Applied Environmental Microbiology
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Lecture – 19
Microbial Ecosystem IV

Dear students in the previous lecture I talked about the three different ecosystems; atmospheric, terrestrial, on surface and below the surface when it came to microbes. So, today let us dive further into all these three of them and look at the major phenomena that happen in these three different types of water habitats aquatic habitats, now one thing I want to mention that typically in the microbiology course you would learn about different microbes that are found in soil, microbes that are found in air and microbes that are found in ground water, now the interesting thing is that as we have developed new tools we are realizing the immense diversity of microbes present in all of these three aquatic ecosystems and the other part we are noticing is that a lot of them are common to each other because the soil microbes can get aerosolized and then can become airborne, similarly the airborne microbes can wash away in rain and then become terrestrial or surface water micro biome.

So, because of the interconnection and the common microbes that they share with each other many environmental microbiologist are of the opinion that there is no there is less point in remember rising the details of the microbes that are found in different environment, but there is more it is more important to understand the geographical the chemical and the physical factors and the different nutrient cycles that actually impact the microbial growth population and activity in these ecosystems. So, once we have that we can use any high throughput and sequencing based techniques or metagenomics based technique and then we can understand what is present and get an idea of what they are doing right. So, now let us go ahead and dive into the three core systems and see; what are the major phenomena there?

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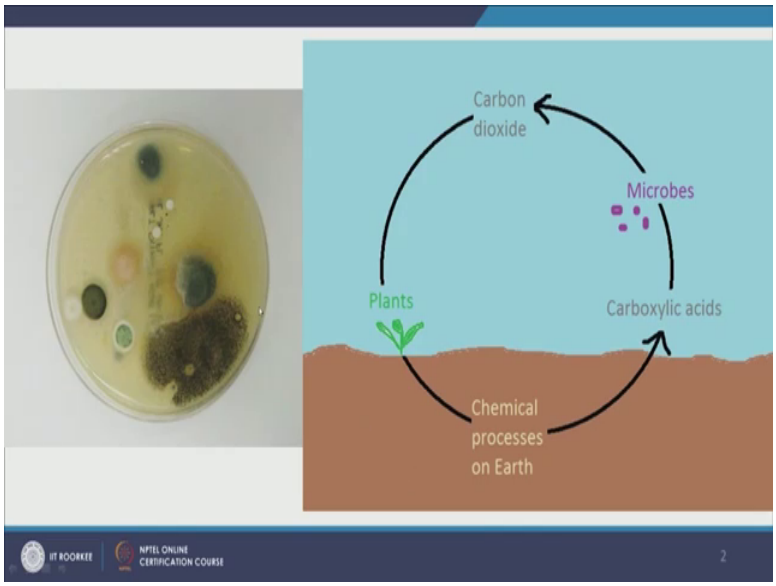

So in this slide on the left panel you have this dirty looking plate and if and nothing else look here, this is an auger plate by the way very well labeled and there are at least 1, 2, 3, 4, 5, 6 different kinds of microbial communities growing. So, there is this black mold kind of fun fungus kind of community this looks like colony from bacteria and same thing some interesting stuff growing here this is green so it might be phototrophic, now this all this is a culture of airborne microbes so this is a culture of bio aerosol it captured from air. So, look here the microbes that are invisible in the air because you know their habitat their bio aerosol is really tiny when they get a larger habitat to live like this auger plate they are visible and so you can just see the morphological diversity here.

Now, on the right panel we have a very basic schematic of how the microbes are processed from air to terra? So, let us start from plants; they have the root activity, they effect and the chemical processes in the earth they affect the surface sorry the soil microbiology and then these microbes are released into the air and here we have carboxylic acid we have carbon dioxide so there is a chemical reactions also happening, but they are released into the air and then they use whatever nutrients they can find in the air and eventually find themselves back in the soil.

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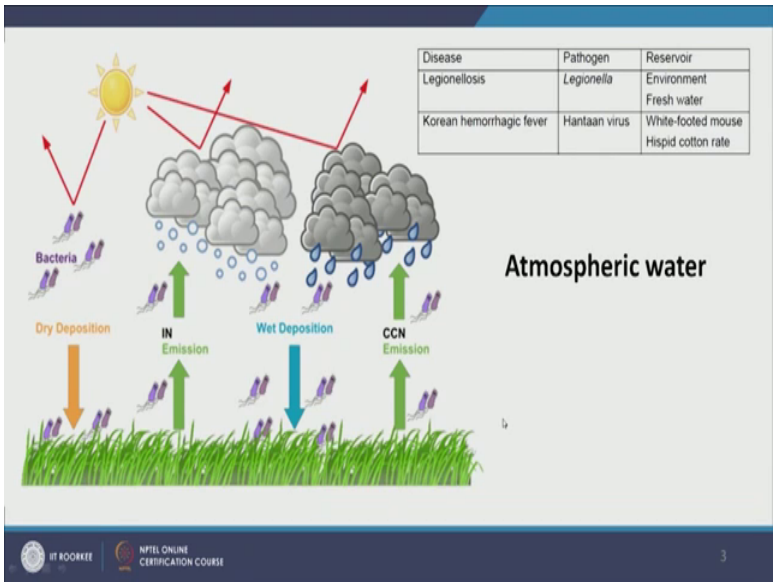

So, this is a little more detailed diagram and I think more helpful. So, let us say we have a bacteria in the air or microbes in the air some of them would get disinfected by the sunlight itself you know U V rays kills microbes some microbes and the way it does that is; U V creates thymine dimers in the genetic material of any microbe that it can and when that happens the microbe cannot replicate and thus it is progenies are no longer formed and it dies a natural death and the community suffers the population suffers.

So some of them would actually die off because of the U V irradiation some of them will actually do the job of reflecting the U V irradiation back into the atmosphere, but here we have bacteria happily floating something in the air, because of their small size they can persistent subsistent air for a really long time alive or dead it did it will take them a long time to come and settle to the earth's surface so but it does happen and this is called dry deposition, so when they naturally succumb to gravity and come down to earth it is dry deposition and then we have the other directional movement also where we have emission for after Easter micro biome.

So, the terrestrial microbes you remember in the previous lecture I talked about a human being walking into the room in, the moment we walk in the room it is like the microbes are just being shed from us and entering the air and does not happen just when you walk into the room in fact, wherever we go we do this we are continually shutting the microbes and we are continually being exposed to environmental microbes and similarly

the earth is also in a continual equilibrium in which it is sending the microbes to the air and the air is allowing dry deposition of microbes to happen.

So, this emission of microbes will allow the microbes to go all the way to the clouds definitely depending on the local weather and atmospheric conditions, but once it has reached the clouds here it will form very stable bio aerosols it can help the clouds formation also we will talk about nucleation in the previous class and then what we have is wet deposition let us say there is the rain, so these microbes can be embedded in the rain particles and they will come down and they will deposit. If you ask me this is the reason why people talk about do not bathe in rain you will fall sick I am not sure that is a reason, but the might be not remember not all microbes are bad for health so please do not worry before you bathe in the rain if you like doing that kind of stuff, already and next we have C C N emission so this is also another route through which the microbes can get aerosolized.

Now, one very obvious method for microbes to get aerosolized that we have not talked about yet is human activities, especially when it comes to public health this is very important. So, think about a person who is sick let us say I have flu I am sick and I go sneezing everywhere because that is one of the symptoms every time I sneeze I am emit I am emitting the aerosols that have the flu virus and with these and depending on the size of the aerosol, depending on their characteristic physical chemical characteristics they will persist in the environment for some time and any human being or any being who comes into contact with these aerosols will receive the virus and sometimes it does not have to be just directly received but it can deposit on a fore might and then the human being can pick up from the fore might. So, fore might is any surface that has a pathogen and when we come in touch with the pathogen it makes us sick.

So, we I mean this diagram we are not considering that, but in context of public health this is very important and I would like to mention here one of the studies that happened at Virginia tech some years ago, where they looked at how viral pathogens persist in air in bio aerosols and the question they were trying to target was why is the flu season in India? The rainy season the hot and humid season whereas, the flu season in North American countries is the winter season when it was a dry and cold.

So, remember with flu we are talking about viral flues and in flue we know that these viruses can travel really long distances, so go back to your previous lecture and notice that how I talked about the microbes; specially, the flu virus traveling from one end of the world to the other end diametrically opposite end of the world, so we know that they can persist really long but why is the seasonality present in the flu virus epidemics and outbreaks? And the answer that they proposed and they had evidence in support of was; that the persistence of virus in these bio aerosols depends on the weather conditions, so if there is more humidity like you notice here in the clouds and the temperature is hot or humid they will live longer than in case of virus we do not of life we talk of integrity the integrity of viral particles which serve would be longer would survive longer.

And on the other hand if it is a humid and cold not so much if it is dry and hot not so much the proteins will get desiccated and they will lose their integrity, but if it is cold and dry; the other end of the spectrum the violet persistence will be very high. So, we do know now that where the bacteria where the virus where the microbes are going and what conditions we have in the air determines how long they will survive and this is very important from public health perspective and here I will briefly mention another research that is happening in again in north America where they are looking at how the city's bio aerosol is determined by different activities that are happening.

For example: The wind blowing from ocean will bring in some bio aerosols, will bring in some microbial communities and if I have a sewage treatment plant that is undergoing severe aeration and their activated sludge process nearby that will allow some kind of bio aerosols to be emitted, now there are two microbial community by two different types of bio aerosol systems interacting with each other and how that would affect the net bio aerosol community structure microbial community structure in bio aerosols for that shore for that region? So, now there is a lot of research happening and even though it sounds like let us look at more concentrated form of pathogens present in surface water present enough food in our for might's before we go to air, but we are realizing that the airborne transmission is very important.

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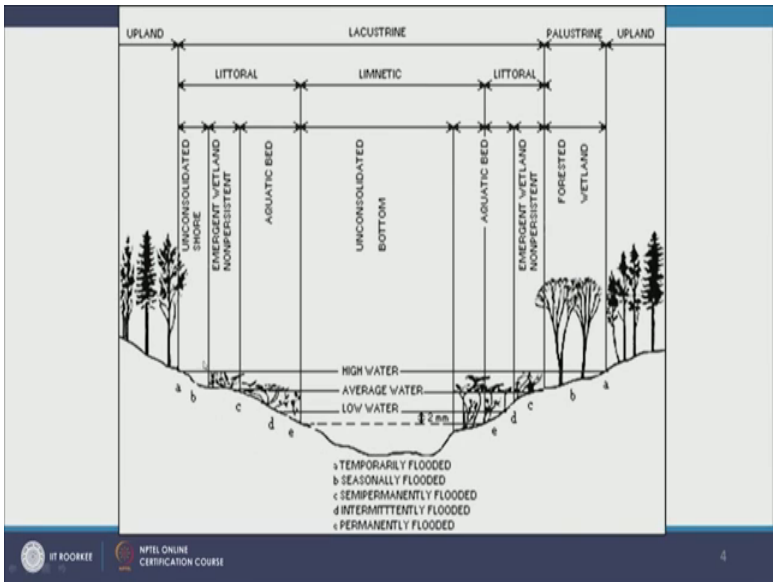

Alright, so let us move to now the aquatic system; so here I have a profile a cross sectional profile of on surface water body and please look carefully now from e to e is the para nearly permanently flooded region and some d to d the line where it says low water, so this is the minimum amount of water that we expect that will be present throughout the year so even in summer and dry seasons it should be present, average water is what will be present on average and then high waters during the flood. Now if you look at the profile you will notice that we have plant like structure is growing from definitely below c to c definitely below d to d and somewhat below e to e, but then in this particular region there is nothing there is no growth this is the unconsolidated bottom so we do not have any major vegetation growing in this region and one of the very simple reason is that the question is how deep this slide go to allow the vegetation to grow, now because it is unconsolidated bottom there are very interesting things that might be happening on the physical process level and we should be affecting the microbial community.

So, and then we have between the low water average water and high water we have the consolidated region we call anything below as aquatic bed and their different names here which I encourage you to take a look at. So, when we talk of higher water the; that is a flood zone, any place until where the higher water will go is called as the lacustrine system ecosystem and the microbiology of this system is very unique.

Now, notice here is in some parts here between average and high; they are the parts of the soil there are the parts even in the terms of water when it is there is flood, that have only seasonal presence of water they are own seasonal presence of flood and thus the microbes that survive here or the variation they undergo through the air would be different than between d and e layers, there is always water present and definitely in the unconsolidated bottom where they have very little root activity and very little vegetation, but lot of physical processes governing this part lot of sedimentation So, take some time to go through this diagram and learn the names of different parts of a river system of a surface water system.

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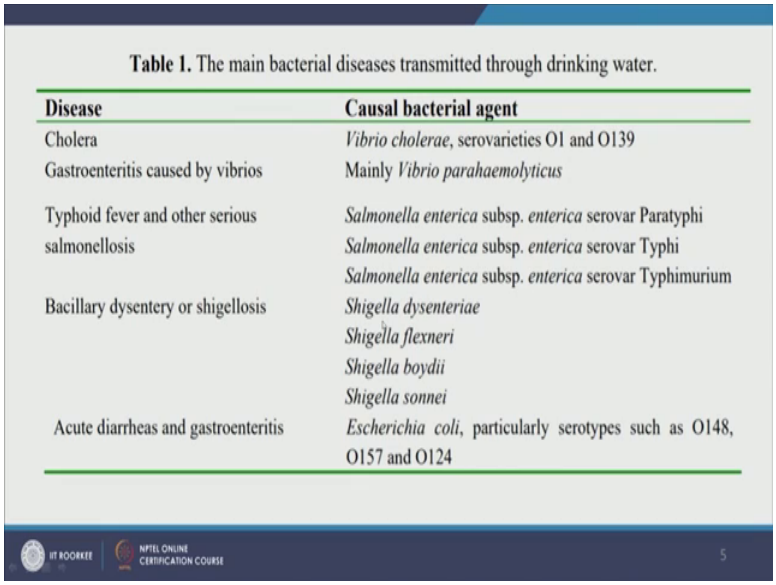

Alright, so when we talk of surface water as I have mentioned in the previous lecture we are very interested in public health, because that is still the major source of drinking water for most communities across the world. So, here are some lists of diseases that are water related and in the subsequent lectures when I talk of drinking water microbiology I will go through them and many more in detail. So, this is just for your information and the chief one that we have mentioned them here are the vibrio cholera that causes cholera and by the way any in our world as I am recording right now there is a very bad cholera outbreak in Yemen which is a refugee crisis so this is very relevant.

And then we have salmonella; which causes typhoid, a part of a type of salmonella that cause typhoid and this is very big issue in India and then we have Shigella which causes

the dysentery this is again another big problem in our country and then we have E coli and there are particular types of E coli; O 148, O 157, O 124 that causes acute durian gastro enteritis. So, these are only some of the water related diseases there are many more, but we are very interested when we are talking of surface water microbiology we are very interested in them.

In fact, in our regulations the pathogens we will look for are we look for E coli kind of coliforms we look at Shigella salmonella. So, if they are present we know that water is not safe, we will we do not go ahead and do detection for giardia cryptosporidium call them regular level, so these are the most important from regulatory perspective also.

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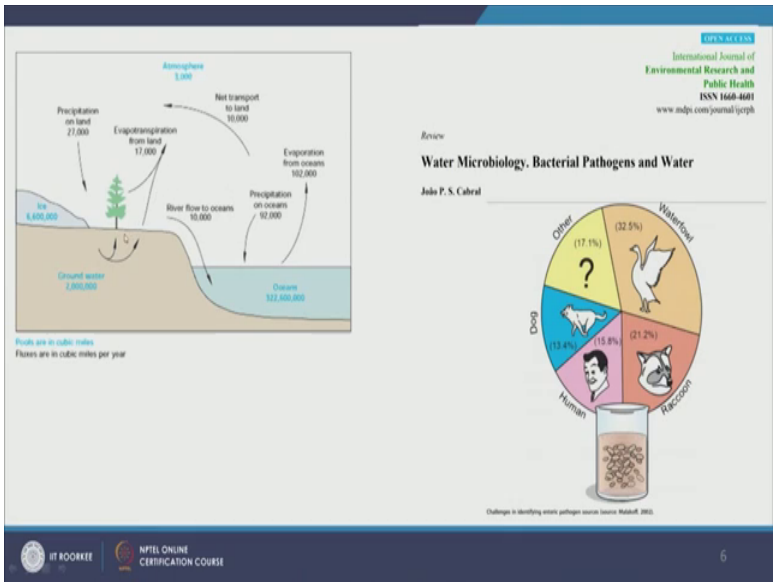

Now let us look at the water microbiology interface. So, this is very nice diagram. So, look here in oceans we have certain amount of pathogens some of them escaped into air through evaporation and then precipitated back some of them reached atmosphere in the clouds they precipitate on land some of them are trapped in ice and in fact, the ones that are trapped in ice is how we tell lot about ecosystems of past.

So, we can drill cores and we can see how what microbes are trapped from 1000 of years ago and then get an idea of what the air quality was? What the water quality was? How did the world look like then?

And then we have some that percolate down in the ground water we will talk about them and then there is a lot of microbial activity that happens around root. So, in one of the previous lectures I talked about the root micro biome the bacteria that fungus and bacteria and other microbes that live with the plants in their root system and they have lot of root activity going on and then you have evapotranspiration.

So, you notice that the microbes follow the water cycle and this is because remember the cellular membrane of water is cellular membrane of a microbe in general is perfect for it to survive in water based system, alright this is a very wonderful cartoon that I took from one of the papers and I like this because whenever we do analysis of surface water microbiology and ecosystem we notice that it has it represents or we notice that it is a collection of microbe with microbes from very different sources. So, for example; this cartoon says that 21 percent is 1 raccoon, 15 percent for human, 13 percent from dog, 32 percent from waterfall, 17 percent we cannot do so we do not know.

So, now because of our metagenomics we can actually do this analysis and then we can do a P C O A analysis principle coordinate analysis and we can get an idea of what percentage of the microbes match different sources and we can get an idea waterfall is the major cause of contamination there is also some human contribution in this particular sample, in India most of the water samples in surface we are more likely to see a very high contribution of human just because of our overpopulation definitely very little raccoon. Alright, so now let us see how the human activities animal activities affect microbes in our environment.

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So, this is a very common sight in India and you must see this every now and then if you travel any bit outside the city sometimes even there in the city, this is we have animals grazing interacting with the water bodies and pooling here and releasing their micro biome into the water. So, the water will take the animals fecal matter the animal skin mat and microbes and it the microbial community of the water will change, this might you know go into the fields where and the food is grown so it interact with the soil microbial community and then they wash from the agriculture feel again might enter the stream.

The other way direct the other direction that the water can flow is that; let us say, the irrigation is practiced here then the soil microbial community comes and becomes part of the surface water and then we have definitely another practice of money order applications. So, in India we use gober whether it is cow manure or buffalo manure and we use them for fertilizing our field and it is really a good application of otherwise solid waste so it is really nice and upon manure application when we have when we wash by irrigation of if there is a rain then that again enters the watershed that again enters the surface water.

So, the surface water when comes to agriculture will definitely get sourced from animal that directly interact by surface water and the agricultural activities that we have and then the microbial community in this surface water would have some components that match

animal fecal matter, some will that match you know daily animal fecal matter and some will match a humans and other things too.

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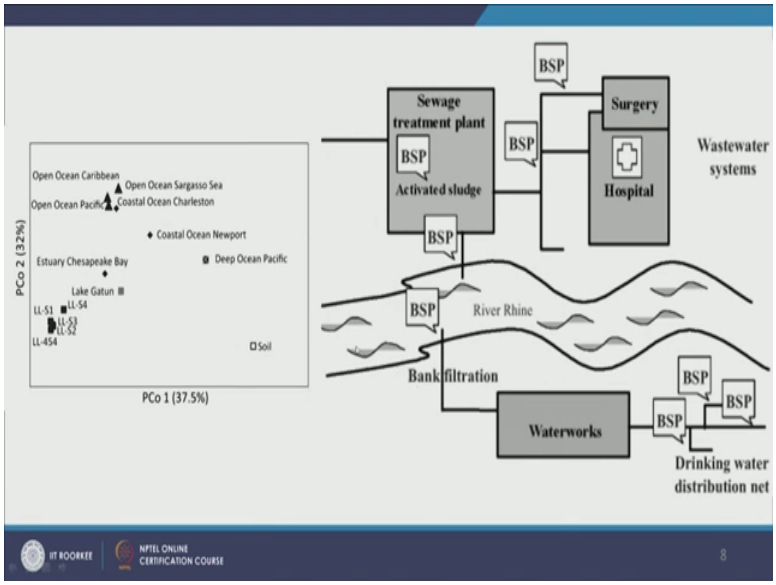

Alright, so because each watershed is very unique not every watershed is in touch with agriculture not every watershed has fecal contribution of animals and manure, but some of them have industrial sources of microbes that come in or contaminants that come and affect the microbial communities in the water, sometimes it is predominantly human for example; in cities such as N C R, the N C R region or even in Kanpur in major cities of India lot of untreated sewage is directly released into the surface water and when that happens it affects the microbial community in the surface water, so in surface water we will have pathogens that are that that are found in human fecal matter we will see sort of gut micro biome there alright. So, because the there is immense diversity in the human activities and yeah mostly human activities and also the geographical location the surrounding the environment of the water body, we noticed that the water we notice that the water micro biome from different surface water can be very different for and notice here this is a soil microbial community here we have the open or coastal ocean micro community and here we have a just a big bay in northeastern America and then we have other lakes here.

So, they are different from each other some of them are very similar for example; these are very similar, these are very similar, but we notice that usually the oceans the open

oceans will orchestral ocean would cluster together the deep ocean would be little different from them, the soil would be very distinct and some lakes might be same some might be very different. So, the reason for difference could be the geography and the human activities around them the similarity is just because of their ecosystem the kind of geography they have the kind of water that they have you know the salty water the less salty water the deep ocean so no light no oxygen very different chemistry very different functions very different microbial community and soil completely different place.

So, what we notice is that? The environment of the aquatic water system even now here we are talking about two surface water bodies ocean and lake salty not so salty different limiting nutrients and they have very different distinct microbial communities and then so we notice that there is a lot of diversity we cannot generalize and say surface water bodies will have these microbes in fact, we will have to profile the microbes and get an idea of this is what we are seeing for example; the coastal ocean in Newport Virginia is very different from the in Charleston north Carolina, so these are very different from each other, even though they are the similar environment coastal ocean environment and that is why we need to profile and make less blanket statements about ecosystem who is present alright.

So, now let us look here at this beautiful diagram when this diagram is for me a very good representation of human activities and the impact of human activities. So, here we have a sewage treatment plant they are throwing an effluent in the river Rhine, then we have another drinking water treatment plant that is taking the water in through riverbank filtration, so in this surface water body it has some initial microbial community and when it receive the seepage effluent it is microbial community changed, because it received the coliforms from the sewage and depending on how good operation of the sewage treatment plant was the input of microbial community would be very different.

So, here we have a very different microbial community than we had here, the other thing is now when the water works the way a water treatment plant is taking in the water it is taking in through bank filtration which is basically riverbank filtration we will briefly talk about it later if you have not already done.

So, in riverbank filtration we allow the water to percolate into the ground and then we dig up well near the river and we take the water from the river so it has been filtered by

the soil, so now the water that we will take after it undergoes filter filtration from riverbed, riverbank we will have different microbial community than it is present here because lot of the microbes will be filtered out, a lot of the soil microbes will percolate and find their way and then finally when we treat the water and send it to drinking water to system very different microbial community would happen and one of the interesting thing is; we might assume, we might believe that this infection will remove all the microbes but we know now it does not right.

So, some part a particular kind of disinfectant might kill one part of one kind of population better than it does another, so some microbial community differences will emerge after disinfection also after treatment disinfection. So, we notice that both the kind of environment we are living in ocean environment versus soil environment versus lake environment and the human activities like shown on the right panel and affected represented by the difference in the coastal ocean Charleston and cushion ocean coastal ocean Newport Virginia.

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Now this is a picture from Chennai a very beautiful city by the way and this is a major wetland right in the middle of Chennai, unofficially it receives most of the toxic wastes of the city.

So, the lead levels level of other heavy metals level of antibiotics pharmaceuticals antibiotic resistance is extremely high in this lake. So, you can assume that the kind of

ecosystem that you would have in this lake is very different from a relatively pristine lake that that you can expect for a relatively pristine lake so here we might have lot of antibiotic antimicrobial resistant microbes growing and we might have microbes that can resist the presence the damaging effects of heavy metals and other xenobiotic and xenobiotic are chemicals that otherwise should not be there in this lake and we notice that because the nutrient level is very high we have a lot of excessive vegetation growth in this wetland and that is and that is not really healthy for the wetland in the long run, but it is one of the side effect of the extreme human interference with environment.

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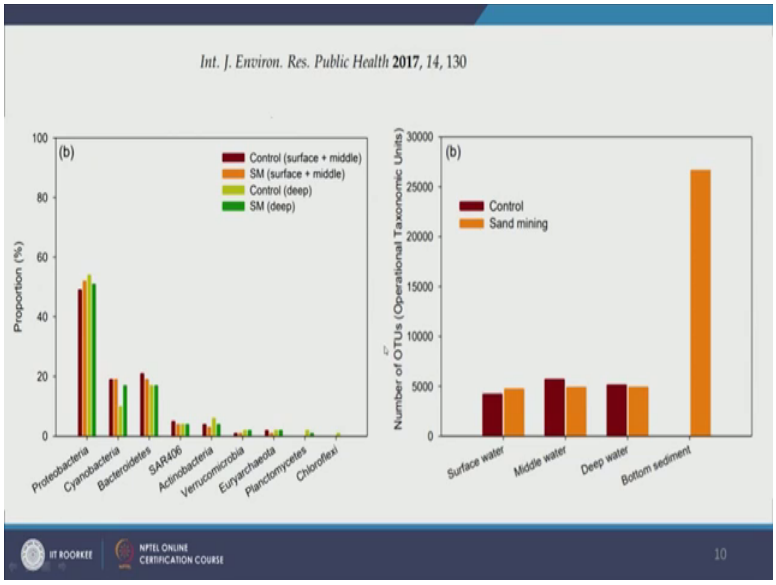

Alright, now talking of human interference with environment we have a phenomena called sand mining pretty rampant in many parts of our country definitely I know we would be not thinking it is very rampant. So, notice how human activities such as sand mining so if I am mining sand of a river let us say river ganga because I am recording this lecture in a gang etic plain, so in if I am doing sand mining even the fact that I am mining this sand near the river will change the will change the microbial communities in the river. So, here I have the bottom sediment so the; which is being mined the sand microbial community and here I have control where there is no mining.

So, we notice in this surface that the diversity, so y axis is giving you an idea of diversity it says here a number of OUTs which are operational taxonomic unit. So, operational taxonomic unit are when we do when we have not profiled or annotated the microbial

community not given it particular name then we can just say they we have these many different kinds of OUTs, now OUTs might be different species different strains we do not know but we decided a percentage difference in the genetic sequences and that is the number of OUTs, so the more OUTs you have the more diversity you have. So, we notice that the diversity in surface water when there is sand mining is different when there is no sand mining so when there is sand mining it increases the diversity and one of the very simple reason is when you are doing sand mining you are disturbing the otherwise stable bed of the river.

Now, let us look at the middle water in little water it is the other way round, middle water of a river middle we are talking from tapped surface middle and deep, so in the middle we have more diversity when there is no sand mining and in the deep it does not make a difference so remember sand mining happens near the surface. So, basically what this is suggesting is that the microbial effect, the effect on the microbial ecosystem microbial microbiology of the river would be most near the surface due to sand mining. So, it is not just diversity, but if you look at different kinds of microbes that survive we notice that; so here as I am sand mining in surface plus middle microbial community from surface plus middle and control is no sand mining, so if you look carefully at this diagram you will notice that there are differences.

So, in basically we can summarize that human activity is; geography, chemistry within aquatic systems of definitely surface water will affect what kind of microbes survive thrive and how close and distinct they are to each other.

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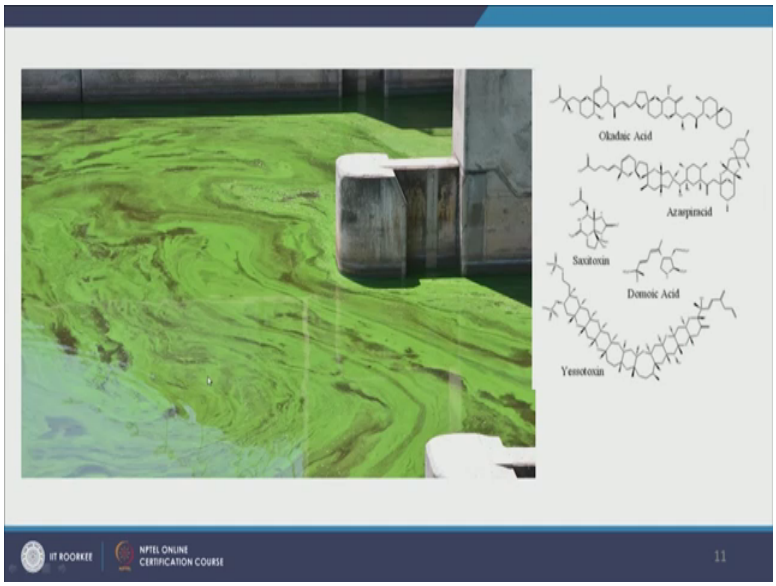

Now another feature of surface water is algal blooms. So, there are algal blooms and this is a picture from again I think Chennai where we have pretty good algal blooms growing here the dissolved oxygen in daytime is very hi up to 40 milligram per liter I have measured it. Now, one of the side effects of the algal water is that even despite the high do is that some algae produce really bad toxins, so these are some chemicals produced by some algae and these are all toxic to us.

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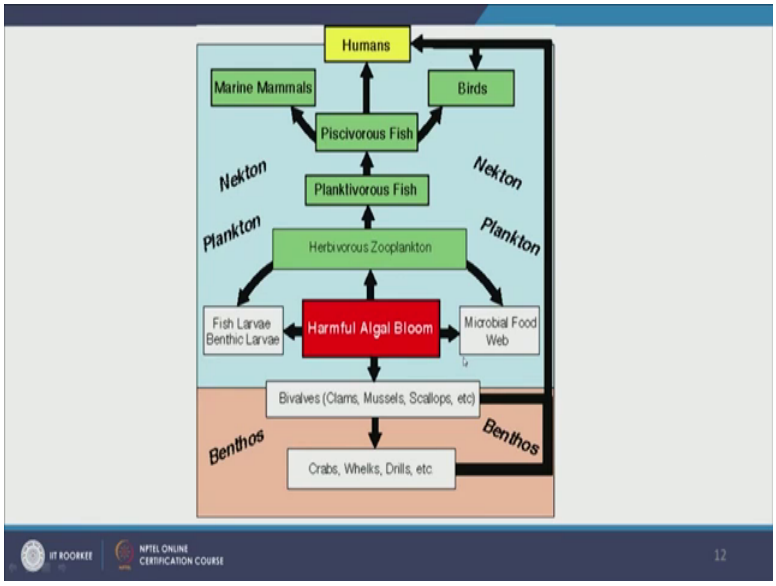

So, we do not want to have the algal toxin and here we have a brief diagram showing about how the harmful algal bloom finally affects humans. So, what we humans do is? We mess up the nutrient levels and we allow the harmful algal blooms to happen, they are eaten up by zooplankton, which are eaten by fish larvae, benthic larvae, benthic is this system is by the way the sediment system deep our water body system.

They are eaten by other crabs, mussels and scallops and they entered and they also enter the toxins that algal bloom into the microbial food web and they are eventually from zooplankton they go to Planktivorous fish which eat zooplankton and then Piscivorous virus fish which it is a fish which eat other fishes and these are eaten by birds which can be eaten by humans or the fishes are direct eaten by humans or the fishes are eaten by other marine mammals, so it affects the marine mammals we do not usually eat marine mammals, but if we do then it will affect humans and then. So, this is how the harmful algal boom we do not have to drink the water, but even if you eat the fish it might affect us.

Alright students, so today we will end with the algal blooms and in the next class we will talk briefly more about the aquatic system and then move out move on and cover the other portions of ecology and with the next lecture we will be done with the microbial ecology and then we will go ahead and we will start tackling real world environmental challenges and the applied environmental microbiology aspect of them that is all for today.

Thank you very much.