cake.

As the thickness of the cake increases  
→ resistance to flow of filtrate increases  
→ rate of filtration gradually decreases.

If rate is maintained to be constant then pressure difference driving force ( $-\Delta P$ ) will increase.



The diagram illustrates the process of filtration. A dark horizontal line at the bottom represents the filter medium. Above it, a layer of small circles represents the filter cake. Above the cake, several larger circles represent the filtrate being collected. A vertical arrow on the right side of the cake indicates the thickness of the filter cake.

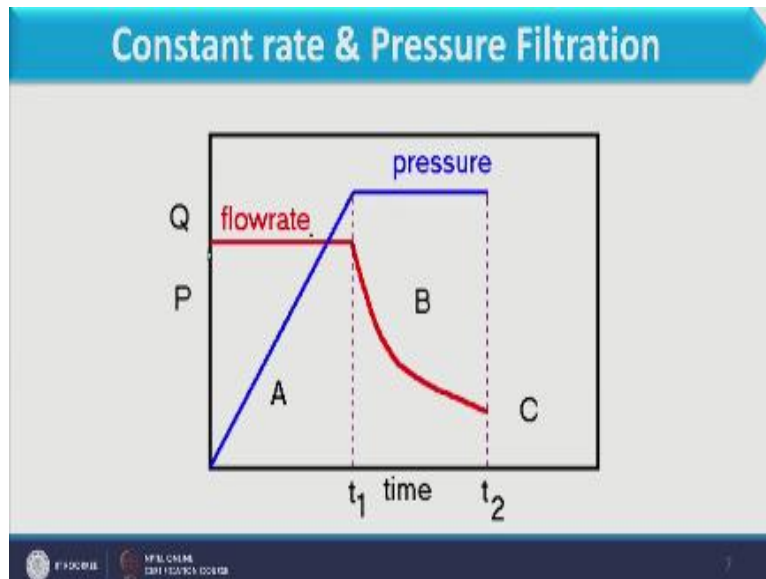
Therefore, a batch filter is operated either at constant pressure or at constant rate.

So as filtration proceeds solid particles accumulate on the filter media forming a packed bed of the solid and we call these as a filter cake. So what happens first we take the media, slurry is passed through it, and after sometime the thick layer of solid will be formed over the media that we call as the cake. So what we can understand over here that as the thickness of this cake increases, you can understand when we have the formation of solid over the filter media what happens it will offer a resistance to for a liquid to pass through the media. So as the thickness of cake increases resistance to flow of filtrate increases, the rate of filtration gradually decreases.

Now here due to increase thickness of cake over the filter media the filtrate which is collected over, collected through it that will be decreased after, that will start decreasing after sometime because of the resistance which is offered due to the formation of cake. So if rate is maintained to be constant then pressure difference driving force will increase. So what we have to do over here that due to the formation of thick layer over the filter media, the filtrate volume collected per time will keep on decreasing.

If you want to maintain same rate of filtration that is volume collected per time should be same. So we have to increase the pressure drop across the filter media or across the filter media as well as cake. So therefore, the batch filter is operated either by constant pressure or at constant rate. So as for as its principle is concerned, we either go for the constant pressure process or we can go for the constant rate process. Now what happens when we consider these two?

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So that can be illustrated with this figure where at Y axis we have pressure as well as Q that is volume collected and here we have the time. So as time proceeds if we want to maintain the flow rate constant, maintain the flow rate of filtrate constant, then continuously we have to increase the pressure. Pressure will keep on increasing, so we will collect the constant volume of the filtrate, and when the pressure will be reached to the permissible value after that pressure should not be increased because of the operational difficulty.

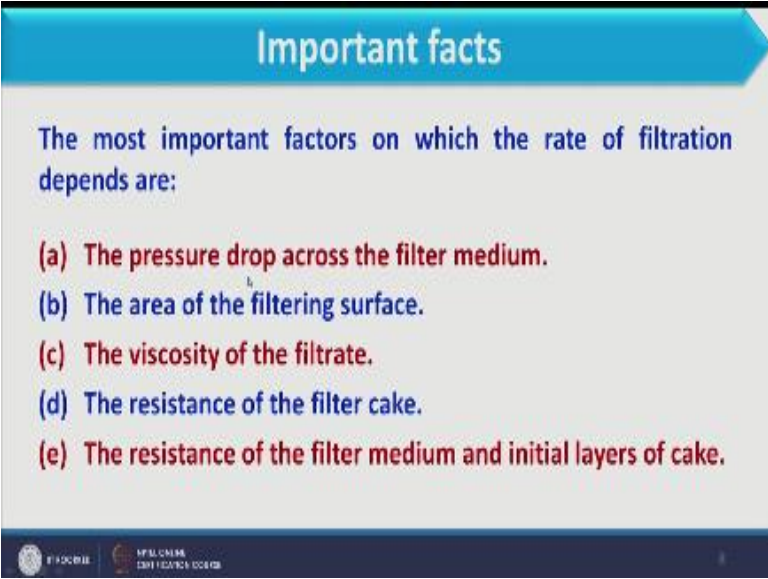
So after that pressure will remain constant and once we keep the pressure constant the volume of filtrate collected per unit time will keep on decreasing. So what we have to do first of all we have to increase the pressure to constant, the rate of filtration and then we have to go for the constant pressure, so that filtrate volume will keep on, or rate of filtration will keep on decreasing. So to get the maximum output first of all we have to operate at constant rate and then we should proceed with constant pressure.

Now what happens when we consider vice versa of this like if we maintain the pressure constant and slurry and filtrate, rate of filtration will keep on decreasing. So you can see this section of the image appears first and after that when we increase the pressure the filtrate can be constant. So



you can see the filtrate can be constant at this level. So obviously the filtrate which has to be collected its volume will be decreased, our rate will be decrease significantly. So for maximum output we have to operate with constant rate and then with constant pressure.

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**Important facts**

The most important factors on which the rate of filtration depends are:

- (a) The pressure drop across the filter medium.
- (b) The area of the filtering surface.
- (c) The viscosity of the filtrate.
- (d) The resistance of the filter cake.
- (e) The resistance of the filter medium and initial layers of cake.

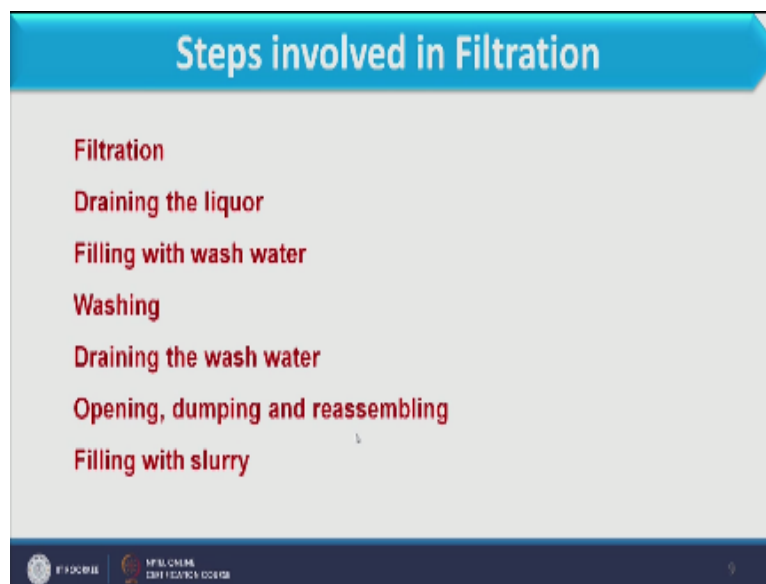
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Important factors which affect the rate of filtration are the pressure drop across the filter media, obviously because we have to maintain the rate of filtration, so pressure drop is an important factor across the media. Secondly, area of filtering surface, when we increase the area we can handle more and more slurry at one time, but at the same time we should take care of the filter media, because accordingly we have to use larger filter media and the larger system which will be difficult to handle.

So but area of filtering surface is an important factor, another factor is the viscosity of the filtrate it has to be not so much viscous, so that the penetration of liquid should be easier, so its viscosity should not be much, but viscosity affects the filtration process. Next is resistance of the filter cake, the filter cake resistance can be offered by the thickness of the cake so we should take care that after sometime these cake should be removed.

So the thickness of these cakes gives the resistance and that will be the factor for designing of filtration system. Finally the resistance of the filter media and initial layers of the cake, now initial layer when the slurry contact the filter media what happens initially a layer is formed. So that layer works also as the resistance, also as a filter media because it stops, it blocks other particles to, or it blocks liquid to pass through this so that will also work as a filter media. So resistance will be offered by the initial layer, filter media, as well as total thickness of the cake.

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So here we will discuss different steps which are involved in filtration process you see first is the filtration where slurry is in contact with the media, filtration takes place and after that we have second step is draining the liquor the filtration which is, filtrate which is formed that we have to drain from the system, then further the system should be filled with wash water, because whatever cake is formed over the filter media that we should wash with the clear water or this clear water we also call as wash water.

So third step is filling the system with wash water, then washing takes place in the similar line as the filtration takes place washing also takes place in the same, following same method that instead of slurry clear water should pass through the cake, so that it can wash the cake. Next step

is draining the wash water and finally we have to open, dump, and reassemble the whole system, so these are the steps involved in batch process for filtration purpose.

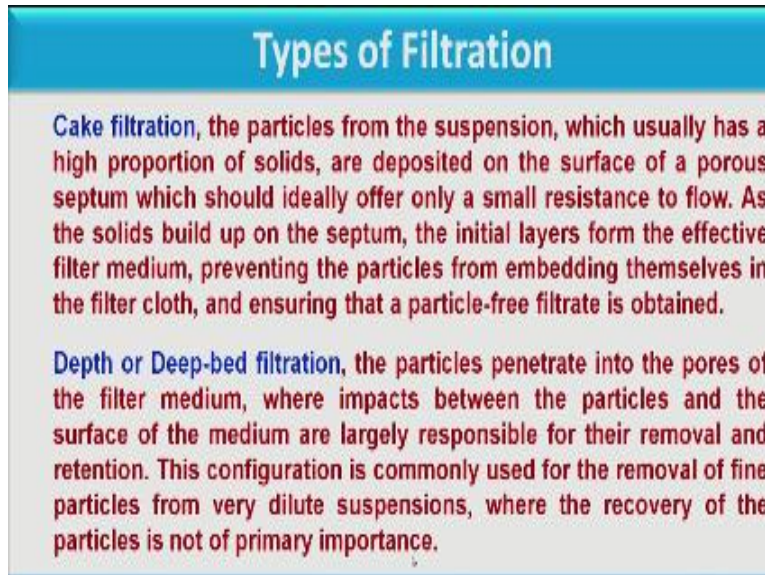
And then after dumping, after reassembling again we fill with the slurry so you see filtration draining leaker filling with wash water, washing, draining the wash water, opening, dumping and reassembling this is one cycle of filtration. Now if we consider the example from our day-to-day life many of us used to prepare the cheese at our houses. So how we prepare this first we have the curdly milk then we strain with the media that is very fine cloth and through this we pass through the whole mixture.

So the lump inside the mixture that will be collected in the media and liquid pass through this, okay. So that will be a few step of the filtration that is filtrating and then draining the liquor. Now what we do we then wash the lump which is collected over the cloth. So we again fill this with water, clear water, the water passes through this through the lump and then we again, we keep that lump one side and press with some heavy weight so that it has the proper shape.

And whatever drainage, whatever wash water we have used that we have already discharge. So you see all these steps are involved even when we do the filtration process in our houses also. So what happens here we have to, the cake is formed we have to wash the cake and then we have to discharge al the cake, so that the system will be reassembled for the next cycle. Now it happens by some means if we continuously remove this cake because the cake is main huddle in the process.

So if continuously remove the cake the filtration process can be translated into the continuous system from bad system.

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Now we have already seen the step involved in filtration now we will see the different types of filtration. The very common filtration is the cake filtration, now if you see what happens in the cake filtration the particles from the suspension, which usually has a high proportion of solids, is deposited on the surfaces of a porous septum that is filter media, which should ideally offer only a small resistance to flow. Now usually it has very less resistance because that passes through the media.


So the resistance is very less, now what happens after sometime the solid layer will be formed over here that offers major resistance for the liquid to pass, so as solids build up on the septum the initial layer forms the effective filter medium, preventing the particles from embedding themselves in the filter cloth, and ensuring that a particle-free filtrate should be obtained.

So what happens that formation of a layer of solids stops the other particles of solid to pass through this, therefore we can get the clear liquid, but because of this what happens the solid will be deposited continuously on the filter region and therefore cake formation takes place. Therefore this complete process is called as complete filtration it is called as cake filtration.

Another filtration we have is depth or deep bed filtration, what happens over here? The particles penetrate into the pores of the filter medium, where impacts between the particles and the surface of the medium are largely responsible for their removal and retention. This configuration is commonly used for the removal of fine particles from very dilute suspensions, where the recovery of the particles is not of primary importance.

So when the particles which are available in the fine size then we go for this, and what happens these particles penetrate through the medium, these particles entered through the media, but it cannot be penetrated through this, liquid will pass through this, so after in the case solid is entered into the media. This takes place this type of filtration is required when solid recovery the recovery of solid is not only the aim, only getting the clear liquid is the aim.

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### Types of Filtration

**Depth or Deep-bed filtration**

The filter bed gradually becomes clogged with particles, and its resistance to flow eventually reaches an unacceptably high level.

For continued operation, it is therefore necessary to remove the accumulated solids, and it is important that this can be readily achieved. For this reason, the filter commonly consists of a bed of particulate solids, such as sand, which can be cleaned by back-flushing.

So in such type of filtration what happens? Filter bed gradually becomes clogged with particles and its resistance to flow eventually reaches an unacceptably high level. So you see because particles enter into filter media it would not allow a liquid to pass through this so after some time because of clogging this complete system, we have to stop because the further penetration of liquid is not possible.

So that is the main disadvantages of this, now to overcome the problem of clogging, it is necessary to remove the accumulated solids, and it is important that this can be done easily. Now how it can be done easily? The filter commonly consists of a bed of particulates solids, so instead of clot or very fine filter media if we can keep a sand bed or bed of a particular solid, if that bed of a particular solid works as filter media so what happens? Fine particle will be accumulated inside the particulate bed and filtrate will pass through this.

Now these particulate solid and the fine particle deposited over here and that can be recovered by back flushing process. So you can use bed or particulate or other particulate solid bed to carry out this deep bed filtration.

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### Filter Media Requirements

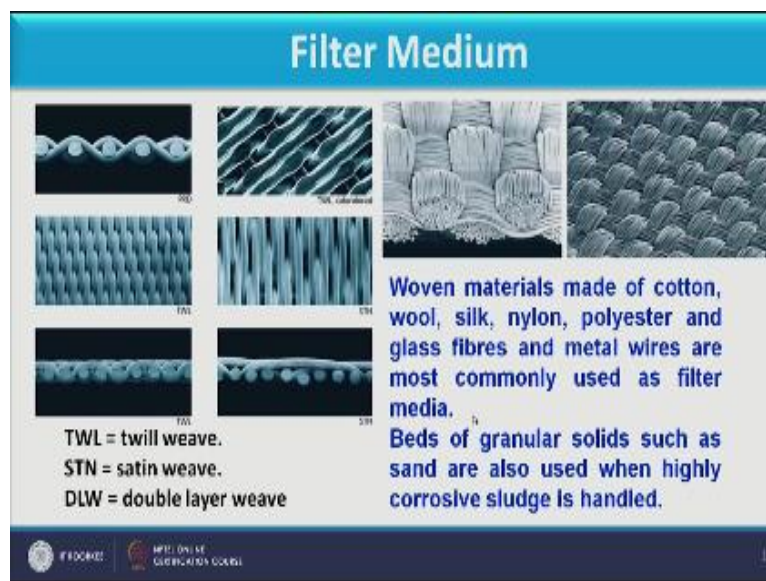
- Retain solids to be filtered
- Give a reasonably clear filtrate
- Does not plug or blind
- Be chemically and physically resistant to process conditions
- Permit cake to be discharged cleanly and completely
- Should not be too expensive

Now here we have the filter media requirements, so what of quality we should see as far as the filter media is concerned and these are the filter media should retain solids to be filtered. So filter media has to retain the solids that is the 1<sup>st</sup> requirement, 2<sup>nd</sup> give a reasonable clear filtrate, it should block the solid particle to pass or retain the solid particle and filtrate very clear filter we should get.

Does not plug or blind, the filter media should be like that, its pores should be like that, the solid will be deposited over here, it should not penetrate though very fine particles penetrate but we should take care of the filter media. We should collect in such a way so that the particles should not penetrate and should not clog the filter media. Filter media should be chemically and physically resistant to process conditions.

So what happens it should, whatever slurry we are using the filter media material should not react with this? So filter media material should be chemically and physically resistant to process. It should permit cake to discharge cleanly and completely. Yes that is a very important factor and it should not be too expensive. That is again the economic will involve over here, so based on all these points we should study the filter media. Now the common type of filter media is shown in this slide.

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So if you see this image here we have different types of filter media that is if we consider this one will leave and this is the satin wave and this is double layer weave also for the filter media. Filter media images you can see over here, it gives the idea of that a filter media. Filter media is



basically the weed stuff of cloth. So a very thick cloth is there so that we use as a filter media. So these are different types of media.

And usually woven materials made of cotton, wool, silk, nylon, polyester and glass fiber and metal wires are most commonly used as filter media. Beds of granular solids such as sand are also used when highly corrosive sludge is handled. So you see there is different type of filter media, not only cloth but sand can also used as filter media. Here we are stopping the 1<sup>st</sup> lecture on this session, in the next session we will discuss about the governing equation which are involved in filtration process. So that is all for now thank you.

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