Physico-Chemical Processes for Wastewater Treatment
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Lecture - 30
Filtration - III

Good day everyone and welcome to these lectures we will be continuing with respect to filtration. So, in the previous lectures we studied regarding the filtration, like constant volume filtration, constant pressure filtration, in the last lecture, we studied regarding the equations which are used for design of filtration unit and the equation the derivation of these equations are broadly based upon the assumption that it is very similar the assumption during filtration is that the flow is similar to the flow through a porous packed bed and that is based on the assumption that the cake which gets deposit it is like similar to porous bed.

So, we can apply the same concept and we derive the equation and used the Blake-Kozeny equation etc, for finding out the pressure drop and other parameters, and using the same equation we can develop the ultimate filtration equation also. So, that can be used for design of filtration unit. Now, in today's lecture, we will try to discuss or understand some of the basic filtration units which are used in the water and wastewater treatment.

So, we will classify the filtration units and then further discuss them in detail, in the last we will try to again reevaluate the various mechanisms under which these filtration units operate, so this is there. So, in general the filtration types which are there the filter types which are there they are they may be classified as depth filtration.

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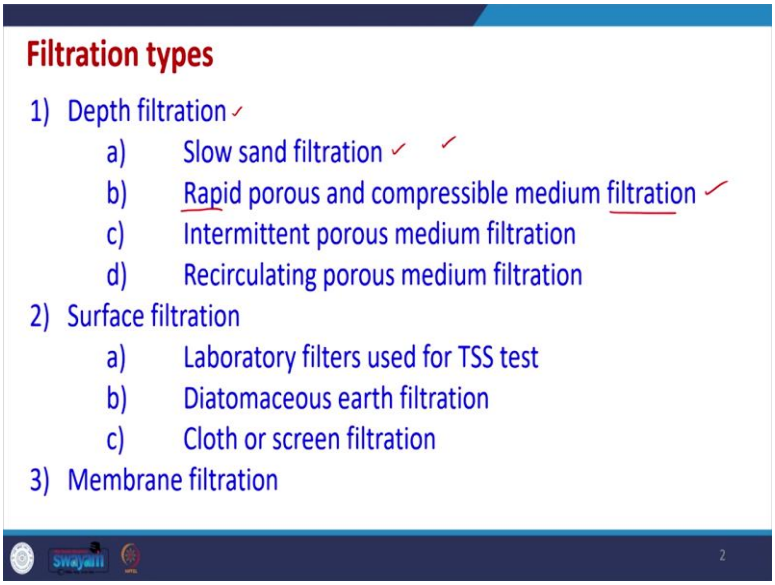

So, the depth is very large with respect to the bed, which is there and which is used for filtering out the undesired flocs and other things out of the water, so this is there. So, it will include Slow sand filtration, Rapid filtration unit also, it may include porous or compressible medium filtration, then Intermittent porous medium filtration, this is also possible then Recirculating porous medium filtration, these first two are the most common, which are used in the industry.

Then surface filtration like Laboratory filters which are used for TSS test, then we have Diatomaceous earth filtration which is there, then Screen or Cloth filtration, but, we will be discussing more on the depth filtration. Similarly, membrane filtration can also be used. So, this is, membranes can be used or these are also referred to as membrane separation. So, that subject will be studied in detail, but little bit idea we will study here also along with the filtration itself, detailed lectures will be delivered later on the membrane separation later on after some more unit operations we study. So, that will be detailed, but that can also be considered as a filtration unit, because we actually filter the things only in membrane also.

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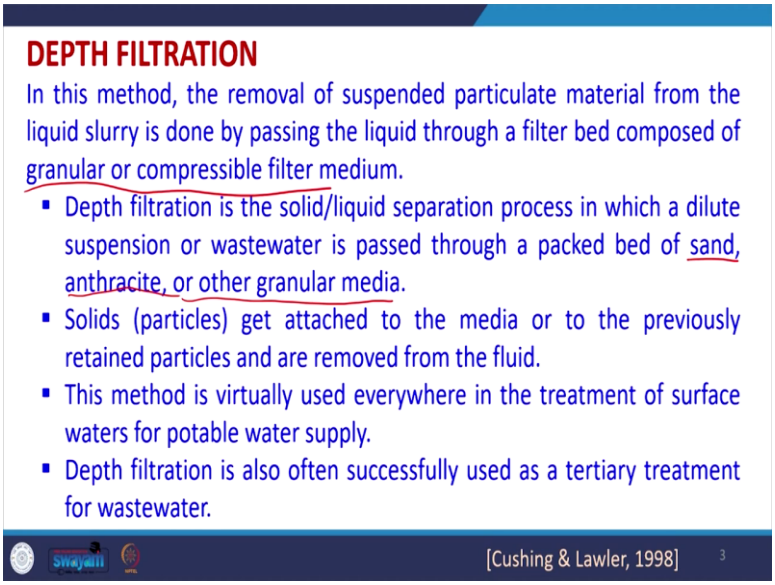

Now starting with depth filtration. So, in this method what we do is that we remove the suspended particulate matter from the liquid slurry and it is done by passing the liquid through a filter bed, which is composed of granular are compressible flitter medium. So, it may be incompressible, it may be a little bit compressible and we pass the slurry through that. So, all the suspended particulate matter etc gets filtered out or that is blogged because of the smaller pore size as compared to the size of the suspended particulate matter.

Now, depth filtration is the solid liquid separation process in which a dilute suspension or wastewater is passed through the packed bed of sand, anthracite or other granular media. So, what this statement means that we can have a combination of media also. So, it is possible to have one media, single media, dual media, tri media packed bed and through which the wastewater is filtered through, so this is there.

During this filtration the solid particles get attached to the media or to the previously retained particles themselves. So, in the starting they will be retained by the media, but after some time some cake deposition will be occurring. So, the previously retained particles will also be there. So, they will also filter the much smaller size particles which are coming now, so this is there.

So, this method is widely used in most of the treatment plants for surface water, for portable water supply etc. So, this is also will these filtration units are many times used in the industry in the later stages also. So, their placement in the treatment plants may be different, but they operate under same idea, so this is there. Depth filtration has also been successfully used for tertiary treatment of wastewater and which is used in the last in the industries, so this is there.

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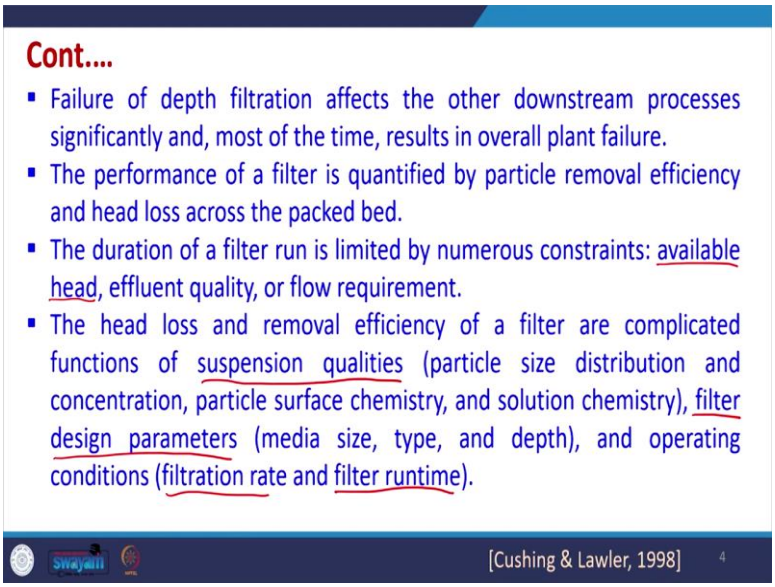

Now, the failure of if suppose any depth filtration unit fails and it is not filtering the suspended materials. So, it will affect the downstream processes significantly and most time it will cause the, it may cause the overall plant failure also, if the pressure drop increases too much also then also there will be a lot of effect on the overall efficiency of the plant. So, the

performance of a filter is quantified by the, what is the particle removal efficiency and head loss. So, both are very important parameters.

The duration of a filter run is limited by numerous constraints. So, how much time a filter will operate that will be dependent upon the available head which is there, the effluent quality which is going through the filter. So, whether our sedimentation unit is working very well or not if sedimentation unit or the units before the filtration units are working very well then the filter may also work very well. And so, overall effluent quality after the filtration will be good, so this is there.

This will also be dependent upon that how much volume of water has to be filtered out in the filtration unit. So, this is important consideration. And so, all these have to be taken care of. The head loss and removal efficiency of a filter are complicated functions of various parameters including the suspension qualities, the filter design parameters.

So, all these are important, in the suspension qualities the particle size distribution of is important, the concentration, the particle surface chemistry whether it is getting attached, if suppose the particle surface chemistry is such that it is getting attached to the via chemical bond to the filter media, then the backwashing will become difficult, what is the solution chemistry, whether it is P? What is the pH? All those parameters affect the removal efficiency in a filter.

In addition, there are certain parameters that we can design by our self while selecting the media. So, what is the media size? What is the type of media we are going to select? So, that we have to understand beforehand, we can select based upon the suspension qualities. Now, similarly, we can design the depth of the filter bed as well as the diameter of the filter bed. So, that is one parameter which is in our hands, so, we can design it.

Similarly, what is the operating conditions under which we are operating? What is the filtration rate and filtration time, filter runtime? So, at this we can vary by having a number of filters in parallel. So, through that we can optimize or we can manipulate these variables as well. So, filtration rate, size media type, media size and the depth and the diameter of the bed all those are the parameters that are in our hand and we can select them properly.

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Now, continuing one of the first unit which is very common, it is called slow sand filtration. So, it is very effective in removing flocs containing microorganisms such as algae, bacteria, virus, etc. And slow sand filtration generally operates in the range of 0.1 to 0.2 meter cube per hour. This is the usual which is common, and if the flow rates are higher or otherwise, we can have a multiple units in parallel, so this is there.

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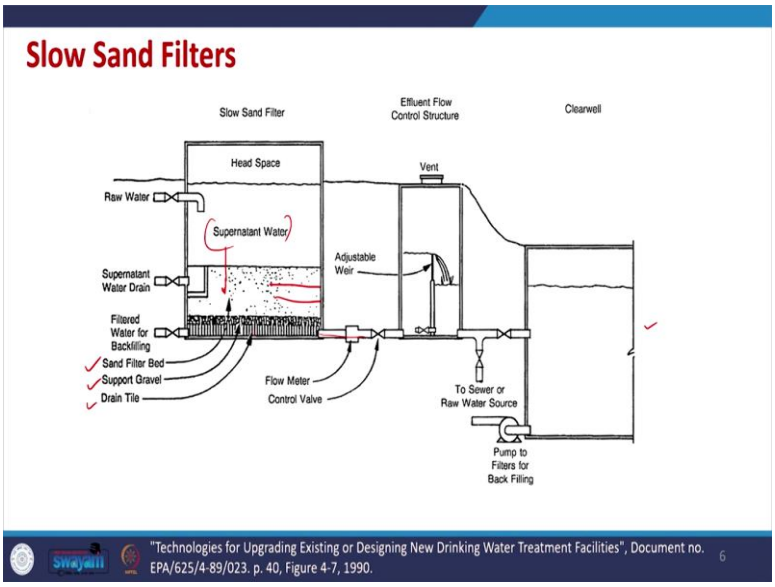

This is how slow sand filtration is there, raw water is coming. So it will be here and then it will be percolating we have different types of beds you can see, so, we have sand filter bed, support gravel, then there is a, grey, drain tile is there, we can have multiple beds also here, possible of different filter media, so this is there.

The water is coming here and it is going to this effluent flow control structure and finally, going to the clean well, which may be pumped further. So, this is how it operates, we can have a backwashing option here also within this bed. So, there is a backwashing also because this bed has to be back washed after some time. So, this is possible.

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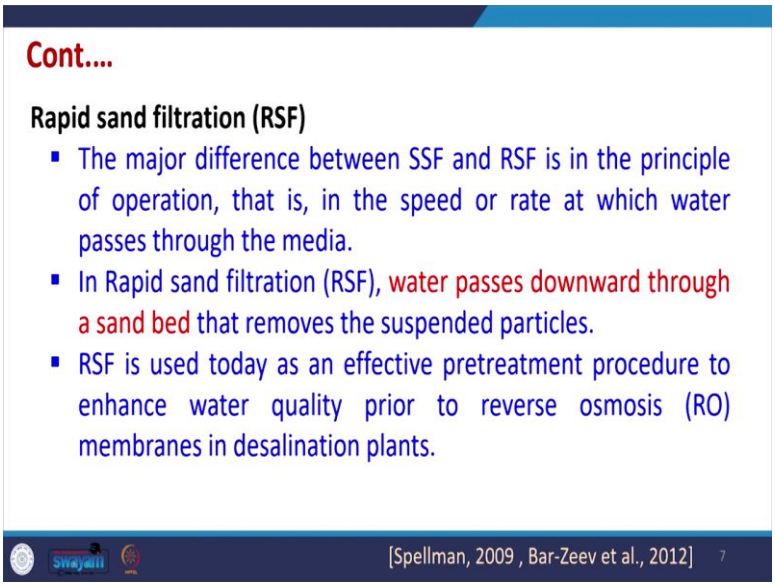

Then, Rapid sand filtration, the major difference between the SSF and RSF is in the principle of operation that is the speed or rate at which water passes through the media. In the Rapid sand filtration water passes downwards through a sand bed that removes most of the suspended particles and it is very common pretreatment procedure before we use the RO membranes in the desalination plant, so this is there.

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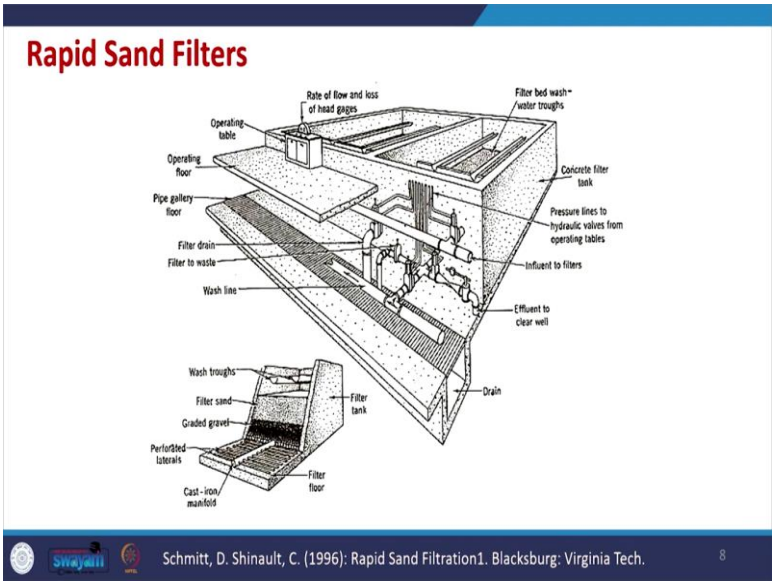

And this is the diagram of Rapid sand filter. And so, we have different components within this Rapid sand filter including like wash lines, filter Drain, filter to waste, operation is very similar to that only the rate of operation is faster.

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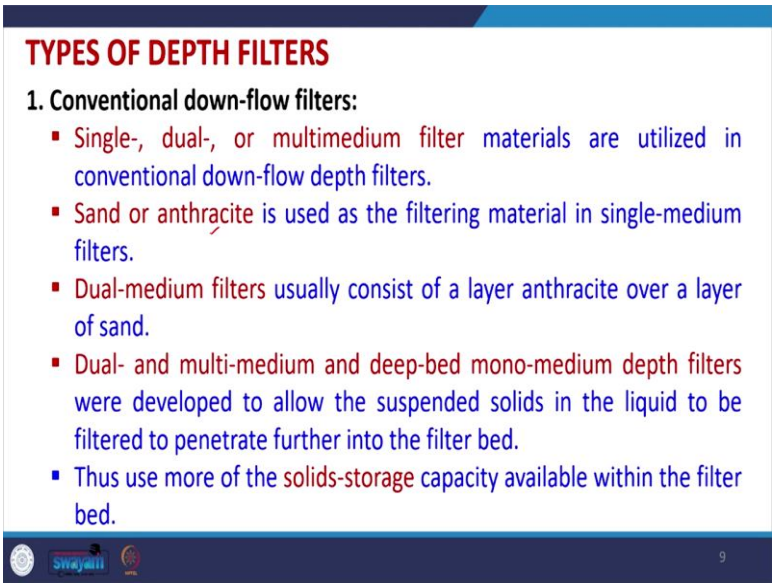

Now, there are other ways also we can define that depth filters. So, one is called conventional down-flow depth filter. So, it can have a single, dual or multi medium filter materials that are utilized for conventional down-flow depth filter. Already we have got an idea with respect to SSF. So, sand or anthracite coal is used as a filter medium in single medium filters, in that dual medium filters, they may consist of additional layer of anthracite over a layer of sand. So, that is possible.

So, we have to, we can have multi-medium filters also, we can use other types of material as a media for filtration and multiple medium filtration units were developed to allow the suspended solids in the liquid to be filtered to penetrate further into the filter bed. So, thus we can have a solid storage capacity available within the filter medium itself. The time which is required for backwashing the time which is available before the backwashing that improves, so, that is the possibility which is there.

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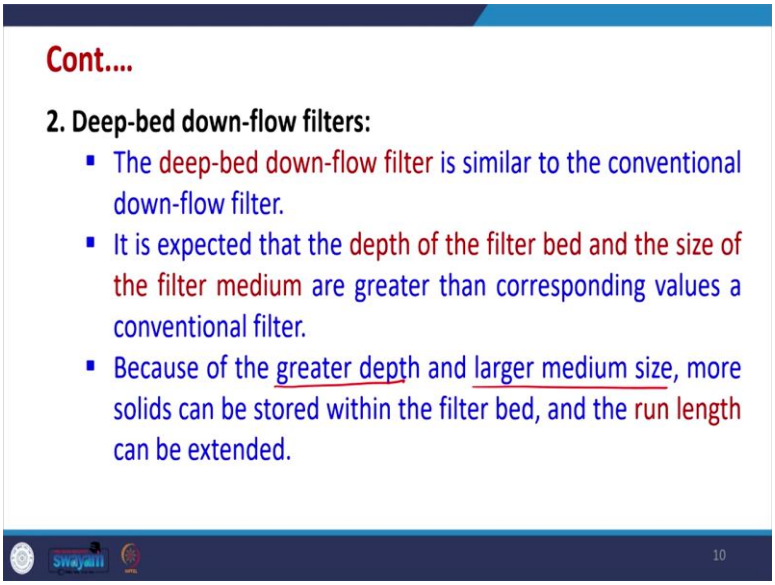

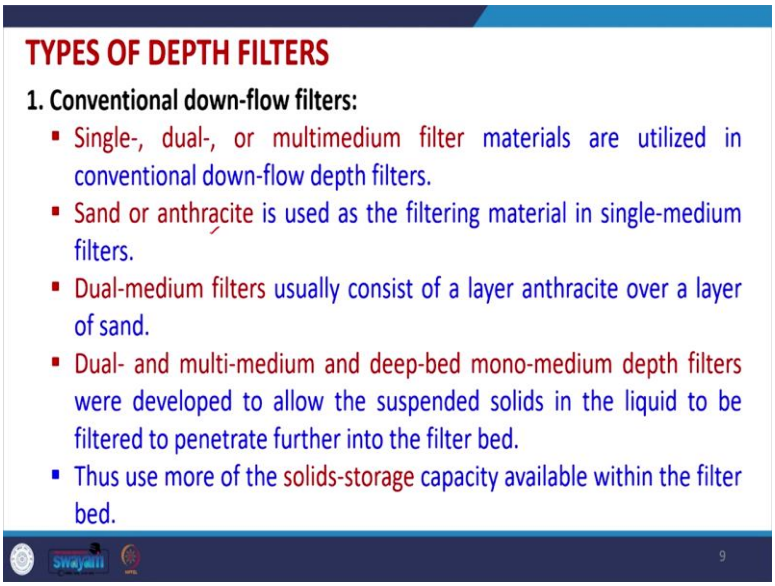

Now, deep-bed down-flow filter. So, this is conventional down-flow filter, then there is another classification which is called as deep-bed flow filters. It is very similar to conventional down-flow filters, except that the depth of the filter bed and the size of the filter medium are greater than the corresponding values in the conventional filter and because of the greater depth and larger medium size more solids can be stored within the filter bed and run length of the each bed increases a lot. So, this is a possibility with deep-bed down-flow filters.

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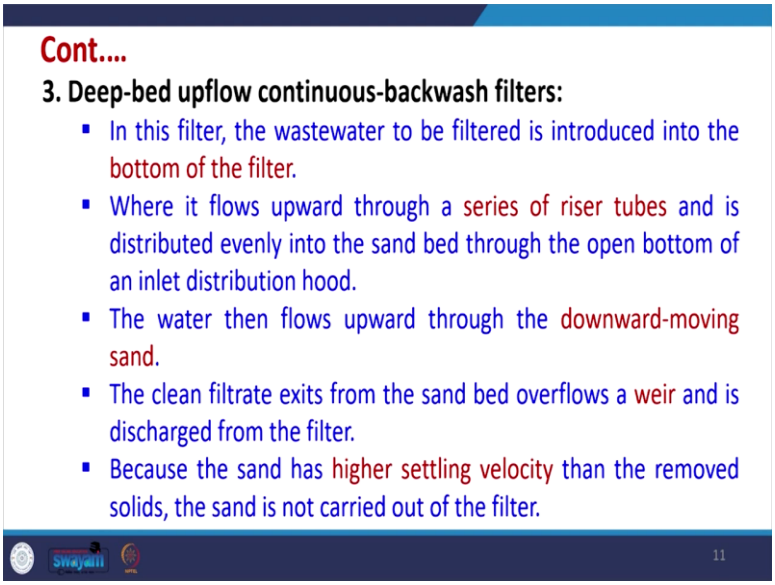

Then deep-bed upflow continuous backwash filters are also there. So, in this case the wastewater to be filter is introduced into the bottom of the filter and it flows upwards through a series of riser tubes and is distributed evenly into the sand. So, whenever there is flow upwards, it will always get distributed evenly in the sand bed in the down-flow condition there is the possibility of channeling, there is a possibility of some section of the bed not being utilized at all. So, all those possibilities are revealed out when we have upflow filters, so this is there.

And now the water while flowing upwards through the, it flows upwards through the downward moving sand. So, both the conditions are different. Now the clean filtrate exists from the sand bed overflows over a weir and it is discharged from the filter. So, ultimately the clear water will come out from the top because the sand has high settling velocity than the removed solid, the sand is not carried away out of the filter. So through this we can use.

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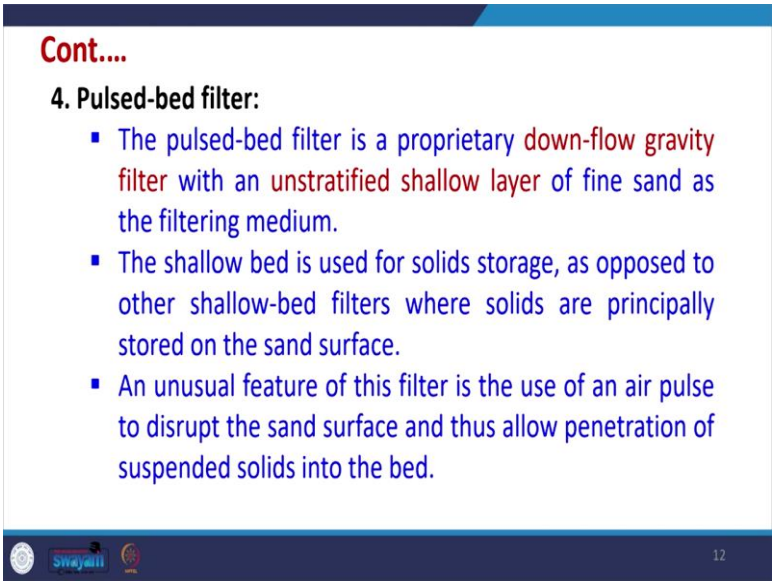

Then we have a pulsed-bed filter also. So it is a proprietary type of filter and it has a unstratified shallow layer of fine sand as the filter medium. The shallow bed is used for solid storage, as opposed to other shallow bed filters where solids are principally stored on the sand surface, but here there is a shallow bed which is used for the solid storage.

An unusual feature of this filter is that use of an air pulse to disrupt the sand surface and thus allowing the penetration of suspended solids into the bed. So, this air is used as a pulse, air pulse is used for disruption after some time so, that the solids which have been there, they again go into the bed where they get accumulated.

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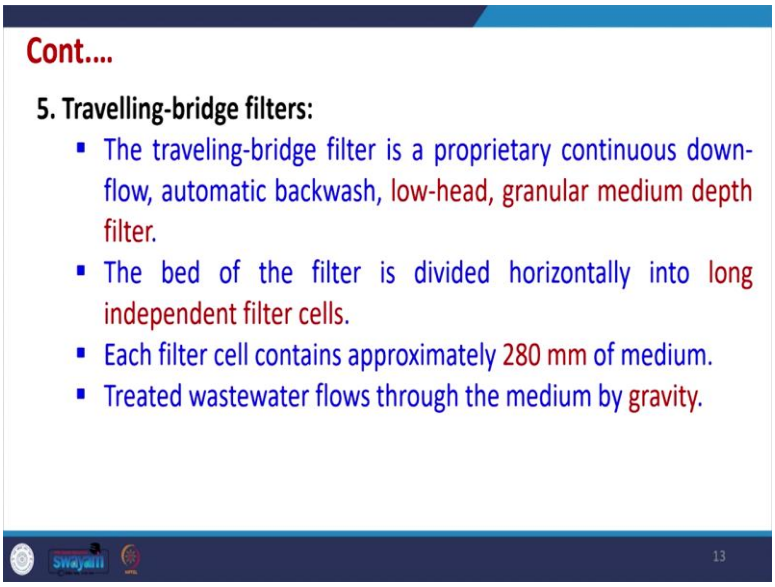

Similarly, there is another type of depth filter which is called as traveling-bridge filter. And again it is a proprietary continuous down-flow automatic backwashing, low-head, granular medium depth filter, we can go and cross-check these filters in detail if you are interested. The bed of the filter is divided horizontally into long independent filter cells.

So, they can be divided into various filter cells and each filter cell may contain around up to 280 millimeter of the medium and the wastewater which is treated it flows through a medium by gravity itself as earlier, but in this the filter bed there is a traveling component within the filter bed itself.

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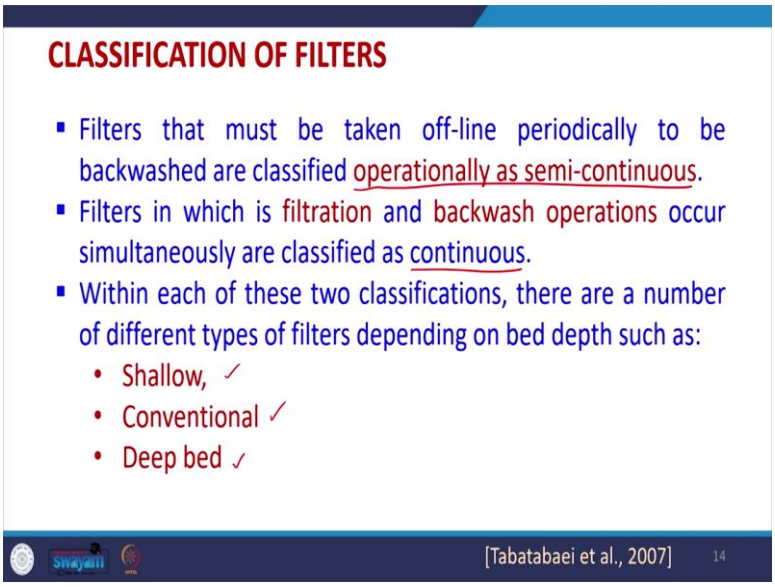

Now, classification, these are the simple classifications, there can be other classifications also, like if the filters that must be taken off periodically to be backwashed. So, they can be classified as semi-continuous, because we have to go for backwashing, so, they are not continuous.

So, in this case, we have to use a number of filter beds in parallel and one is in backwashing and others are in operation mode, the simple filtration mode. So, filters in which filtration and back-washing operations occur together they are called as continuous otherwise, they will be called as semi-continuous.

Within each of these two classification there are a number of other types of classification possible, depending upon the bed depth whether it is shallow, whether it is conventional, whether it is deep bed, these possibilities are there. So, there are a number of classifications which are possible.

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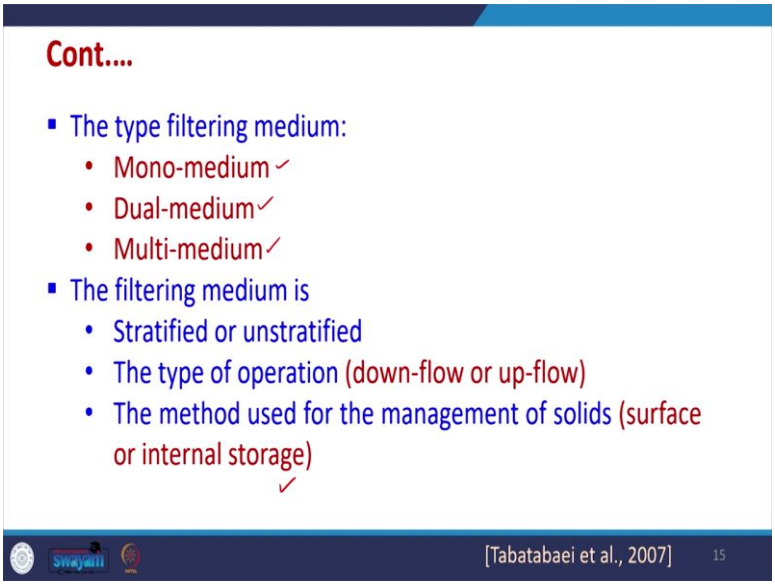

Similarly, based upon the type of filter medium, we can have mono-medium, dual-medium or multi-medium filtration, which are possible. The filtering media can be stratified, unstratified. The type of operation the flow may be down-flow, up-flow, the method used for management of solid maybe surface it may be only captured on the surface, it may be some possibility of internal storage may be given. So, these are the different ways in which the filter mediums can be classified.

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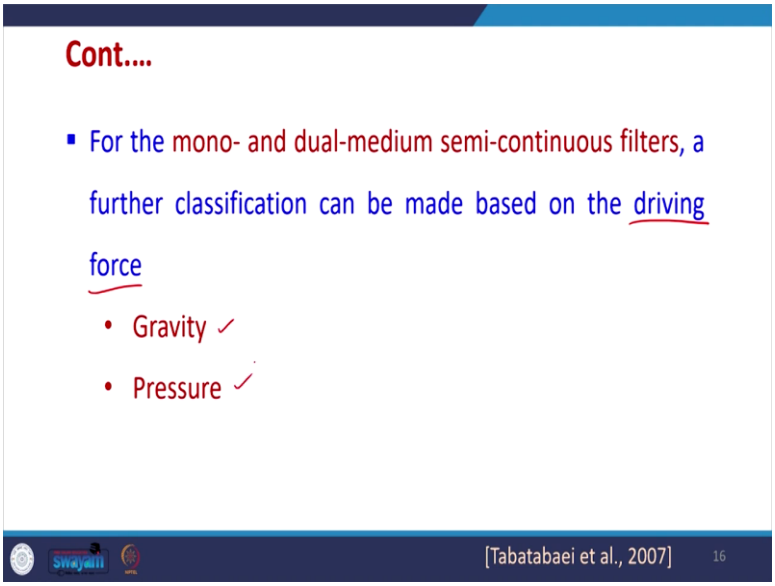

Also for the mono and dual medium continuous, semi-continuous filters, a further classification may be with respect to the driving force. So, it may be possible the flow is via gravity and or some pressure has been applied. So, both possibilities are there. So, if via

gravity certainly the filtration rate will decrease with time as the filter cake gets deposited on the filter medium, so this is there.

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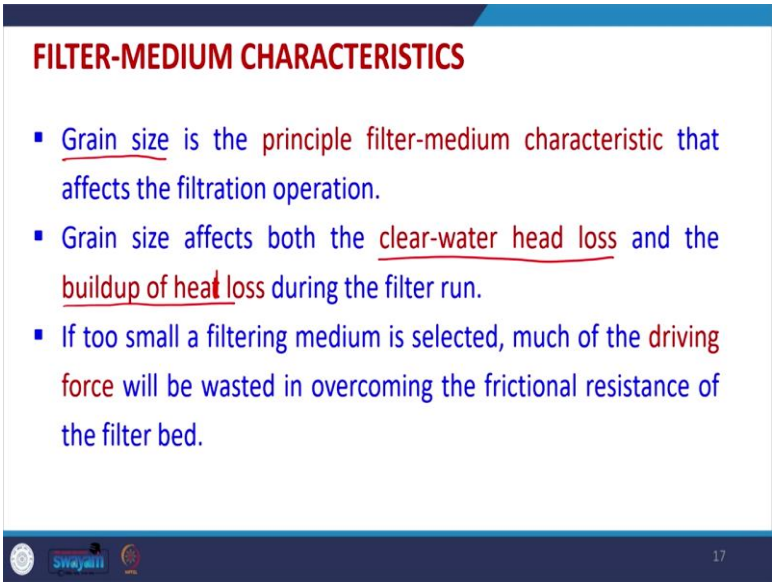

Now, filter medium characteristics are very important and one of the important characteristics which is required for filter medium is the grain size. So, this is the most important characteristic that affects the filter operation. So, because the porosity of the bed will also be dependent upon that and porosity and what is the pore size. So, and anything below that pore will certainly, anything about that pore will certainly be filtered by the filter medium.

But with addition of lot of cake or deposition of the cake, other smaller-sized particles will also be filtered. Now, grain size affects both the clear-water head loss and the buildup of heat loss during the filter run, so this is there, this is head loss. If too small a filter medium is selected, so, much of the driving force will be wasted in overcoming the frictional resistance of the filter bed.

So, we have to see with respect to head loss that we should not select very very small size filter medium, so, that the head loss is very high. So, we have to take care of the head loss also that is very important. If the size of the medium is too large also, then the pores will become very big, so, particles will directly pass through the bed.

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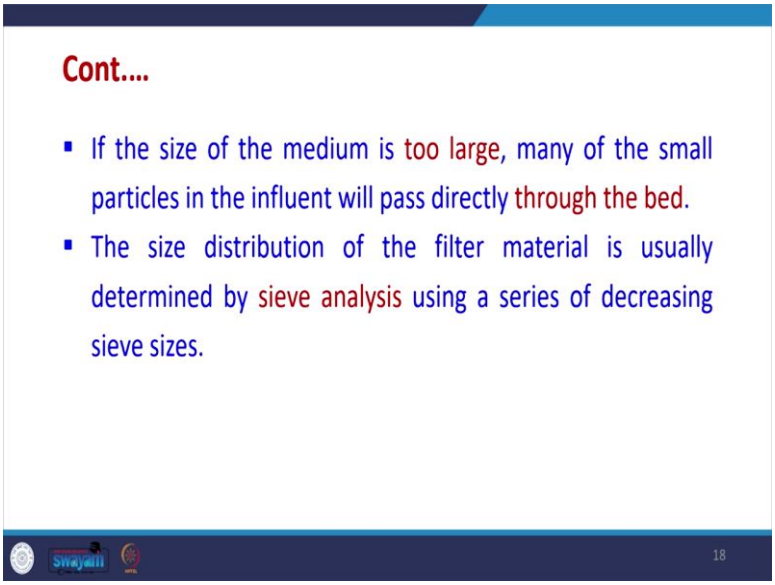

So, there is a situation that we have to properly select the size of the medium neither we can go for too small, where the head loss will become very high or too big, where the particles are not filtered at all, this is the possibility. The size distribution of filter medium is usually determined by sieve analysis or a number of other methods can also be used, this is the possibility.

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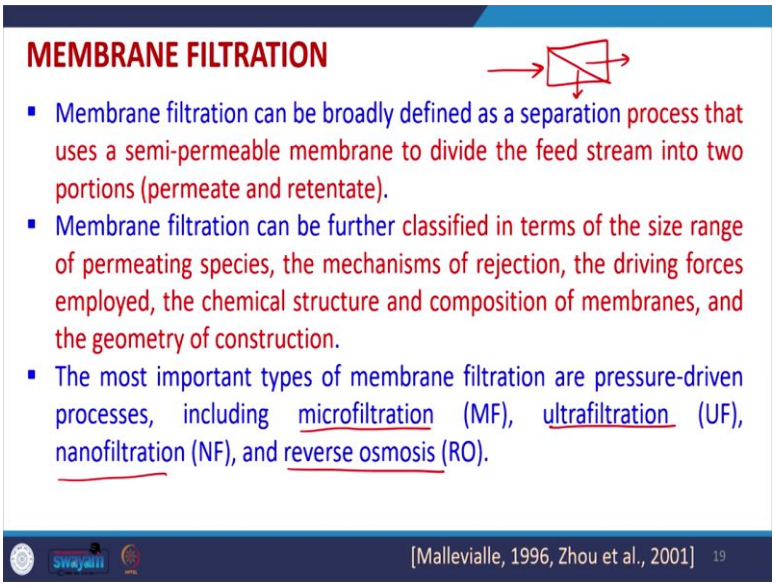

Now, there is a second type of filtration which is, which we will be discussing only a little bit, it is called as Membrane filtration. So, it can be broadly defined as a separation process in which a semi-permeable membrane is used to divide the feed stream into two portions, and which is called as permeate and retentate. So, a membrane filter can, we have two streams

which are divided because of these membranes which will be there, so, it is possible to have such type of unit.

So, like suppose a membrane is kept here and water is coming. So, water, clear water will be going out from here and another stream which will be having more amount of concentration of solids will be coming out from here. So, this is the filtration which is happening. Now, membrane filtration can further be classified in terms of size range of the permeating species, the mechanism of rejection, how the particles are being rejected. The driving force which is employed for forcing the particles or clear water to grow across, the composition of the membranes and the geometry of the construction.

So, depending upon the size, there are different possibilities. So, membrane filtration units are generally pressure driven and they may be classified as Microfiltration, Ultrafiltration, Nanofiltration and reverse osmosis and the first three are based upon the size of the particle they can filter, whether it is in micrometer range, ultra filtration more or up to nanometer range also, this is possible. This is how the membrane filtration units can be classified.

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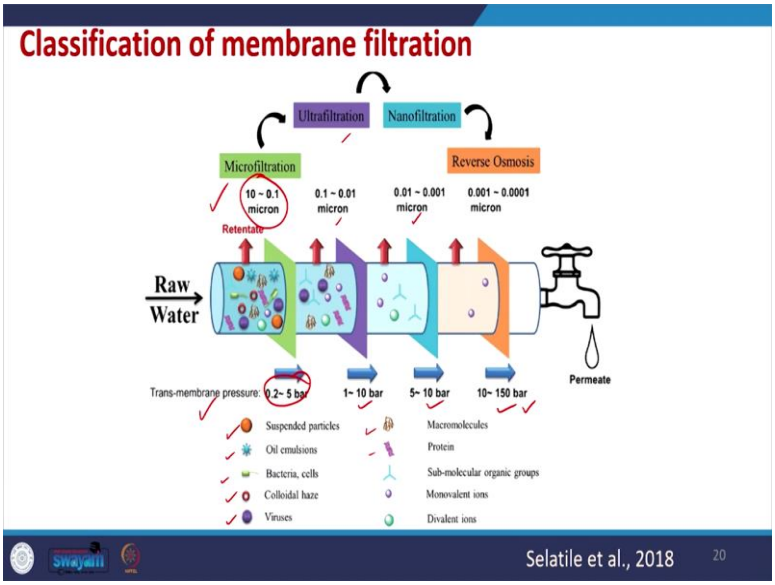

So, raw water is going through a number of sections and in these sections we can see micro filtration which will actually filter the particles in this range 10 to 0.1 micron size then from 0.1 to 0.01 micron size Ultrafiltration then from 0.01 to 0.001 micron size Nanofiltration and then we have RO also, and along with the same we can see the pressure amount of trans-membrane pressure which is being used is going on increasing we can see here.

So, we have the consumption of electricity for having this much pressure drop and certainly but we can filter more amount of material. And here in this picture, we can very easily see which type of materials can be filtered by all these methods. So, we can see the suspended particles oil emulsions, bacteria cells, colloidal haze, virus, macromolecules, proteins, so, we can see RO can virtually filter out everything.

So, there is a limitation with respect to size of each of these membrane filtration units and they can be used differently in the water or wastewater treatment plant. We will study these things in detail later on. So, now mechanisms which are involved in the filtration unit, they may be a different mechanisms which may be there and they have been divided in the table which has given further.

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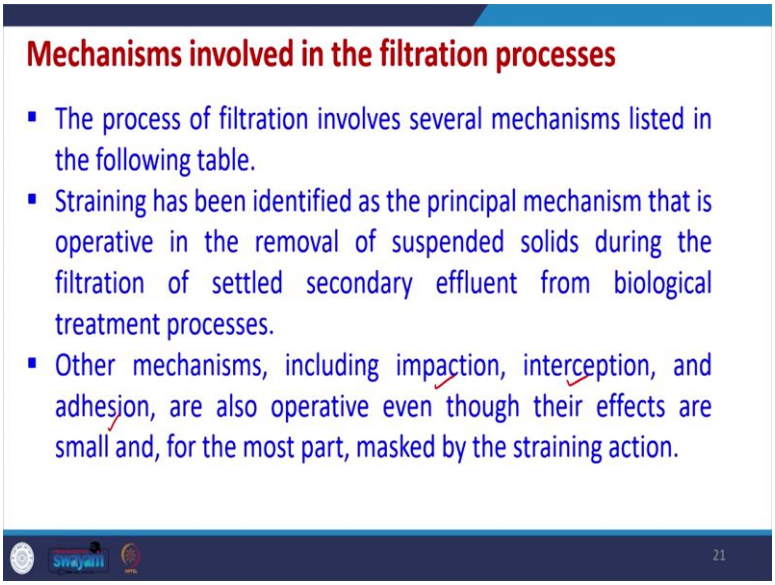

Now, these mechanisms may include single mechanism or a combination of mechanism, so, they may include, simple filtration mechanism in addition to that, they may have, impaction, interception, adhesion. So, all these are possibilities which are there during the filtration all these mechanisms may also be occurring. So, let us try to understand this what are the different mechanisms.

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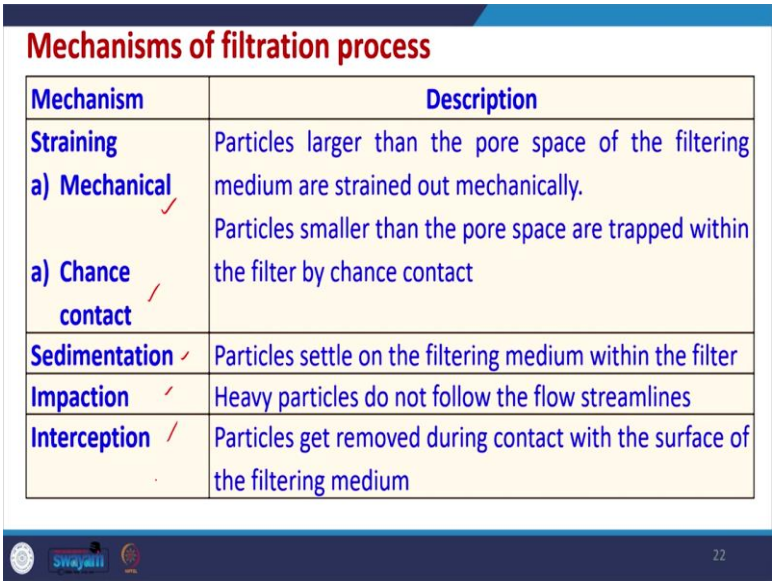

So, straining is the most important mechanism in any filtration unit. So, we can have mechanical straining or chance contact. So, particles larger than the pore size of the filtering medium are strained out mechanically. Particles smaller than the pore size can also get trapped within the filter by chance contact also.

So, we can remove some of the smaller size particles also, then, sedimentation, impaction and interception. Sedimentation like particles settle on the filter media within the filter, in the impaction heavy particles do not follow the flow streamlines and they impact the bed or etc and they are getting removed.

Similarly, interception particles which get removed during contact with the surface of the filtering media. So, that is interception, which will be there. So, all these possible three mechanisms are there.

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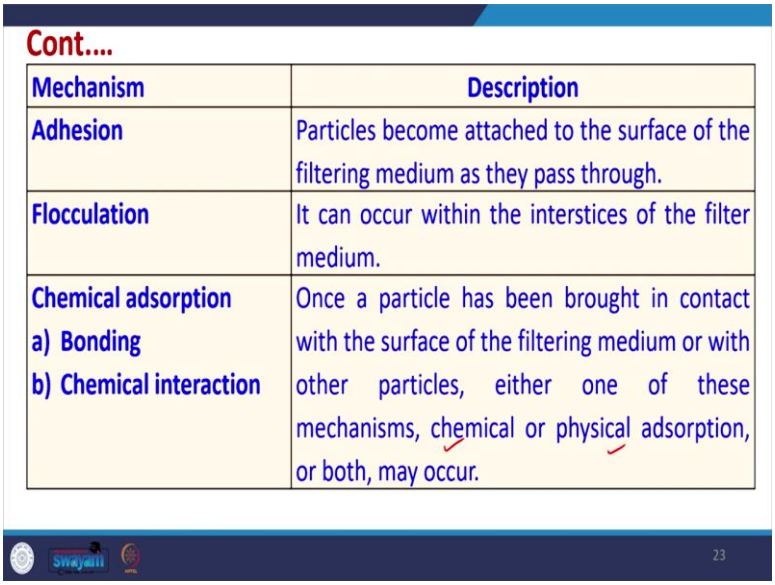

Similarly, adhesion is also possible. In the adhesion particles become attached to the surface of the filtering medium as they pass through. So, they get adhere there. Flocculation, similar to flocculation that we studied earlier may occur inside this filter media also and they form bigger sized flocs, because the flocs are coming together close by, and because of that flocculation is occurring and then they are filtered out.

Then similarly, chemical adsorption may be happening. So, once a particle has been brought in contact with the surface of the filter medium, there the adsorption may occur and that adsorption may be because of the, it may be chemical or physical absorption or both. So, it is possible that only Van der Waals force of attraction is being playing some role or a chemical bonding may also occur. So, it may depend upon that. So, both the possibilities are there. So, we will study adsorption in detail and during that this chemical and physical adsorption will study in more.

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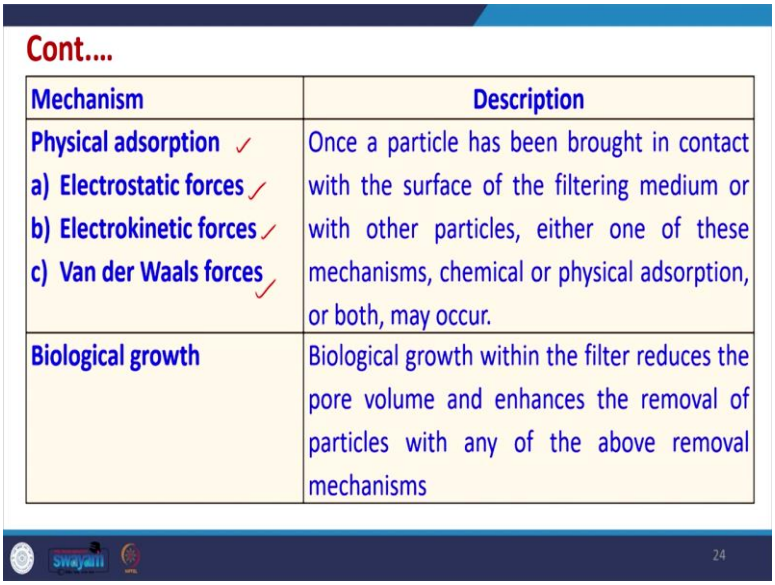

And so, within that adsorption, there are physical adsorption where electrostatic forces of attraction, electro kinetic, Van der Waals forces of attraction any of these possibilities are there, so, this is possibility. Then biological growth may also happen within the filter medium during its movement and that will reduce the pore volume and enhance the removal of particles during when the suspended matter is going through the bed.

So, this biological growth on the filter media is also a possibility and that will also remove a lot of suspended matter from the water itself and that will be filtered out. So, all these possibilities are there. And during filtration we have studied all these things in detail. There are lots and lots of possibilities of design possibility within the filtration medium, there are a few key points that have to be taken in from the filtration thing.

One thing is that there is a theory which is, which has been developed based upon the flow through porous packed bed and that theory can further be extended to get the filtration equation, and along with the theory and the equation and the filtration equation we can design any filtration bed. Now, within the filtration bed there are other possibilities. So, head loss is very important criteria. Flow through the bed, what is the velocity or the how much amount of filtrate we are getting per unit time, that is very important parameter.

So, head loss and filtration rate, those are the parameters that we want to, we want them to be in certain range and for doing this we can manipulate a number of variables and those variables could be what is the type of filter medium? What is the size range of the filter medium? What is the flow rate at which we are operating the filter bed? And what is the

pressure drop in which we are operating the filter bed? How many filter beds are there and whether they are totally continuous or semi-continuous? If they are in semi-continuous what will be the backwashing time, etc.?

So, depending upon that we can have a parallel sets of filter bed etc. So, all these are different possibilities. Within the suppose we have to select the filter medium, it is possible to directly go for membrane filtration that we will study in detail later on, but membrane filtration are generally costlier because they involve a lot of they are pressured even forces, so, we have to apply that much pressure.

Second we can go for traditional or conventional sand filters or anthracite filters also, within that also there are a combination of different types of filter beds we can design, whether it is slow sand filtration, high rate filtration, etc, so, various possibilities are there. We have studied some of the basics of the filtration in these few lectures. And if you wish you can go on and study, go on and study these differences for further understanding of the filter.

Now onwards from the next lecture onwards, we will go for absorption section, and we will study adsorption in detail. And in adsorption, during adsorption, there is a possibility of some filtration happening also, so this is there. But adsorption we will be studying in detail with respect to water or wastewater treatment in the next few lectures. So, thank you very much. I will continue later.