Water Quality Management Practices

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Week-10

Lecture - 55

Other Tertiaty treatment systems

Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Dhar Bhowmick. I am from the Department of Agriculture and Food Engineering of Indian Institute of Technology, Kharagpur. In this module we are discussing, continuing on discussion about different types of emerging biological processes for nutrient removal and also different type of tertiary treatment processes. Here in today's lecture we will majorly be focusing on different types of other tertiary treatment units which are quite advanced in nature and some of them are already considered as a cutting edge technology and has a quite a good future in coming decade. So what are those to start with? The pressure filters, the adsorption techniques, different type of ion exchange membrane or resin preparations, electrodialysis, solar steel and the membrane filtration.

To start with we all know that the tertiary treatment unit it actually what it does it normally fine tune the wastewater characteristics so that it is it actually the moment it will come out of the system the effluent will have will abide by the rules and regulations of the standards set by the regulatory bodies like in Indian context we have the central pollution control board. So it normally does the removal of the removal job for the inorganic pollutants from the secondary treated wastewater like the heavy metals, reserves, etc. It also used for enhanced removal of organic pollutants from the secondary treated wastewater so that the treated wastewater can meet the reuse norms. It used for removal of suspended solids and turbidity from the for effective disinfection of secondary treated wastewater.

So one of those tertiary treatment units which we will be discussing today is called the pressure filter. In the pressure filters what is happening? We are we are having a filtration media. This filtration media is kept on a certain stratum and in a inside a reservoir or like in a filter unit. So the wastewater is pressurized to pass through those through those porous media so that it will get rid of its suspended solid portions during while passing through this porous media this filter media. So in general we have this depth filtration which involves the accumulation of solid in the filter depth with particle size lower than the pore size of the filter bed and it also removes the suspended solid from the secondary treatment effluent which is coming from the just earlier treatment units and here focus is majorly on effective disinfection in the downstream regions and also facilitate the reuse of the treated water.

Straining is the one of the primary mechanisms. Straining is like you know like we use it for preparation of tea also we get rid of the tea leaves using the strainer. So this strainers are used which is a primary mechanism of removing the finer suspended solid in this filtration process and in case most of the pressure filters it uses the top layer of sand or coal and underlying the coarser matters which are preferred over gravity filters in the wastewater treatment plants now a days. It majorly operates in a closed vessel because you are using some and suction pressure into it right. So because of that it has to be a closed vessel with a well stuck design.

In this pressure sand filter it can handle higher terminal head loss than the gravity filters because of your backwash cycles that is involved with it. So you can see this figure that is how it looks like the sectional view of a vertical pressure filters and then the right side how it is like you know involves a closed chamber how it look like. So it is there in IIT Kharagpur itself it is installed in IIT KGP in Kharagpur itself in India so you see this is how it looks like. So majorly we have the top distributor for uniform effluent distribution as you can see from the figure and then we have a under drainage systems for collecting the filtered effluent. The major head loss is of course like you know during the operation due to the accumulation of suspended solid with time and it leads to the reduced treated effluent flow rate.

In order to get rid of that problem we normally do the backwashing. So backwashing with water and sometimes even we use the air scouring also like we supply the air in high pressure so that what happens so it use it cleans the filter media very precisely and then however there is one problem one major drawback with the pressure filter with the conventional treatment or conventional filter systems gravity filters is the backwashing process is not observable because you see this structure this in the installation that is there in IIT Kharagpur it is a closed chamber and it is very just not possible for you to observe the how much backwashing is done how successful your event is the backwashing event is. However, nowadays we have started having some open tank or some arrangements that the tank will have you can open the tank during the backwashing process or you there are installations where there is like window like structure with the hardened glass so that you can actually check the what about the reactions that is going on inside and I mean like you can actually get an idea about the amount of backwashing that has been done. In general we provide a free board of around 50 percent minimum of

50 percent of the media depth so that when the backwashing will be done there will be enough amount of space available for the expansion of the sand or the expansion of the media that is that is that you are using inside the this pressure filters and pressure filters. So let us do one design to make it easier for us to understand the concept wise.

So here if you suppose are asked to design a pressure sand filter for treatment of secondary treated waste water flow with a 100 meter cube per 100 cubic meter per day of capacity in a flow rate to be operated under a filtration rate of 15 meter cube per square meter per hour. So the information that is known to us the flow of waste water that is 100 meter cube 100 cubic meter per day or 4.167 cubic meter per hour if you divided by 24. Now what is the surface area that it requires? We know the filtration rate right. So if you simply divide the waste water flow divided by the filtration rate you will get the surface area which is 4.167 divided by 15 that is 0.278 square meter.

$$\frac{4.167\frac{m^3}{h}}{15\frac{m^3}{m^2h}} = 0.278m^2 = \frac{\pi}{4}d^2$$

So which is equal to the pi by 4 D square from like where we will we can easily get an idea about the area and this area from there you can easily calculate the value of D or the diameter of the pressure sand filter which is coming as 0.6. So pi by 4 D square equal to 0.

278 so D is equal to 0.6 meter. Now suppose you are providing a depth of sand of say 1 meter depth of gravel or under drainage of 0.5 meter and 1 meter clearance above the sand bed. So total overall height would be say like 2.5 meter. So height of the sand filter is 2.5 meter what is the surface what is the surface area or diameter of the sand filter is 0.6 meter and suppose we have a considering a backwashing rate of 25 meter cube per meter square meter per hour for 10 minute so what is the quantity of filtered water that is required? 25 meter cube per meter square we already know that the meter per hour basis if we divided by 60 we will get it in per minute basis 25 by 60 meter cube per square meter per minute multiplied by 10 minutes so that means you need to backwash it for 10 minutes. So that means what is the amount of water that it requires? So multiplied by 10 minutes you will get the total amount of time that it requires and multiplied by the area. So what is the area here? 0.278 from there you will be able to get an idea about the amount of water that it requires so it is almost 1160 liter. So 1.16 meter cube of water is required for backwashing purposes as easy as that. So with this concept we normally design the pressure filters. Next is the adsorption.

Adsorption it can be defined as a process of molecular transform from one phase to the another phase somewhere like liquid to solid or gaseous to solid or sometimes we just literally like you know like you know place the particle on top of another one. So we will discuss about it so which one is called what? So the moment the contaminant which is available in the solutions which are concentrated on a surface of a solid it is called as adsorbent. And the dissolved contaminant that is intended to be removed from the waste water is called as absorbate or the sorbate. So absorbate is the contaminant itself and the surface on top of which the solid surface on top of which you are actually absorbing it is called the adsorbent. Suppose you are using activated carbon as an adsorbent to remove the ammonia from the system.

So here the adsorbent is the activated carbon and ammonia is the adsorbate. So this is how it the nomenclature is done. So majorly most of the refractory compounds and removing the odor and like refractory compounds means as you know they are majorly of hardly biodegradable in nature like the chlorinated compound, hydrocarbons, heavy metals, pesticides, fungicides, surfactants, any other genobiotic compounds etc. So in order to remove those genobiotic compound or those biorefractory compounds you need to install this kind of adsorbent and all you need to apply this adsorption phenomena. There are physical adsorption phenomena driven by the weak van der Waals force allows the adsorbent to move freely on the adsorbent surface and it is reversible as well.

There are chemical adsorption or the chemisorption where it involves the chemical bonding between them resulting in a fixed monolayer of adsorbent. Adsorption require a very high temperature for the desorption to take place because like you know in case of physical adsorption it is easier to do the desorption again so that you can have a concentrated effluent somewhere else you can collect it somewhere else. However in case of chemical adsorption it is very hard to do this desorption techniques because it is like literally they have a chemical bonding with each other. Next is ion exchange which relies on the electrical attraction of with a higher surface charge ions being more attracted to the active sites on the adsorbents. So, this is how the process called the ion exchange fundamentals of adsorbents.

So, activated carbon most widely like quite widely used adsorbent in water and wastewater treatment it is classified into granular activated carbon or GAC most popularly used which is having a particle size of more than 0.1 millimeter and then we have the powdered one. The powdered one having in general the particle density particle size of less than 0.074 millimeter and with powdered activated carbon considered as superior due to its increased surface area. Whereas powdered while powdered activated carbon requires the additional separation process such as the coagulation or settling or filtration granular one is more practical to use for field scale application because it avoids the excessive treatment cost for the desorption.

Exalted alumina which is synthesized from the aluminum trihydrate it undergoes a transformation based on the heating temperature and is effective for removing the fluorides from the wastewater. There are synthetic polymers which can be used as an adsorbent which offers the benefits like chemical stability and high adsorption capacity which can be used as adsorbent despite their high synthesis cost in wastewater treatment applications because of its like point uses like you know where you are collecting a very specific type of pollutants which are very hard to get rid of from the wastewater treatment lines and all. So, what are the factors in which the adsorption phenomena is depending upon? First one is the surface area of the adsorbent the higher the surface area obviously the higher the active sites available for the adsorbate to act on it. pH of the solutions depending upon the pH the state of the adsorbate can change and even the adsorbent of state of can change and based on that their chemical or the physical reactions will like the it will change. The characteristics of the adsorbent adsorbate obviously because if it is quite easy like you know if had some physical affinity or the chemical affinity towards the adsorbent it will be much easier for us to remove those adsorbate from the structure from the system.

And the size of the adsorbent material molecules are also important because if the size is quite higher it is very difficult for us to like you know like you know to collect it using the adsorbent different kind of adsorbents and all. If we compare the properties of granular activated carbon and the powdered activated carbon it will give us an idea about like which one is beneficial for which particular type of purposes. Suppose in case of granular ones it has a very low surface area of around 700 to 1300 square meter per gram of we call it BET surface area or the specific surface area and we have a for powdered activated carbon it is almost up to it can be as high as 1800 meter square per meter cube of per gram of the powdered sample. Then we have a particle diameter it is normally greater than 0.1 as I have already discussed and in case of powdered it is less than 0.074. Burnt density it is around 400 to 500 kg per meter cube whereas in powdered it is only 362 it is around 362 to 740 so the range is quite higher. In case of ash content it is like less than 8 percentage in case of powder it is even further less, less than 6 percentage. Mode of operation of in water and wastewater treatment in general we go for the column or the continuous mode of operation if we can do it in case of granular activated carbon. However in case of like in a powdered activated carbon it is very difficult to for us to go ahead with the operation to do go ahead with the continuous process. So in that case we need to go ahead with the batch process.

In chemical application it is normally it is in the form of continuous filter we use it quite often in tertiary treatment as a tertiary treatment process. This granular activated carbon however in case of powdered activated carbon it is mostly added into the contact basin following the secondary treatment systems and all. In case of pollutant removal efficiency less than much less than the powdered activated carbon in case of granular but because powdered one has a much higher specific surface area to start with and it also has a phenomena by which you can like you know the ion exchange phenomena by which also it can effectively remove the adsorbent from the adsorbate from the system and all. So there are different modes of operations there are like active portions of the adsorbent if you see the exhausted portion of the adsorbent and the mass transfer zone is determined in this figure and also if you see this cumulative volume of water treated to the normalized effluent concentration of the adsorbent adsorbate. So you will see this graph actually clearly showcases the it is called the breakthrough curve which showcases the activated carbon column with the movement of mass transfer zone with cumulative volume of polluted water that is being treated over time.

So how this adsorption is happening? If you see this figure this figure gives you a overall idea it is like you know perfect example of how it looks like how it should look like how it should perform. First one is called the bulk transport. In this bulk transport what is happening the pollutant in the bulk liquid it comes in contact with the it comes in the near vicinity of the solid activated carbon metal due to the advection and the diffusion phenomena. Then film transport on top of it the transportation of pollutant via diffusion towards the adsorbent it is called the film transport. Then there is a pore transport when once it enters the pores of this surfaces and all so it is called the pore transport and then there is a adsorption the final attachment of the pollutant on the surface of the adsorbent is called the adsorption.

So in cases case by case basis it is not necessary that it will follow all these pore transport phenomena it can be as little as only two only bulk transport and film transport and that is there it remains there only. In some cases it can go with the all the pore transportation process so it varies with time to time with the point of applications and all. The feasibility of this any specific adsorbent like you know can be accessed by the performing lab scale experiment and plotting a graph of QE or CE this like what you can see in the right side the figure 3 where the mass of adsorbent adsorbed per unit mass of adsorbent versus CE which is the concentration of adsorbent in the solution. So if you see this red line it is this red line showcases the linear values. The linear values means like the linear value means the adsorption is linear quite like in there I mean like equal the amount of mass of adsorbent is actually equally responsible for the mass of adsorbent to adsorbed on the surface of this adsorbent.

Whereas in case of blue line it showcases the favorable adsorption that means the adsorption phenomena is actually like the higher the concentration of the adsorbent in the solution it actually increases the concentration increases the adsorbent phenomena. However adsorption phenomena however in the green line it showcases rather the negative ones which represents the unfavorable adsorption that means the increment in the concentration of adsorbent it actually decreases the amount of mass of decreases the amount of adsorption that is actually being taken place in the system. So that means it showcases the inefficacy of the of your adsorbent to utilize the excess amount of adsorbent adsorbate that is available in the system. So the blue line is actually showcases the favorable conditions red line is the most optimized one the linear representations and green one showcases the unfavorable ones. Another treatment another technology which is also coming to the scenario for long that is called the ion exchange.

In ion exchange process what is happening we are literally displacing the target ion from the solution with some other ion on an insoluble exchange material. So commonly we use it for removing the hardness causing ions like calcium, magnesium etcetera and also for treatment of nitrate, nitrite also from the waste water it is also being used nowadays. What are the typical exchange materials? Natural like geolite used mainly for hardness and ammonium ion removal, some synthetic ion exchange materials are also there like copolymerization of styrene and the divinylbenzene. It forms the resins with the defined in the very uniform exchange capacities. So that also can be done in laboratory the synthetic exchange materials and natural materials like geolites are also available which is used for hardness and ammonium removal for long period of time in treatment this waste water treatment sector.

What are the factors on which the ion exchange performance is depending on? First is the exchange capacity, it measures the exchangeable ion expressed as equivalent of equivalent of equivalent per liter or equivalent per kg. The higher capacity it reduces the need for frequent regeneration cycle which is good for us right and particle size they influence the rate of ion exchange. Stability we have to design the systems which can which is associated with the long term use of the ion exchange materials which cannot have the ion exchange material which can be easily chemically rusted or chemically leached into the medium. So we have to design the system in such a way that the chemicals that will use for designing those resins designing those ion exchange materials has to have a capacity to chemically withstand for longer period of time so that it can increase the stability of the whole process. What are those synthetic? We already discussed the natural one is geolite.

So what is the advantage and disadvantages of synthetic ion exchange resins? It can be cationic or anionic based like you know it can exchange the cations and ions based on your demand point of demand. Sodium cation it exchanges commonly used in hardness removal regenerated with sodium chloride molecules then there are other cationic exchanges used in the various cations regenerated from the mineral acids like the sulfuric acids as well. What is the if you compare between the synthetic and the natural materials? The synthetic materials like the resins is generally have the higher exchange capacities like 2 to 10 equivalent per kg whereas compared to the natural materials like the geolite it has only 0.05 to 0.1 equivalent per kg so it is quite less and also synthetic materials it offers defined and uniform exchange capacity which is also comes as handy in this case.

Applications majorly the synthetic ion exchange resins it's widely used due to their superior performance and the versatility in water and waste water treatment processes and there are exchange ion exchange membrane materials which can you can even commercially also available for treating the waste water constituents. So what are the applications of this ion exchange process? First to remove the heavy metals like the lead, mercury, cadmium, nickel, vanadium, chromium and coppers which have been successfully removed using the ion exchange. There are removal of nitrogen like geolite which is quite natural material which is used for ammonia removal and also sulfur dions are also used in waste water having the higher affinity towards the resins than nitrite that's why it can lead to the nitrate dumping if not managed but however the synthetic nitrate selective resins can prevent this kind of phenomena. What are the for removal of different other dissolved solids like the cationic or anionic dissolved solids we use different cationic or anionic exchange resins which are employed in series for removing of dissolved solids from the waste water. Cationic exchange resins exchange the cationic ions using the with hydrogen and the effluent is then passed through the anionic exchange resins where anions are replaced by hydroxide hydroxide ions and all.

So this way you can get rid of the other dissolved solids from the systems there are cationic anionic resins which are further classified as the strong acid some all the cationic anionic resins which are further classified as strong acid cationic exchanger, weak acid cationic exchanger, strong base cationic anionic exchanger and weak base anionic exchangers. So based on the target molecules based on the target like in our pollutant we can actually choose any one of this how about the combination of this. What are the major limitations of this ion exchange process to start with the presence of turbidity and there are you know what you are doing you are pretty much transferring your problem from one place to another. So you will have a concentrated pollutant like you know concentrate in one side so that concentrate has to be treated properly in order to get rid of the pollutant from the from the actual like you know to treat it properly or to use it for different purposes and all. We have a formation of different type of precipitates it is possible the operational cost is very high because this ion exchange resins comes with it is quite it is quite costly and you have to prepare different kind of membranes also out of it which design exchange membranes also out of it which also comes as not as easy it is easy to make.

Then the microbial contamination is also something of that is possible in this kind of ion exchange membrane that is also causing a nuisance to the system. Another type of systems which we call it electro dialysis and this electro dialysis is a tertiary treatment unit which designs for the removal of dissolved solid from the designated wastewater it is a separation process in which the potential difference generated between two adjacent electrodes leading to the separation of ions from the solutions. So when the wastewater is installed introduced so what happen the wastewater it actually because it has a two permeable membranes on our side to it say cation exchange membrane, anion exchange membrane, cation exchange membrane, anion exchange membrane like this continuously continuous set of membranes and then both the sides we have two electrodes cathode and anode. Cathode and anode we are supplying with the some external voltage external potential difference we are applying some external potential difference because of this external potential difference all the ions will start migrating. So the wastewater when you introduce it the wastewater whatever the ions present there the cations and the anions it will go toward the respective like you know zones.

So that is why it is this process is called electro dialysis process and the cations normally cation permeable membranes are normally used and which are normally negatively charged and which allows only the passage of cations like the sodium, potassium, magnesium etcetera and it repels the anion to pass through it. Same way we can have the anion exchange membranes which are positively charged and which allows only the passage of the anions through it like the calcium sorry the chlorine, fluorine, sulphate etcetera through it and repels the passage of the cations. So this way we can have a concentrated flow and we have a treated effluent at the end. So this treated effluent which will be like you know void of any of this ions and that can be utilized for further purposes.

Then there are technology called solar steel. Solar steel it is like a low cost technique for the removal of dissolved solid from the wastewater that utilizes the solar energy for the evaporation of wastewater and which is condensed in the attached unit leaving behind only the dissolved solid. So it is more like you know we earlier also we use this kind of systems in our school level also if you remember we use this kind of systems like in a kind of say like rotor evaporometer that we normally use in the lab. So there what we are doing we literally evaporometer what we are doing we will try to evaporate the liquid and we are collecting that liquid from another side from the other side of it we try to condense it and we collect it in a condenser and which will left out it we only left with the salt particles from the system. So it is like a natural evaporation fundamentals we are converting we are using it in a solar steel. So main drawback of this system is like the requirement of a high surface area when you are dealing with a huge amount of water and however it does not require any external energy and it is also free from any moving part because of that the operation maintenance cost is very less and now it is becoming quite popular in different parts of the world.

And moreover the yield of the treated effluent is very less compared to the other desalination techniques so that is one major issue with that. So that is why this steel does this we are still not using it in a like you know in a broader scale in all over the world but however this yield is because it depends on the solar radiation surrounding temperature wind velocity the operating conditions like the dissolved salt concentration water depth etcetera and etcetera. So because of all these factors and we still don't use it more in widespread manner in all over the world but still the research is going on and solar steel will definitely find its way to the wastewater treatment plant very soon. Then there comes the membrane filtration, membrane which is used for water and wastewater treatment systems it is like a material which allows the certain component to pass through it and selectively from its source by acting as a physical barrier to prevent the contaminant of the foreign particle to cross it. So because of its this perm selective or the selective quality in nature it constitutes the passing of the constituents which passing through it is called the permeate and which is rejected it is called the retentate.

If you see this figure 8 the retentate is passed like you know it is it does not allow the membrane does not allow the retentate to pass through it so it is called the retentate which is like more concentrated liquid and the permeate is like a more like a dilute liquid because it is already filtered all the foreign particles or solid particles when it was passing through it. Based on the pore sizes there are different types of membrane materials like we have the micro filtration it has a range of say 0.1 to 1 micron it normally we normally use it for getting rid of the suspended solid red blood cells, clostridium or say like cryptosporin or the other bacteria and all. There are ultra filtration membranes which are used for getting rid of the albumin proteins colloids etcetera. We have the nano filtration membranes which we having a range of 0.01 to 0.001 micron of pore size which can effectively get like we can reduce the presence of endotoxins, myrogens, viruses, herbicides and pesticides from the waste water. And the most effective one is the reverse osmosis process or RO membrane. In reverse osmosis process practically it is non-porous because of the so tiny the size of the pore size are in angstrom size and because of that this tiny select 10 to 100 angstrom in nature and because of that it can be considered as almost non-porous in nature. So, this non-porous membrane thin film composite membranes and all we normally use it in reverse osmosis process it can get rid of the complete removal of all foreign particles like the even the dissolved solid and the organic monomers as well from the systems. So, it is not really letting the fresh water isotopes like you know only H_2O to pass through it.

There are studies which we are doing we have done it along with the help of our Israeli counterparts. So, where we have actually proved that this kind of membranes can even does not allow the heavy isotopes to pass through it as well like given the H_2 instead of H_2O or D_2O it will always prefer the H_2O to pass through it because of its the size of the pore and the other diffusion parameters and all. So, it will not even let the higher isotopes like you know like in the D_2O, H_2O 17, H_2O 18. So, they are not allowing this heavy isotopes also to pass through it. So, this is the technology that is being quite wide spread right now people are working on it researchers are working on it and they are using it in different verticals.

Normally most of the polymer membrane materials are made up of polymer this polyethylsulfone or the polyvinylenedylenedylene or the polyvinylenedylforide or PVDF we have the polyethylene or PE we have a polypropylene or the polyamides. There are ceramic membranes which are also nowadays people are working on which normally made up of clayware with the different kind of ion exchange materials we add like cation exchanges like monmolylonite, kaolite etcetera we added with the clayware. So, it will be acting as a better ion exchange having a better cation exchange capacity or ion exchange capacity. Based on the configurations it can be called flat and frame type or the flat sheet type. It can be hollow fiber as you can see this figure 10A it is a hollow fiber membrane how it will look like.

So, from one side you will feed the suppose from the inside and the permeate will come out of the from its wall. So, this is called the hollow fiber membrane. Then we have a spiral membrane, we have a tubular membrane also as you can see like you know in the rice tress. So, there are tubular membranes also which are quite famously used in wastewater treatment technologies. So, majorly the flat sheet membranes it is pressure driven and it is used in mite filtration as well as ultra filtration units and it is used in electro dialysis, it is used in wastewater treatment.

The hollow fiber ones majorly it contain in a pressure vessel it is a pressure driven and where it is used for say like product recovery it is used for wastewater water treatment technology etcetera because in wastewater treatment it cannot be used because it is already like you know it has a pore size of quite like you know tiny tinny and it once it is clogged it is completely you have to discard it. It is very hard to backwash it. Immersed module with the pressure vessel that is also vacuum driven and that can be used for auto treatment. Tubular ones which is also pressure driven it can be used for product recovery as well as for the wastewater treatment as well. If you can see there are two types of technique in hollow fiber membrane outside in or inside out.

Inside out also you can feed the system and from the outside you can apply the pressure in the overall the cartridge you can apply the pressure to permeate the only the water will come out of this membrane or from the outside you can feed the system and from the inner side like a syringe pump like structure you can have I mean like you cannot syringe pump a suction pump only with the very tiny suction pressure you can apply. So the water will from outside the water will enter the fresh water will enter and it will get rid of the all the pollutant as a retentate. Based on the filtration mode it can be configured as cross flow filtration or the dead end filtration. First one is the cross flow filtration you see the feed is going parallel to the membrane surface and from another side the from here we are applying the pressure through this twist direction. So, you have the permeate you have the waste water or waste water or the sample your sample going like this and from here you are supplying the suction pressure.

So, it will cross this membrane and it will come into this other side of the membrane. So, this is called the permeate will come out of the other side of the membrane and finally you will get the retentate at the end of the filtration unit. So, this is called the cross flow and then there comes the dead end ones where it literally suck through the membrane surfaces. So, it will directly come it will directly come perpendicular to the membrane surface and the feed and then it will passes through it. So, it is called the then in case of perpendicular dead end ones the keck layer formation.

Keck layer formation is nothing, but the amount of how to say the clock or the port that is the how fast it will with the ease it will form the keck layer and which will actually provide additional resistance for the same amount of flow rate to maintain and it will increase the amount of pressure that needs to be applied which we call it transmembrane pressure. In case of that is the best thing about the cross flow filtration it reduces generate the enough shear stress for scouring of the surface. So, because of that the keck layer formation is less. Then there comes the surface filtration and the depth filtration. In case of surface filtration you see this membranes we normally provide this polymer membranes only the top part of it which is having the skin layer where normally the particles are retained and filtered and then the permeate will go through the support layer.

And in case of depth filtration we have like you know in different depth we have the water like you know we have like multimedia filters and sand filters and there. So, there with the different level the your pollutant or the foreign particles will get choked into the system and it will pass through only the fresh filtered out of it. So, perfect so we have discussed about the different adsorption techniques I hope also we have discussed about the different advanced pressure treatment units like technologies like ion exchange we discussed about the membrane filtration we discussed about the solar steel we discussed about the electro dialysis and I really hope that you have gone you have really understood this concept in a much like you know as a manner and you actually have a some basic understanding about all these technologies and due to the time limitations I cannot go through the individual design and the uses or other elaborated discussion on individual of this segment. But I hope like you will once the because your basic understanding is clear now you can just simply Google it and you can simply search for different materials and in YouTube I mean like in YouTube or in Google and you can go through it. So, it will give you some additional knowledge you can go through this references that is mentioned here this references will give you some more in depth knowledge about this subjects that I just discussed.

So, thank you so much for listening to it. So, we will meet in the next module in the coming week. Thank you so much.