Wastewater Treatment and Recycling
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Lecture - 16
Fate and Transport of Contaminants Discharged in River

Hello friends and a very warm welcome to the 4th week of this course, Wastewater Treatment and Recycling. In the past 3 week, we had the basic discussion about the various sources; various types of waste water what is this status and then, how we can estimate the quantity of the waste water being generated. And in the last week, we discussed about the qualitative characterization of waste water, what are the various parameters based on which the waste water can be characterized.

So, this week, we will be moving ahead and the first discussion that we are going to take up is what happens, then when waste water is introduced in the nature? When it is either treated, untreated, partially treated; whatever we can say. So, when a waste is stream, industrial waste is stream or municipal waste stream is introduced in the nature and as we have been discussing this: the most prominent root of waste water disposal is the discharge in the rivers. So, the waste water which typically or usually is discharge in the river comes from the different can come from the different sources, can come from the industries or can come from the municipal sources.

Generally, the municipal sources dominate over the industrial sources in terms of volume. So, like for say in the river gang Ganga, we will see that the total discharge may be the waste water which is being discharged around 90 percent of that by volume is from the municipal sewage, while around this 10 percent is from the industries. But if you see this in terms of the pollution load in let us take BOD as a indicator parameter for pollution that way. So, if you see that the amount of organic waste or amount of the BOD being discharge in the Ganga from industries and domestic sector. So, although by volume that industrial sector contributes just 10 little under than 10 percent in fact, by pollution it will be contributing nearly half or around 40 to 50 percent.

Whereas, the domestic sewage which is by volume contributing over 90 percent will only be contributing some 50 to 60 percent by the pollution load because, industrial wastes are more polluted. So, the point is what happens when this waste goes into this

natural systems ok, what happens when this let say sewage stream is being discharge in a river? So, the receiving body or river which receives that waste stream along with the waste stream, waste stream of course, the majority of the waste stream is water, but along with water a lot of contaminants are also introduced in these natural systems.

So, for say in the river, it will receive some volume of water or waste water what you call; it is waste water because there are lot of contaminants in it. So, otherwise it is also a form of water only. So, it receives that water, but along with that it receives significant or substantial amount of contaminants. Now, these contaminants when introduced in the river what happens to these contaminants that is what we are going to discuss primarily in this week and particularly in this lecture.

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So, when the waste water is discharged in the natural environment, the pollutant in it water is of course, going to be the mixed; but the pollutant in the water can undergo the different processes ok. So, what could be these different processes? These pollutants undergoes combination of various fate and transport processes right.

So, the it could undergo various transport mechanism because see what happens that if let say this is your river and your contaminated water or pollutant is being introduced at one particular point in a river. But this contamination is not limited to this particular point ok. The pollution the pollutants that are being added into this river at this particular point depending on the direction of the discharge will flow along with the river ok. So,

the pollutant which is being introduced here or the pollutant let us say a sewage stream which is being introduced say in the Kanpur, the pollutant could travel a long distance in the downstream could come to the could be detected Allahabad could detected in Varanasi; could be detected in Patna that way in the river Ganges if it been discharged let say at Kanpur.

So, what are these major transport processes? So, these transport processes primarily includes Advection. Advection which is the which a process, which carries the mass of the contaminant or mass of the pollutant along with the mean fluid flow. So, if your river is flowing if you introduce something in the flowing water, let say like you put sheet of paper in a canal or in a river as the water flows, the sheet of paper will also be flowing right

So, that flow is basically along with the bulk flow of water; as the mass of water is also flowing it is carrying that additional stuff that contaminant that pollutant as well. So, this process is called Advection ok then, there is diffusion so, which is practically a mass transfer phenomenon. So, when we when the contaminants are added; it is not going to remain at a fixed point or all of it may not be remaining together.

It depends on the nature of contaminant; you take a piece of glass and throw it in a river that piece of glass is going to be intact ok; that is not going to a like it may flow along with the water, but if let say I am introducing a piece of glass at this particular point and it is travelling towards the flow is towards this direction. So, the piece of glass or piece of paper or let say I take a wooden piece. So, wooden piece if I throw it here along with the flow in the river that may come here, but the entire mass in that glass or paper or wooden piece is going to remain intact.

But what happens if I throw a bag of dye at this place? So, that dye molecules are not going to remain like if I say put down 1 kg of dye at this particular point. It is not that along with the flow of the river here, I can detect 1 kg of dye because that dye molecules will get dispersed ok, get diffused in the water so that is what diffusion means. Diffusion is essentially that movement of or a transport of molecules of a contaminant from a zone of higher concentration to zone of lower concentration.

So, where I have introduced that becomes my high concentration zone and it will diffuse all over because of the random molecular motions. So, those molecules, those fine

molecules are going to diffuse all over in the water and this is the cons a concentration gradient is the driving mechanism for diffusion. Diffusion is the natural process it will take whether you like if you put such kind of diffusive molecules or diffusive chemical in a medium. Even in a static glass you take a you take a water in a glass and you add pinch of salt in that or pinch of color in that.

So, what happens that that color will slowly, slowly, slowly, slowly get mixed in the entire water. It is not going to remain only at the point where you have mixed ok. So, that mixing takes place because of the concentration gradient which is the deriving force. So, that is what is diffusion. So, when we adds when the pollutant is introduced in the water it also get diffused in the different directions.

It could undergo dispersion which is or we can say rather than mechanical dispersion which is because of again it is a random, but because of certain other driving mechanisms. So, for say if let say this is your river ok. So, all of this like if this is your cross section of river. So, all water molecules or all molecules of the river, all packets of the water of the river are not flowing with the exact same velocity ok.

This by the time, it reaches here something might this might have just reached here or this might have reached here. So, there could be a different velocity of different flute packets that is one reason. So, what happens let us say I introduced a contaminant across this cross section of the river. So, some after sometime some contaminant may remain here; some contaminant may remain here; some contaminant may reach up to there. So, they get dispersed in the river because of variable flute velocities or could be because of variable fluid paths also ok.

Some component of the river, you have seen natural rivers, it is not always straight forward ok. So, may be this component is going like this, flowing like this here and this component is flowing in straight away. So, even of the velocities are same, the distances has travel or the points where this contaminant could taken could be very different ok. So, because of variable flow path or because of variable flow velocities, we can get the contaminant dispersed in the system that is one thing and then, it can leads to the sub surface which is sub surface transport the contaminant can leads to the ground water.

So, that could be the another mechanism guiding the relocation or transport of the contaminant. There are phase transfer or relocation mechanisms also there it could

undergo Sorption-desorption; which is sorption is basically a combination of adsorption and absorption. So, contaminant can get adsorb on to the surface of let say the river bed sediments or some other materials, pebbles, holders, rocks present in the river can get adsorb on to the surface of this and then later on could actually dissolve also. So, that Sorption-desorption could be one mechanism that is adsorption a for some spongy material, it can actually enter the body also which is typically called as Absorption, where the it is a bulk phenomena entire body is involved; whereas, Adsorption only surface is involved.

Then, it can undergo Volatilization. So, the some volatile compounds if let say some those kind of volatile impurities coming in with the water and as soon as it goes into the river because temperature also fluctuates. In day times temperature could be relatively high and some stuff could actually turned volatile ok. Then, we have transformation or degradation roots also which is there could be biotic transformation means the transformation or the degradation involving microbial consortia.

So, involving bacteria or fungi or those kind of stuff. So, that is biotic transformation or bio degradation what typically we call. There could be abiotic transformation as well which is chemical transformation, which is not because of any bacteria. So, simple abiotic hydrolysis and those kind of process could also happen with some of the contaminants discharged and there is a possibility of photo degradation because it is expose and receives sunlight. So, some compounds can actually get photo degraded as well.

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So, these are some of the things that could happen to the various contaminants present in the river which are introduce in the river which are present earlier in the discharged waste water. So, as we discussed there could be variety of processes which there could be variety of process or variety of mechanisms which act upon the contaminants which are introduced in a naturally stream or in a natural river. So, because of these processes, there is some of the contaminant, some of the pollutant gets treated within the river itself without having without doing any engineered interventions.

So, we are not applying any engineering there the natural system by itself takes care of not some in fact, if you see there is a good velocity and all these things. So, it can take care of the majority of the conventional pollutants ok. So, we know that our rivers have been taking care of the waste discharge into the rivers since edges. So, that is because those conventional pollutant or the natural pollutant earlier in the earlier edges we were using less and less of chemicals.

So, there were not chemically synthesized and very hard to degrade compounds. You know that now a day, we have variety of those emerging contaminants which cannot be degraded. We have polythenes, we have plastics which are difficult to degrade. So, earlier when we were relying mostly on to the natural systems ok. So, we were using this natural products, natural fibers all this. So, they were already there in the nature and our river systems where capable of not only river systems in fact, our natural systems

including river soil, all the eco systems where capable enough of handling the waste as well.

However, this has now been changing because we have started introducing lot many engineered or synt chemically synthesized comp compounds which are very difficult to degrade. So, coming back to the natural purification which is also called as Self-cleansing ok; so Self-cleansing in the river, what happens that each river has a self cleansing ability; how much it can how much waste it can handle; how much waste it can sort of manage ok?

Now, waste here again depends on the type of waste. It is not that if something is able to handle let say for say 100 units of organic waste it can hand handle. So, 100 units of sucrose sugar or peptides will can be managed can be handled, but if you feed in with 100 units of organically synthesized pesticides, pharmaceuticals or polythenes; it cannot handle that 100 units right. So, it depends on the nature of waste as well. So, this natural purification process was always present in the surface water and was able to remove or reduce most of the conventional pollutants over edges ok.

This incorporates series of physical, chemical and biological processes. Many of that we discussed, we just briefly discussed and it take cares of sediments and decomposable organic waste and that way release the stream or relief the river of it is pollution burden. What so ever pollutant is being added some of that burden is reduced or removed ok. So, this process is known as the Self purification or natural purification process.

The rate and the extent with which this processes occur depend on many variables and these variables could include the what is the flow rate or flow velocity of the river; what is the degree of turbulence; what is the depth of the river; what is the sort of it is Arial spread right; what is the nature of the river bed; what kind of stuffs are there; what is the type of biota present in the river and what is the temperature variations across the day or across the different seasons; what is the status of sunlight prevalence?

So all these variety of factors that will actually govern; so, what happens if you let say discharge a municipal water over here, there is possibility of something undergoing photolysis; then, some can go under hydrolysis. There could be a biodegradation transformation, there could be dilution and diffusion, the waste can be diluted and diffuses diffused ok. The particles particularly the sediments and those kind of things can

actually get transported along with the flow of the river; the dissolved particles can also get transported ok.

Then, there is the possibility of something getting deposition and recess coming in to the recess pension, some going to the bio concentration means taken up by the fishes and taken up by the biota. So, getting concentrated over there ok; some disposition and accumulation in the river bed, in the bed of the river. So, these kind of variety, these variety of processes can take place and can lead to the different type of treatment or different degree of treatment to the different contaminants present in the waste stream which is getting introduced into the river.

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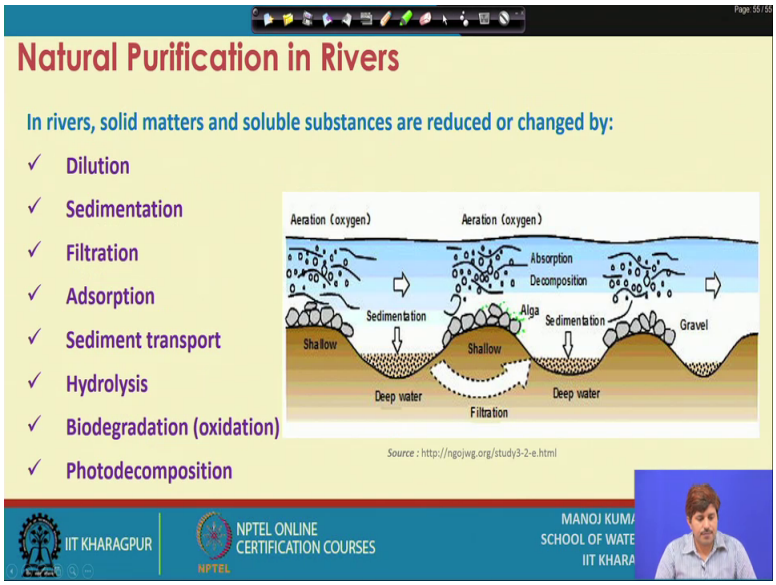

So, if we see various Natural Purification stuff in the river; so, solid matters and soluble substances are reduced or changed either by the processes that we were just talking about; either by Dilution or Sedimentation; there could be Filtration; there could be Adsorption; there could be Sediment transport; there could be Hydrolysis, Biodegradation, Photodecomposition. So, these are the some of the common processes which governs the fate and transport of the pollutants introduced in the river ok.

And these processes in combination overall will see how far the pollution will stay in the river or how fast it can actually be taken care of or it can be river can actually sustain that way ok. So, for say the water is coming, there are biological organisms there are biota.

So, that thing can happen. The sediments can get settled in the form of sedimentation; then water passes through.

So, there would be when water passes through this way, there could be the possibility of some filtrations as well. If there is some growth of algae and these things; so there is a possibility of bio degradation by alga and bacteria, these thing decomposition. So, all this processes will be happening in the river.

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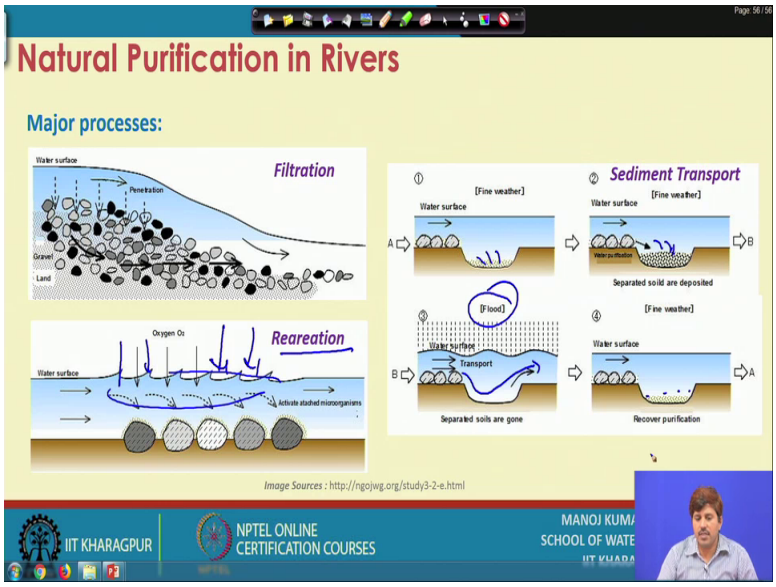

So, if we see the major processes there is Filtration ok. So, filtration is simply the major stuff is straining of filtration. So, the water when penetrates it, some contaminants can get retained in this and the water which comes out could be relatively cleaner. There is a re aeration which with oxygen label depleting by the waste introduction ok, the lot of oxygen gets consumed in the waste decomposition process.

So, when this oxygen level falls below saturation limit, the oxygen from the atmosphere comes back into the river. So, there is the atmospheric transfer of oxygen takes place and this leads to the dissolution of oxygen in the water which is typically the process is called Reaeration means water gets aerated ok. That is one phenomena. There could be sediment transport ok. So, initially the sediment are getting deposited more and more sediments are getting deposited and when there is a some kind of turbulence or let say the this in the fine weather, but when this flood occurs, lot of water gets and flow becomes very high. So, that can actually clean this entire sediments and take it to the sea.

And further, there is after the flood has gone the weather has turned fine this disposition again started occurring.

So, those kind of processes happened. One of the prime roles of the river is to basically also transport the dissolved impurities, dissolved substances to the river to the sea and sediment transport also. It should be able to take sediment and some of the dissolved solids to the or majority of the dissolved salts to the sea.

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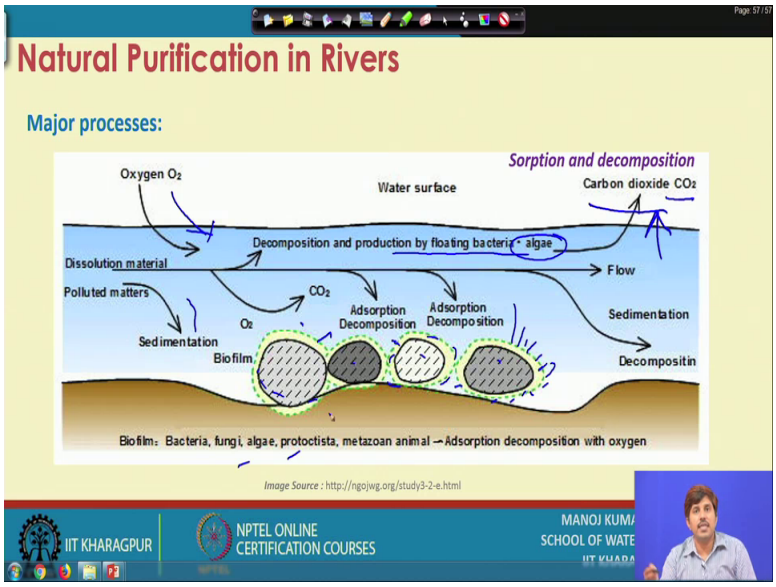

So, that is one of the primary function of the river and our river usually like keep on doing that. Then, there could be Sorption and decomposition. Various adsorption, absorption and decomposition processes ok. So, let say the dissolved materials which is coming in. So, that can actually get's decomposed and by the portion of the floating bacteria or algae which again release the carbon dioxide, the process will need oxygen consumption oxygen is taken from the atmosphere.

Atmosphere means oxygen is taken which is there in the dissolved state, but then it gets replenish from the atmosphere ok. Some of the matters can get sedimented then the dissolved oxygen what is ever are there they could be possibility of bio-film formation and over and above that there is decomposition takes place. The material can get interacted with this bio-film and can get decomposed and the byproduct of mineralized product can actually remain in the river water or if it is in the gaseous form it can scrape back to the system. So, that is how these processes can happen and this bio-film could be

mostly primarily it is bacteria, but could be fungi, algae and various other microorganisms as well ok. So, that way this self purification processes keeps on happening within the river system.

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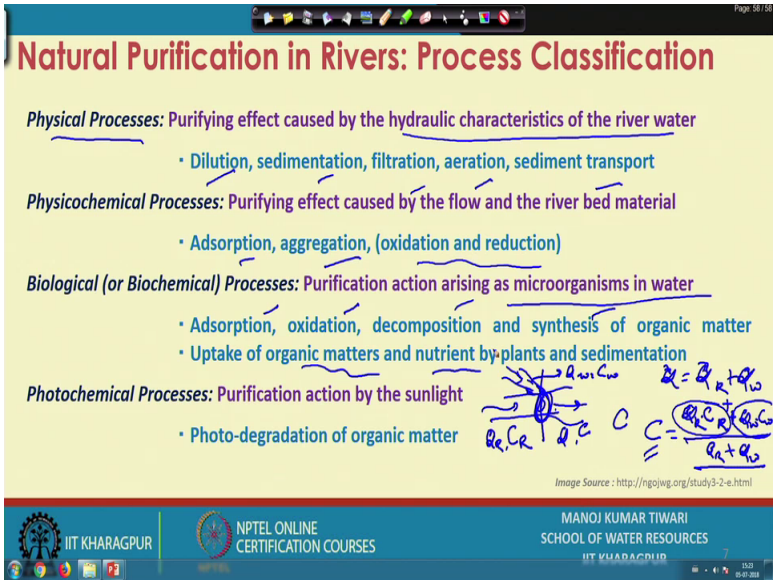

Now, if we see this natural purification process in the river, we can classify it in the different categories ok. So, there are physical processes which are essentially works on the effect of hydraulic characteristics of the river water ok. So, like the Dilution. So, water which is or the waste water which is coming quickly gets diluted. And if we sort of considered a homogeneous or sort of good dilution, it is fairly simple. Let say you are having, you are having a river and you getting a stream. So, how it is get diluted for say your river water is having a flow rate of Q R and contaminant concentration, basic background contaminant concentration is let us say C R; any contaminant it could be BOD, it could be any other contaminant ok.

The sewage water which is coming in let say this one is having a flow rate of Q W which is your waste water and a contaminant concentration C W in this. So, when the instantaneous or what so ever when the homogeneous dilution occurs, the downstream in the river or the final concentration C in the river is let say in the downstream the concentration contaminant concentration is C and the total discharge in the river or total flow in the river is Q.

So, by the mass, Law of Mass Balance, your Q will be equal to Q R plus Q W obviously. So, let say 100 let say 2 meter cube per second flow is coming from here and 0.2 meter cube per second flow is coming from here. So, this point onwards 2 meter is coming from this side and another 0.2 meter is coming from this side. So, this point forward obviously, the total flow is going to be 2.2.

So, that is simple Law of Mass Balance. So, total discharge or total flow will be equal to the summation of these two; while total concentration in the water is can be taken as the weighted average if it is getting diluted or instantaneously mixed. So, that will be your here you are having Q R concentrate Q R flow was having C R concentration. So, total mass is Q R into C R plus your Q W flow was having C W concentration. So, total mass here is Q W plus C W.

So, summation of these two mass of the con contaminants divided by the total flow which is your Q R plus Q W will give you the total concentration in the river ok. So, that way by simple dilution effect, we can actually get the final concentration over there. Then sedimentation, it can get settled physically; it can undergo filtration which is another physical process, it can actually have aeration and there is a possibility of sediment transport. These are some of the processes. Then, there are physicochemical processes. So, the earlier that one was seeing were primarily physical process, but physicochemical process get chemistry is also involved.

So, could be adsorption, could be aggregation and could be even at times chemical oxidation and reduction. There are biological or what we can call biochemical processes which at based on the actions of micro-organisms present in the water. So, that could be biotic adsorption, it is adsorption, but biological adsorption or up take biological oxidation decomposition by or the synthesis of organic matter. It can also be the uptake of organic matter which is called bio concentration ok; bio up taken bio concentration. So, it can be taken up take of organic matter and nutrients by plants and sediments.

So, the biological entities or the plants or fishes and these things can actually uptakes and adsorb some of the nutrients, some of present in the water or even some of the organic matter present in the water and concentrated within themselves. So, that is called bio up take and bio concentration. So, that is another biological process which can take place

and then, there are photochemical processes which are the purification action by sunlight and is actually the photo degradation of organic matter.

So, these are the different major classes on which the we can classify the different processes that takes place when the contaminant or when the pollution or when the polluted water is introduced in the river systems.

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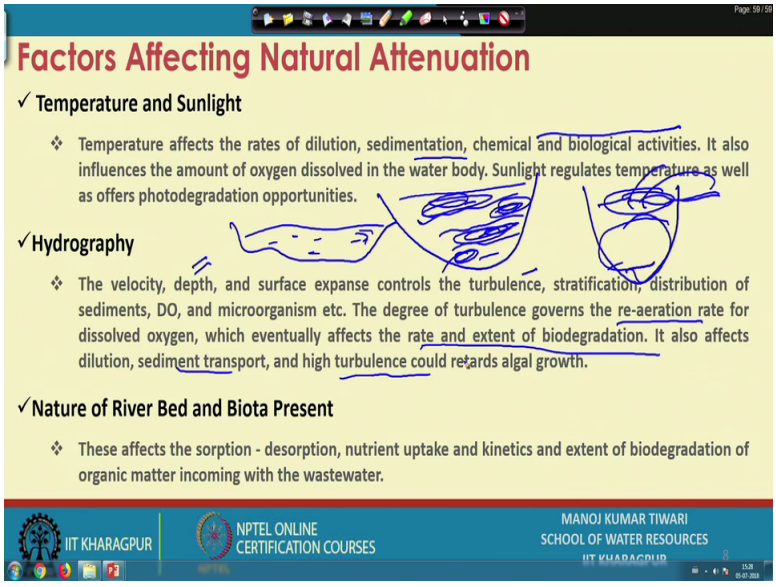

There are various factors that affect the natural attenuation, as we were discussing. So, these factors could be temperature and sunlight ok. The temperature affects the rate of dilution. How fast it can get diluted? It can affect this rate of sedimentation chemical and biological activities primarily the biological activities.

Because the biological processes, the rate of biological process is highly dependent on temperature. You are the microorganisms work in a suitable temperature range; if your temperature is let say exceeding 60, your mesophilic range of bacteria will be almost dead. So, there will not be any biological activity beyond that temperature ok. Their optimum range is say 35 or 30 that degree. If you are having a very low temperature, temperature around 4 degree or 5 degree, you know that biological activities stop at that low temperature that is why we use refrigerators to preserve the food and other stuff for longer time and we keep the temperature low. So, that the biological activities does not spoil our food right.

So, that rate becomes excessively slow even at lower temperature or almost negligible. So, these are all temperature dependent processes. It also the, temperature also influence the amount of dissolved oxygen in the water body. We did discuss this while discussing the parameter DO ok. So, the saturation DO, where is based on the temperature at a higher temperature the dissolved the saturated or the saturation value of the dissolved oxygen is very low. So, we cannot retain high dissolved ox high oxygen in the water or high dissolved oxygen in the water at higher temperature. The lower temperature is better to retain more and more of the dissolved oxygen.

Further, sunlight regulates the temperature which eventually affects these processes as well as it provides photo degradation opportunities, it offers photo degradation opportunities. So, these are the major affect of temperature and sunlight. Then hydrographic of the river that includes velocity, depth, surface controls' how much surface expense expansion is there and what kind of sometime even the what kind of what is the degree of undulation and all that which are there.

So, these controls eventually the turbulence stratification; how the water is stratified means because if it is a let say the depth is too high. So, in a river with too high depth, this water here and here will not be of same nature ok; the homogeneity changes. So, there could be heterogeneity can come and there could be basically stratification different layers could be formed. So, temperature in this zone may be different in temperature in this zone. Similarly, dissolved oxygen in this zone could be different than the dissolved oxygen in this zone ok. So, this kind of stratification can also happen.

How this sediments get distributed the dissolved oxygen levels and the microorganisms; how they are present, where they are present in a shallow water body? You will see that the mixing is more or less homogeneous; but in a deep water body, you will see that do level is here is different or do level there is different. You may see that not very micro-organisms are present in here, they are more present in the near surface water probably because of the easy access to oxygen and light and those kind of thing.

So, this all this processes this kind of thing can happen. The degree of turbulence eventually governs the re aeration ok, rate for the dissolved oxygen. So, high degree of turbulence there is more of mixing of atmospheric air in the water and the rapid oxygen transfer can take place and this eventually affects the rate and extent of the

biodegradation because biodegradation will eventually depend, on the amount of dissolved oxygen available. So, it also effects the dilution sediment transport and high turbulence could sort of retard algal growth right.

Then, there are nature of river bed and biota present; they also play some role into the natural attenuation process ok. So, how would be the Sorption and desorption depending on the, what kind of sediments; what kind of biota is present in the system; what is their uptake ability? So, the nutrient uptake will depend on that. The kinetic and extent of the biodegradation process; so, how fast this degradation process can happen will depend on what kind of microorganisms or what kind of biota is present in the system?

So, it eventually will depend on that. So, the how fast this biodegradation can take place or this adsorption process desorption process; all this will be governed by the river bed and biota present. Also there are other factors like velocity and these kind of things will also come and play a role into this. So, these are the major factors that eventually governs the natural attenuation of the pollutant which enters the stream.

We end this class here and in the next class, we will have further discussion on when polluted water enters a river. So, how the DO and BOD changes and how we can express that mathematically. So, thank you for joining and we will continue this discussion in the next class.

Thanks.