Water Quality Management Practices
Dr. Gourav Dhar Bhowmick
Agricultural and Food Engineering Department
Indian Institute of Technology Kharagpur
Week – 08
Lecture – 37

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. So, with in continuation of our earlier reactor earlier discussion about the aerobic treatments wastewater treatment systems, today we will be discussing about three very important aerobic treatment systems. One is aerated lagoon, another one is fluidized bed reactor and the third one is biological active filter ok. These are the concept that we will be covering the aerated lagoons in wastewater treatment, the design of aerobic flow through type lagoons, fluidized bed reactor, different types of fluidized bed biofilm reactor, minimizing the fluidizing velocity and also we will understand about the biological active filter ok.

To start with the aerated lagoon we it is if you think about it is nothing, but it is aerobic suspended growth biological treatment system process where the treatment is happening through a flow through basis with or without the solid recycling. Oxygen is supplied as a from by the surface aerated systems maintaining the aerobic condition and the floating aerator or the diffused air unit are commonly accommodate for accommodate for the water level variation based on the water level variations. A facultative stabilization pond can follow the aerated lagoon integrating the aerobic and anaerobic zone and no final clarifier is needed in case of facultative lagoons like this. Mechanical aeration you can have the floating aerator or the diffused aerator for induced mixing and also keeping the biomass in suspension.

Depth range around 2.5 to 5 meter it determine based on the based on the aerator based on that only you have to choose the aerators depth of influence and partial or complete mixing of lagoon contents are possible using this mechanical aeration systems. Effluent characteristics effluent contains around one third to half of the incoming BOD as cell biomass and solid must be removed by settling before the discharge. This is how it looks like if you see the wastewater enters from one side and there is like surface aerator system is provided in this big lagoon which improve the aeration systems which better the oxygen supply and also better biological kinetics and smaller lagoon can also be used to finally, get a clean water. The major advantages is it includes the operational ease, heat dissipation is possible and the lower construction cost then the activated sludge process.

Disadvantages it involves a huge surface area large area is required and higher effluent suspended quality solid can be there and it has also the sensitivity towards the ambient temperature. Aerobic lagoons this lagoons operate at a high power level maintaining solid in suspension and providing the dissolved oxygen throughout the liquid volume. High f by m ratio and shorter mcrt is there like aerobic lagoons are characterized by a high food to microorganism ratio and low mean cell residence time. Limited organic solid stabilization the this this kind of systems is achieved the minimal organic solid stabilization, but convert the soluble organic matter into cellular organic biomass. Therefore, this organic this suspended solid will stills remain there and it may come out as a effluent.

So, that case that is one of the major issue with this kind of system. Operational lagoons this lagoons it aims to convert the soluble organic matter efficiently through aeration and control mixing method. There are two types of this systems first one is aerobic flow through with partial mixing and the aerobic lagoon with solid recycle. In case of aerobic flow through with the partial mixing what is happening the energy input is quite sufficient for the oxygen requirement and in, but insufficient for complete biomass suspension ok. So, in case of partial mixing what is happening HRT and SRT are typically the same the mixed liquor suspended solid concentration is also very low around 100 milligram per liter of suspended solid 300 milligram of suspended solid per liter and effluent requires the external sedimentation for the solid removal.

However, in case of aerobic lagoon with solid recycle what is happening it is similar to the extended type aeration type activated sludge process, but aeration occurs in the in an earthen basin and also longer HRT than the extended it is further longer than the extended aeration time ok. And higher air requirement is required to keep the whole biomass in suspension and analysis is done parallel to the extended aeration activated sludge process and then the secondary clarifier is installed to get rid of the solid particles from it. In general design of a aerobic flow through types lagoons similarly similarity to activated sludge process almost most of the design criteria are almost similar, but no solid recycle is happening unlike the activated sludge tank aerobic flow through lagoons do not involve the solid recycling. Hydrodynamic retention time also equals to the mean cell residence time since there is no solid recycling and the retention time majorly 3 to 6 days is erupted for the aerated lagoon which is quite high than the activated sludge process. In case of kinetic modeling it follows the pseudo first order kinetic.

So, it will definitely go through this equation ds minus ds by dt equal to ks where ds by dt is the rate of BOD removal k is the reaction rate constant and s is the substrate remaining at any time t. If we do the material mass balance the accumulation is the inflow minus outflow minus decrease due to the reaction. So, considering the completely mixed condition this v into ds is the accumulation equal to inflow is q into s 0 which is entering s 0 is the food that is entering over time dt and outflow is the amount of water amount of flow like you know outflow the outflow volume I mean like the flow rate multiplied by the your solid concentration. I mean like organic matter concentration or the s 0 or the BOD of your effluent multiplied by the time that time difference that is dt that is the outflow and minus the decrease due to the reaction that is v into k into s t into dt. So, this if you divide this equation 2 with v into dt what will happen in the first one in the left term will become v will cancel or it will become s ds by dt.

So, ds by dt equal to q into s 0 by v minus q by v into s t minus v into minus k into s t. So, now, in case of steady state condition this s ds t by dt will be 0 and also v by q also represent the hydraulic retention time you know that theta. So, you can simply replace this 2 into the in this equation and you can get the equation number 3 that s t by s 0 is equal to 1 by 1 plus k into theta. So, k value is s 0 by s 0 minus s t by s t into theta as easy as that ok. So, where the v is the volume of the aerated lagoon, q is the wastewater flow rate and s 0 and s t is the substrate concentration entering and leaving the lagoon ok.

So, equation 3 can be applied is applicable for aerated lagoon designed under the assumption of a completely mixed model. As no sludge recycling is practiced in this lagoon the mass balance for a microbial solid is at equilibrium is obtained easily obtained. The laboratory experiments involve reaching the steady state over an extended period of time and by increasing the flow rate in steps and allowing the steady state under each flow rate the value of k can be easily estimate you know estimated. The experiment should cover about 5 flow rates to monitor the influent and effluent BOD value and concentration of biological solid inside the solid in the influent and effluent water body. The plotting of s 0 minus s t you see in this equation if you see is k is equal to s 0 minus s t by s t into theta or s 0 minus s s t is equal to k s t theta right.

So, here if you make a plot this like you know y equal to m x. So, if you make a plot of s 0 by s t in y axis and s t theta in x axis. So, from the slope you will get the value of k isn't it k is equal to y by x here say y is the. So, k is the slope. So, from there if you plot an axis.

So, you will get the get the value of k also in this following equation. So, the value of k d and y also can be calculated. If you see here the by plotting this s 0 minus s t divided by x into theta in the y axis if you plot it and 1 minus theta c in the sorry in the y axis versus the y minus theta c on the x axis if you plot it. So, here also you see y equal to c into m x here if you consider it in this way the equation of straight line y equal to c into m x or y equal to m x plus c whereas, this y is equal to y is here the s 0 minus s t by x into theta and m x here the x is 1 by theta. So, m value you will get the slope will be 1 by y and where the y intercept will be there that intercept value that c value will give you the exact value of k d by y.

So, please remember only by plotting the s 0 minus s t by x theta in the y axis and in the x axis 1 by theta c you will get the value of y as well as the you can get the value of k d by y value and from there you can get the k d value as well you understand. So, with this graph you can easily get this values. So, I mean like if you further discuss about the biomass concentration in the aerobic lagoon which is quite low in the range of 50 to 300 milligram per liter because of that this performance of aerated lagoon is normally significantly affected by the temperature variations. The temperature variations it also follows the same equation the k t equal to k 20 into theta to the power t minus 20 whereas, this k 20 is any a moment of time is given the rate constant at temperature 20 degree Celsius. So, this k value typically range between 0.

8 to 2.1 per day and this theta value which is temperature coefficient having a value in the range of 1.06 to 1.1 for temperature less than 20 and for warmer climate like South Asia and it can be considered as 1.035 ok. So, for the temperature of this wastewater in this lagoon is majorly governed by the influent wastewater temperature and the heat loss due to convection radiation and evaporation right.

When it evaporate what happen it reduces the it takes some latent heat for this evaporation action and because of that the heat temperature of your water body goes down ok. Also this lagoon water will gain the heat due to the solar radiation ok. The temperature normally is given by T i by minus T w which is like influent wastewater temperature and the lagoon water temperature the difference you can easily calculate by F into A into T w minus T a by Q. What is this T w here again the lagoon water temperature and T a is the air temperature and F is the experimental factor normally it comes as a 0.49 meter per day and this A is the area of the lagoon and Q is the wastewater flow rate or influent flow rate inflow rate.

So, from there you can easily calculate the value of influent like in a lagoon temperature or you can easily calculate the influent wastewater temperature or any of the unknown parameter from this equation can be easily calculated ok. So, when we design a aerobic flow through type lagoon so, majorly our target is to provide adequate amount of oxygen which is essential for the biochemical oxidation. Total oxygen requirement for the lagoon can be easily calculated using the equation 4. The oxygen requirement in general 1.6 times 5 times 5 day BOD is needed for the required oxygen supply and this oxygen supply per day is equal to soluble BOD removed per day minus soluble the BOD ultimate of the solid leaving the system plus the nitrification oxygen demand.

So, this is the total oxygen demand of your system right. So, that you can easily calculate. Now, what is the aeration power requirement? Minimum 2.75 to 5 kilowatt hour kilowatt per 1000 meter cube of lagoon volume is standard as a thumb rule we take it. Typical requirement is 4 kilowatt per 1000 meter cube ok.

We have to ensure the proper aeration to prevent the facultative microorganism environment growth, environment development and facultative environment it necessitates the longer retention time for desired BOD removal. So, that is why we try to avoid the growth of facultative microorganism in the aerated lagoon. Next technology is called the fluidized bed reactor. In case of fluidized bed reactor what is happening it is a phenomenon of particle suspension caused by the upflow velocity of liquid inside a reactor. So, what is the advantage? It is a proper mixing can be done it increases surface area for the waste for the for your organic I mean like for the biofilm to in contact to be in contact with the organic matter present in the waste water.

It also increases the mass transfer ratio and in uniform ratio mixing of particle is possible with the consistent temperature distribution. This fluidized bed bioreactors which are coming as very nowadays it is becoming quite famous to be for its uses in the industrial waste water treatment application specially. And it utilizes the liquid and solid fluidization fauna fundamentals specially in the waste water treatment and implement the tiny fluidized media to immobilize the bacterial cell. And this aerobic FBBRs are for low strength waste water aerobic FBBRs are for the groundwater polluted by hazardous waste waste and all. This aerobic FBBRs operations majorly it uses the effluent recirculation or oxidation tank to dissolve required oxygen.

And also it has this activated carbon which is commonly used as packed media for degrading the organic pollutants. This is how it looks like if you see the air comes from the bottom it because of the air flow the media is remain in suspension in fluidized condition like you know it is like boiling keep on boiling. So, it stays in the fluidized condition in the media and then from the top you see that because the waste water is also introduced from the bottom. So, it is actually consumed by the microorganisms present in the slime layer on the top of this media and the treated effluent can go out of the system ok. You can have you can simply supply the treated effluent also you can again recycle it a bit and there you can simply use the oxygenation.

Oxygenation means you simply apply the liquid oxygen or I mean like as a liquid oxygenated it is simply supplied into the air water waste water itself ok. This is called the oxygenation process. In case of oxygenated FBBR what is the main difference? It utilizes the oxygen in the liquid form to maximize the transfer and availability. External oxygenation is oxygenator is required I mean like for that and also the before if you introduce into the waste directly to the system it will induce by some gas bubble turbulences and also better to have it and externally and also recirculation can happen the treated waste water. Recirculation helps to maintain this bioparticle to be in fluidized condition it avoids the oxygen limitation and bed height it increases with biofilm formations reported like a monomeric regulated by the periodic logging of the bioparticles and all.

In case of aerated fluidized bed biofilm reactor oxygen supply air is directly introduced there is no separate liquid oxygen and it is through an internally arranged draft tube to enhance the oxygen transfer and mixing and effluent recirculation no need for effluent recirculation liquid recirculation on the gas evervations maintain the bioparticle bio particle fluidizations and all here. And also the biofilm maintenance the continuous clearing of biofilm from this fluidized media through the bio particle impact or attrition and the gas evervations is also practiced. The bed height there is this is not this does not require deliberate control as the biofilm is continuously cleared from the aerated AVBRs. So, now, this aerated AVBRs are quite famous, but in some particular practices oxygenated AVBRs are also prioritized ok. So, you see this picture where the figure like you know the P is the pump like where the feed is actually introduced air is introduced through this air diffusers you will see this diffuser air and draft tubes and all.

And see this zone 5 is the support to align the draft tubes there ok. And the zone 3 which is actually the air like you know air diffuser where actually the majority of the fluidized bed like bed is present there right next to it once it in enters the see this 2 this is the baffle when it crosses the baffle. So, it enters the settling zone in this settling zone what is happening because of the presence of the baffle and the air diffusers because of the baffle and the degashe fires degashe fires and all what is happening there it start settling all the what is called this biofilm this lot of biofilm will start settling and see in the bottom it has a certain angle certain slope because of this slope this all this biofilm will start settling down and settle down in the bottom and it can be collected from the outlet which can be I mean like can be a sludge can be directly supplied to the sludge handling unit ok. And from the top we will collect the effluent. In minimum fluidized fluidizing velocity that we need to maintain it can be easily calculated by this equation EMF or UMF equal to 0.

0055 in bracket EMF cube by 1 minus EMF whole square into d square minus rho s minus rho into g by mu. So, whereas, this EMF can also be calculated by mu by dp into r into e to the e e dash m f. So, here if you see this r e dash m f is the particle Reynolds number at minimum fluidized velocity, UMF is the minimum fluidized velocity, EMF is the voidage at minimum fluidized velocity, mu is the dynamic viscosity, d is the particle diameter, rho s is the particle density, rho is the fluid density and g is the acceleration due to gravity and the g is the Galileo number or the Archimedes number. So, from this you can easily calculate the the you see the Galileo number also you can easily calculate for which is and also EMF you can easily calculate this which is the function of the surface property shape and the size distribution ok. Next important technology is the biologically active filter.

This biological active filters are becoming quite famous nowadays. So, it normally combines the biological oxidation and the filtration at the same time for the effective removal of organic matter of wastewater. So, just imagine so, we are not only doing the biologically biological oxidation of the wastewater, but also the same bed actually being utilized for the filtration purpose mechanical filtration also ok. Then that is why it is called the BAF or the biologically active filter. It removes both suspended and the soluble organic matter.

How it converts the soluble organic matter? It consumes the soluble organic matter in the cellular biomass and whatever the suspended biomass it actually clogs and it filters using the mechanical filtration system. So, this wastewater flows normally downwards through this filter media providing the filtration and the surface of the batter biomass attachment. The aeration is provided from the bottom to support the aerobic oxidation of the organic matter. Various types of media beds are used like activated carbon anthracite sand etcetera and are used based on the removal efficiency needed and the influent characteristics. Regular backwashing is required that is one of the major issue here.

What is the major issue here? That is the regular backwashing that it required. So, because what happened because of the filtration unit it has a certain pore size and this pores will sometimes clogged by the slogged off by media itself slogged off biofilm itself ok. So, because of that you need to provide regular backwashing by the water or by air whatever it is, but it requires because of that it actually makes it a little bit disadvantageous in some sense ok. But it maintain a high filtration rate and remove the inactive biomass. Treated wastewater is then collected from the top of the BAF after the filtration or in or from the bottom after the filtration.

BAFs can operate at a reasonable loading rate and exhibit a smaller construction footprint that is the most advantageous part of it. If you see this reactor, influent is we supplying it from the bottom from the top ok. We have the system for filter media through this filter media. So, this influent goes down slowly because of the air that it supplies. So, because of the air the filter media gets enough oxygen enough air to actually become the aerobic in aerobic condition.

Now it is almost like a media based systems that we just we discussed in earlier also, but here what is happening the it also acts as a mechanical filtration unit ok. Because of this the way it works this mechanical filtration unit the water goes down the wastewater it is treated and then treated effluent can be easily easily thrown out I mean like thrown out for the for the purposes. Some of this treated effluent can again be used for backwashing purposes. So, it sometimes collected in the backwasher backwash water storage tank from that water storage tank sometimes we have to make such an make some arrangement. So, that the water that the water which is treated now can again be used for backwashing and to clean the filter media ok.

After it will clean the filter media it will go up and from the backwash water will be collected through the the in the top there will be some arrangement from there it will go to the primary sedimentation tank. So, that is additional sludge that you will collect through when you do the backwashing all this sludge will go up and it will collected it will collected in the directly to the primary sedimentation tank in the just the previous unit of this biologically active filter the BAPS anode ok. So, in general BAPS are cost effective they have a multivariate you know wastewater treatment technology it is nowadays it is quite famously quite permanently used. It is quite effective in removing the byproducts formed during the tertiary treatment and emerging contaminants at trace concentration. The water reuse and saving BAPS contribute to a water reuse and saving leading to a significant water savings.

Arration cost challenge since BAPS rely on the aerobic decomposition the increased aeration requirement adds to capital and operating on that is one of the cons part of it. The clogging mitigation using the BAPS after tertiary treatment it minimizes the clogging problems due to lower concentration of organic pollutant in the influent. Ideal use case BAPS are primarily used when focused on and treated water use especially after say like tertiary treatment of wastewater with the lower organic content. So, this is just perfect if you see like you use it for especially use it for tertiary treatment and where organic content is already little bit less and, but it may still have some say residual suspended solid you use this BAPS. This BAPS is perfect it will reduce whatever the left over of the organic content it will it will get rid of that also plus it will act as a mechanical filtration unit also of whatever the suspended solid that may create in the in the meantime in the tertiary treatment units like chlorination and all sometimes it creates some amount of byproducts some suspended solid byproducts also those can be trapped in the BAPS as well ok.

So, in conclusion we get to know about 3 very important technologies aerated lagoons which is nothing, but the aerobic suspended growth process that uses the aeration devices to supply the oxygen and maintain the aerobic condition and, but the size is quite huge compared to the activated sludge process and where naturally in some sense you know like you are the because of the size actually it actually can reduce the organic load like anything ok. Then comes the fluidized bed bioreactors the reactors that uses the liquid solid fluidization to immobilize the bacterial cell on tiny fluidized media and they can be used for both anaerobic and aerobic treatment processes and this fluidized bed bioreactors are now it is becoming quite famous because they they can consume they can consume a huge amount of organic matter in its very small period of time. Then the biologically active filter these filters that combine the biological oxidation plus the filtration mechanical filtration principle to remove the organic matter in soluble as well as in suspended form in wastewater effectively ok. They use various media types to provide the surface provide a surface for biological biomass attachment and addition from the bottom and this can be used for polishing purposes also this biological active filter now it is used for polishing purposes even after the tertiary treatment unit ok. Perfect so, we get to know some very interesting new technologies or the technologies involved in aerobic treatment processes and we I I expect that you will use this you will understand you will go through this material again and again at least 2 or 2 3 times to understand the concept more in details and also search for this keywords in Google or in YouTube and to get to know about some more in details about those you will get a lot of videos and all.

So, we will get to know more in details about once you see this how it performs in in in in life real life you will be realizing this lecture more in details you will be understanding this lecture more in details once you see those videos and how it works how it performs ok. So, these are the references that you can follow thank you so much see you on the next lecture video.