Water Quality Management Practices

Prof. Gourav Dhar Bhowmick

Agricultural and Food Engineering Department

Indian Institute of Technology Kharagpur

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Lecture - 15

Self-Purification and its Factors

Hello everyone, welcome to this NPTEL online certification course on Water Quality Management Practices. My name is Gourav, Professor Gourav Dhar Bhowmick from the Indian Institute of Technology Kharagpur. I am from the Department of Agricultural and Food Engineering specializing in aquaculture engineering. So, in this particular lecture material which is the last lecture of module 3 of Fundamentals of Reactor Engineering and Self Purification of Natural Streams. So, in this particular lecture video I will be discussing about you about some basic understanding about the self purification that happens in the natural streams and how and what are the different factors that in which actually the self purification actually depends on. We will be covering the key concerns in the self purification in natural streams, what are the different zones, what are the factors which affect the self purification and the stator films oxygen sag analysis report.

So, based on that we can actually have an idea about how actually this because of the organic matter that we introduce all of a sudden because of the malpractices or the anthropogenic majorly the anthropogenic activities, how this actually creates a caution or some issue in the river bodies or this any freshwater stream or some surface water bodies and how that they normally ah purify themselves with the with the course of time naturally. And this is the this is the natural phenomena that we will be discussing and which actually very much helpful in some sense and that is that is the reason reason actually like earlier days even when the ah the amount of pollutant that is there in the that we normally dispose in the wastewater in the in the surface water bodies was not that much it could easily purify itself and we still could have you know clean water we can directly have water from the river itself now which we cannot even imagine is not it. So, ah to start with there are some major ah nomenclature that I want to discuss first to start with the clean zone clean zone are the one where the stream when it actually regains its natural conditions of all the pollutants and level of pollutants and all. That means, the the it the the pollution is not it is not at all considerable I would say later like it is almost pollutant free and also the all the ah major ingredients I have said a major constituents of

the water is well within the ah you know check for ah the regulated local regulatory bodies then it is it will be considered as the clean water zone.

The major balance that is happening here it is the between the ah the available oxygen and the biochemical oxygen demand ah from the organic pollutant that is actually ah discharge into the water bodies. See just try to understand the schematic here ok. So, first what we are happening what suppose you have a 1 kilometer stretch of natural water bodies all of a sudden in the very beginning say like point A you introduce some wastewater which is having a high amount of organic matter. So, this what will happen when you introduce a high amount of organic matter it will pollute the water. So, with time that that organic matter which actually create a favorable condition to grow some amount of microbes which will actually consume the dissolved oxygen present in the surrounding vicinity to consume those organic matter.

So, dew level will goes down will go down and because of that there is a problem of ah the ecosystem aquatic ecosystems anyway. So, in general this biological oxygen biochemical oxygen demand if you remember the BOD we discussed this BOD and the dissolved oxygen level this the balancing and between this is actually making a major ah compliance major actually in ah like you know ah impact on the ah self purification phenomena in the natural water bodies or the natural streams ok. So, in general we try not to ah like you know put the ah pressure on the aquatic ecosystems by ah decreasing the dew level to less than 2.2 2.0 or 2 milligram per liter because what will happen that can be very threatening life threatening for the aquatic ecosystem to survive.

Even less than 4 is also quite ah like in a vital, but I mean like while dangerous for the aquatic ecosystem any aquatic species that is there our target is to make it somewhere between 4 to 5 ok. Even more than that also it is possible sometimes like when there is a certain amount of natural ah you know turbulence that is happening and in that case because of the diffusion ah x accelerated diffusion phenomena though oxygen level can be replenished, but in general it should be somewhere around 3 4 5 not less than that. Self purification joule in general when ah the wastewater is introduced into the system and to the end when the when it becomes the clean water again. So, this this can be bifurcated into 4 different zone. The first one is the degradation zone you can easily understand what is the degradation zone where the wastewater is introduced.

The point at which the wastewater is introduced for the certain ah fraction of ah time by fraction I mean like certain area that the water will be covering for the next couple of minute or second or hour based on the type of degradation or type of pollutant or the type of water what we are talking about I mean like it depends on the different time frame. So, it will be considered as degradation zone. Then the active decomposition zone

the moment those pollutants will be consumed by the microbial ah microorganisms present there. So, this microbial break down breakdown of pollutants will be considered and the the will be happening in the zone and which will be considered as the active decomposition zone. After then the recovery zone when the oxygen level will start to improve what does that mean in the active decomposition zone what will happen because of the microbial activity it will consume the oxygen.

So, it will reduce the DO level is not it. So, that is why with time it will what will happen in the second zone active decomposition zone the oxygen level will dissolve oxygen level will very reduce it will reduce drastically. With time the when recovery zone the oxygen level will start actually replenishing back to its actual value and after that it will become the clean water zone. So, first the degradation then the active decomposition zone then the recovery zone and the clean water zone ok. So, the major ah impact that it happens like you know how majorly because of the anthropogenic activity it happens, but it is not only the anthropogenic I would say there are instances of you know different other type of ah natural pollutants that is present in the ah environment that can also make a quite a good amount of form in the natural streams and actually that can also be a detrimental source of ah pollutants for the for human body I mean like for if you consume that water in a in in the from the near vicinity.

So, in in general the wastewater which contains the very low dissolved oxygen has a huge amount of suspended solid organic compound or select some toxic compound and if you are introducing it if you are somehow discharging into the river body I mean like any natural streams it will definitely lead to pollution is not it. So, if you see this curve it actually very clearly represents that how it looks like you know when you if you see in the zone 1 and zone 2 in between if you see the wastewater discharge point the moment you know where the wastewater is being discharged in before that it is a clear water zone means the water was completely clean. Theoretically let us let us talk about it like let us think about it the water which comes into before coming into contact with this degradation zone or the wastewater discharge point it was quite ok ok. Then the degradation zone come where the wastewater is being discharged and then during that part I mean like ah wastewater ah like you know all the what will happen the it start ah consuming I mean like the ah waste is coming to the picture and with time the when the active decomposition zone start in the during the zone 2 and zone 3 if you see end of zone 2 and zone 3 what will happen the oxygen level DO level will drastically go down. Then there comes a recovery zone which is zone 4 and onwards if you see here and this particular picture actually zone 1 and zone 4 5 is considered as clear water zone there are ah very nice bifurcation ah it is given and if you see this dotted line as representing the dissolved oxygen and the the straight line is actually the the continuous line is actually representing the aquatic species.

If you see the the the lesser the DO it actually has a quite a connection I mean like it is resembling to the like you know amount of ah the the aquatic species that can actually survive in that aquatic ecosystem. So, with the time with the lowering down with the reducing DO dissolved oxygen the aquatic species number of aquatic species also goes down. So, this is this curve actually gives a gives us a very representative value of you know this and also representative figure actually how the cell purification happens in the natural water bodies or the natural streams. So, in the zone ah 2 the degradation zone that we call. So, what is the major characteristics of it? It it should be dark color dark in color because it just introduced with the like by like in a huge amount of organic pollutant in majorly the organic pollutant they are because of the presence of them they are the water color becomes dark.

It reduces the it started reducing the dissolved oxygen nearly up to 40 percent of the saturation DO can be ah present there and the floating solids and the high turbidity can be witnessed. What is the impact? It will cause the immediate fish mortality it inhibits the sustenance of ah aquatic life it favors the sludge deposition on the top in the bottom and because of that also benthic anaerobic ah microorganism will start growing and that will also make it more polluted. It increases the carbon dioxide concentration and it also supports the further de deoxygenation and slower the re-oxygenation rate. What is the extent? The it extends downstream from the waste water receiving location and the a certain sewage fungi and the bottom worms can survive under this conditions and for them it is a very proper lively conditions and what they will do they will start proliferating and they will actually ah make the area completely unfavorable for the aquatic species to survive. What is the active decomposition zone? What is happening there? The treatment starts play taking place I mean like the natural purification starts taking place I mean like the DO are been consumed by the microorganisms and they are converting that organic matter into their biomass ok.

So, this here the color of the water will become grayish and the if you see the DO may become as low as 0 and sometimes even you know DO rise in DO content can also be observed when it is possible when there is a chance of high amount of DO all of a sudden because suppose because of the not only organic along with organic there are some organic substances also you are introducing. So, what will happen to some amount of algal bloom will also start happening for those algae they will consume those I mean like those or inorganic pollutant and they will proliferate and I mean like they will become in a huge number and they will actually contribute to the dissolved oxygen in the into the system. In general you can see the formation of the scum layer on the top of it and from this sludge particles and also finer solids by adding their gaseous and production of gaseous like methane hydrogen sulfide due to the anaerobic condition on

the bottom and what are the survival is definitely the different kind of protozoa fungi and the larva of sewage flies can be found in this particular zone. Then there comes the recovery zone in the recovery zone what is happens slowly the water is getting recovered the self purification actually starts happening. Here the better re aeration and the improved water clarity can be witnessed the reduction in the turbidity can also be witnessed and the dissolved oxygen also goes slowly in on higher stage presence of different protozoa algae tolerant fish and snails and muscles can be witness in this region and those you know the muscles they are considered as filter feeder.

That means, they are actually they love this kind of environment they actually consume the organic matter present in the in a suspended condition and they consume it and that is that is their food. So, because of that the production even if you culture those muscle in those areas that will actually enhance the purification ah efficiency in this kind of systems, but this is where we are talking about the natural purification. So, when if you want to ah you know enhance I mean like you know you you actually want to accelerate the consumption of the organic matter present in the natural water bodies you can simply form the muscles or any kind of bivalve clam muscles callops all these things. They are the filter feeder they will consume the ah organic matter from the column and they will actually reduce the pollutant level. What are the major survivors as I was discussing the protozoa algae and the various aquatic organisms which can thrive in this zone some type of tolerant fishes can also be ah sustained there.

Basic characteristics of the clear water zone which is zone 1 and the zone 5 it is like DO content up to the saturation concentration or close to the value. So, do not get confused with this the saturation concentration here I mean like it is very hard to achieve we can actually give we can go quite close to that because ah in general if I say ah in a standard ah temperature and pressure ah at 20 degree Celsius and say like one atmospheric pressure the ah this saturation concentration of dissolved oxygen is somewhere somewhere around 9.07 milligram per liter. So, which is ah very hard to achieve, but if you go to 0 0 degree it is around 14 milligram per liter if you go to 30 degree it is around 9.

27 milligram per liter. So, I mean like in general so, this 9.0 to 0.07 milligram per liter at 20 degree Celsius at ah STP is the saturation concentration of dissolved oxygen. So, you cannot just go up to that maybe it will be somewhere around 6 7 that is quite good. In case of clear ah river water no bottom sludge can be ah with nest much and the settlement and the minimum turbidity and the presence of ordinary fish fish fish species including the game fish and another aquatic life can be well thrived in this kind of system in this area.

What are the major factors which affect the cell purification to start with the dilution and the dispersion? When ah the organic pollutant are actually discharged ah into the large and into the natural streams in a large volume if you can somehow dilute it I mean like definitely the I mean like its potential for pollution can also be drastically reduced ok. So, and this dilution is a another in very important factor sedimentation settling down of solids like if the solids are biodegradable they decompose at the river bed and convective currents in the river can also affect the sedimentation causing a huge amount of turbidity and I mean like the water is really ah unbearable for the fishes to actually even take breath because ah they they have the irritation gill irritation that they call that we call ah that can also happen. Biochemical oxidation as I was discussing that organic matter it normally goes undergoes a oxidation ah as wastewater is discharged into the river and different microbial species also plays a very crucial role here and DO also started depleting. So, this oxidation process its continuous until the complete stabilization of organic matter takes place in through the stream is not it. Reduction it majorly occurs due to the when there is a absence of dissolved oxygen.

So, anaerobic bacteria at the water bodies bottom depth hydrolyzes the complex organic matter into the much simpler liquid gases or the other substances. This end products are easy to oxidize and eventually mineralize ah sunlight sunlight plays a crucial role in the photosynthetic activity different kind of autotrophs like say algae they can easily derive energy from the sunlight for food preparation and this algae can also utilize the carbon dioxide and release oxygen. So, it replenish the ah streams oxygen content in a faster rate. So, that is why sunlight in general enhances the organic matter oxidation and the self purification process in the ah natural streams. Temperature as you know the temperature if the temperature is higher what will happen the DO level will reduce because of the gas solubility reduced gas solubility that is why if you know ah what we what will happen when you try to boil the water it starts bubbling.

That means, the all the air actually goes out of the water body. So, I mean like because of the reduced gas solubility in a higher temperature that is how actually you can actually reduce the ah DO concentration for different experimental purposes also. We normally what we do we just boil the water sometime to reduce the dissolved oxygen concentration in the ah or say any other air ah research that we are doing where we need a reduce amount of air presence in the ah I mean like the I mean like the oxygen dissolved oxygen or dissolved carbon dioxide presence in the water that actually we can do it just by boiling the water. Sometimes we do it for experimental purpose by ah different kind of chemicals if I am correct like we use sodium sulphide cobalt chloride all this catalyst to do this job ah which are majorly the oxygen scavenger scavenger. So, other than that in general we just boil the water to reduce the dissolved oxygen level in the water.

So, so when the temperature will increase definitely it will also lead to the same phenomena other than that however, there are some other thing that can also be beneficial in case of temperature increment the temperature because the ah biological and the chemical activity will be accelerated because of the ah the the microorganism which loves to grow which normally ah speed up this organic matter biodegradation and actually reduces the time required for the self purification purpose. So, that is how actually the temperature can make a good impact in this in this particular case. Cetaphils oxygen cyganuses if you see the dissolved oxygen in the natural streams in general the unpolluted natural streams in general it holds a maximum DO close to saturation as I was discussing it normally varies between 14.

6 to 7.6 milligram per liter 14.6 at 0 degree Celsius 7.6 or 30 degree Celsius and at 20 degree Celsius that is the value that we normally take in most of the research this is 9.07 milligram per liter at STP it is always in STP standard temperature and pressure if we change the pressure these values will drastically change. So, polluted streams and the oxygen availability it also matters like you know if there are polluted streams like in highly polluted streams the rate of oxygen depletion process in depletion normally increases while the rate of oxygen replenishment decreases and consequently obviously, the overall availability of the DO will also reduce. Reoxidation curve the it refers to the rate at which the atmospheric oxygen dissolve in the river water and any other water bodies to compensate the declining oxygen level this reoxidation curve is plotted to show the relationship between the rate of oxygen supply and the time of flow ok.

So, in general this reoxidation rate reoxidation means like you know as I was saying like you know again you come back the oxygen from the atmosphere to the water body. It depends upon the depth of water body you can easily understand if it is a shallow pond lake or river it has a higher oxygenation rate reoxidation rate if you have a very deep pond it will not definitely because the oxygen cannot penetrate after a while. So, it will be only the on the top. So, rest of the portion will be on an anoxic and anaerobic zone almost on the anaerobic zone in the bottom the condition of the water body running water condition promote more reoxidation why because of what happened because of the turbulence compared to the quiescent water. There is a if the water is very calm and like it what will happen because of no no turbulence because of no certain phenomena the wind speed or some other phenomena is not happening the diffusion rate will drastically drop down and if the diffusion rate will drop definitely the reoxidation will reduce temperature re reoxidation is lower at higher temperature as we know because of the reduced diffusion I mean like the ah availability of the dissolved oxygen in the ah higher temper at the higher temperature and the DO deficit if the greater the DO deficit it more the re oxygenation ah rate ok.

How ah if you see this curve this curve actually very nicely ah demonstrate the with the distance suppose if you see the very first point the 0 is the point where actually the organic matter reach or say like pollutant reach wastewater actually comes into the picture. I mean like they discharge from some certain municipal water body or say like certain industrial water body what will happen naturally it will take this river in this particular example almost 100 kilometer to come to its natural state. Can you imagine the I mean like the dissolved oxygen grows down like anything from say like it was almost 8 9 it goes down to almost 3 4 like 2 3 level. So, and then with time it slowly replenish again. So, you can really understand right like this is the this is the pathetic thing about it like you have a like when we do this kind of ah un I mean like this kind of anthrop because of this anthropogenic activity we are not taking care of the wastewater before actually discharging into the water body and this is the time that it takes.

And if you cumulatively say like after every 50 50 kilometer in this curve if you suppose if you keep on discharging one after another ah one after another ah like in a industrial effluent point or suppose ah if the every 50 kilometer there is another city who are discharging again they are all the wastewater to the system there will be no point in the natural stream where it will can it will get enough time to replenish itself. So, at the end of the day the whole river what you will look like drain whole look like you know completely full of pollutants. So, I mean like this is the this is the irony of it you should understand this curve you should understand the ah the the basic concept behind this ah oxygen sag analysis and basic understanding behind this why it is called this oxygen sag analysis ok. I mean like this sag like structure if it it makes if you see and also if you ah realize that in general this consumption rate this ah I mean like change in dual value it also signifies the higher amount of microbial activity. That means, they already started the wastewater I mean like the river is already started playing its own game to actually reduce the ah the pollutant level ok.

So, this is how actually it looks like in the ah in the what it happens in the natural ah streams ah where they actually can do the natural purification or the cell purification ah by itself ok. However, we need to because of the our industrial era because we reach to the industrial era 4.0 as we say and so, now, it is very important for us to actually treat the wastewater by our cell before discharging into the river body or the ah any natural streams. So, that ah we can actually help the nature to replenish itself and not to polluted ah which will definitely harm us only ah in return. So, in conclusion we discussed about the natural streams which are the one of the vital ecosystems which is very crucial ah for ah sustaining life on earth.

Anthropogenic sources which can often discharge treated or partially treated effluent

into the natural streams leading to water quality deterioration and this natural streams it undergoes a cell purification forces that we understand it involves 4 zone. First the degradation, second the active decomposition, third recovery and the fourth is clear water. What are the factors which affects the cell purification? Dilution factor, sedimentation factor, biochemical oxidation, sunlight, temperature, the turbulent motion, reaeration rate all these things contribute to the dynamic nature of the cell purification. And the neutratic factors, unconventional factor like the sediment oxygen demand. The sediment which is there in the bottom they may also have some oxygen demand because of they are also benthic they this benthic aerobic microorganisms can also consume some amount of oxygen this called the neutratic factors.

And also the biological oxidation of inorganic nitrogen that can also influence the cell purification ok. The stator phase oxygen cyclic analysis also we discussed where we ah this model we have seen the model which provides the insights in about the oxygen sac phenomena analyzing the deoxination and deoxination rate in a polluted water body. So, I would like to request you to go ahead with go and check this references to understand to read the references to get some more knowledge about this factors. And I hope you get to know about this very important natural phenomena which we call cell purification of a natural streams in details and it will be very helpful for you to understand the nature how beautiful the nature was when if we do not interfere with it. And if you are interfering with it is our responsibility to actually clean it as well to actually treat it well as well is not it perfect.

So, thank you so much that is it for this module we will see you in the module 4. Thank you.