**Applied Environmental Microbiology**
**Dr. Gargi Singh**
**Department of Civil Engineering**
**Indian Institute of Technology, Roorkee**

**Lecture – 33**
**Bioremediation I**

Dear students. So, in this lecture we will continue from where we left it last time talking about the Applications of Environmental Microbiology and we went into Bioremediation.

So, I started talking about bioremediation and we understood that bioremediation is not just degradation of contaminants by microbes, but it also includes other avenues or bioremediation, wherever we find my solutions the remedies to our problems, environmental problems, using biological agents, microbes, that is by remediation.

So, we started with the one of the problems that we face today is that we are running out of our metals. So, we the quality of our ore that is left is not very good we already passed production of our important metals such as copper gold and silver. So, we need to now be able to extract metals from poor quality ores like really bad quality ores the ones that were rejected earlier, and still make profit out of it and have affordable metals available for market. So, for in this case we use microbes to encourage metal leaching.

On the other hand then we started talking about acid mine drainage problem, where because of mining the mine, which is usually reduced the ore gets exposed to oxygen gets oxidized. So, sulphide in it gets oxidized to sulphide which reduces the P H, when the PH gets reduced you have lot of metals leaching out in the water. Now you have acidic water and water laden with metals usually heavy metals, not good for anybody present in the surface water and the groundwater flowing.

And then I asked you how can we remediate this and I offered that one of the ways in which people have remediated is that they have set up columns, that are sulfate reducing columns. So, they are rich in biomass and they have the right conditions for microbes that reduce sulfate to grow in them.

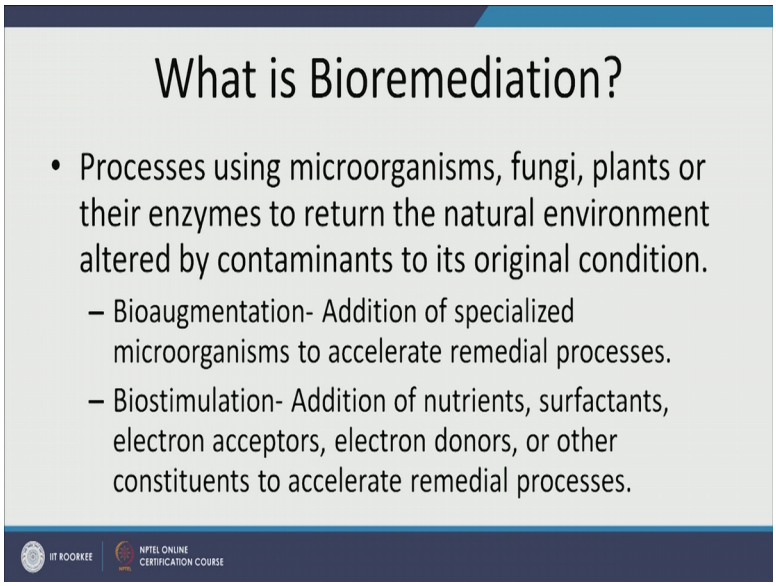
And once we have the sulphur reduction happening the sulfate in the water, will turn back to sulphide, then the sulphide will react with the metal, make metal precipitate, the PH will increase and the metal dissolution will go down anyway.

So, the water that will leave the reactor leave the column that is reducing the sulphite will be higher in PH compared to the acidic water and will have less amount of metals.

So, this is one of the ways in which the microbiological approach has helped remediate the acid mine drainage problem. And some really fascinating and impressive work in this field was done by Doctor in Prudent she was in Colorado State University. And today we will be talking about tools that she used and the tools that we can use now, to monitor the remediation progress. And how can we apply the environmental microbiological techniques that you have learned so far to solve a problem like acid mine drainage. So, let us start from there.

So, in the previous class we talked about bio remediation briefly and what is bio remediation these are the processes that use microbes to return the environment, the altered environment back to original condition or to help us find problems solutions to our problems.

(Refer Slide Time: 03:25)



And when we are using bio remediation to degrade contaminants there are 2 ways we can go about it we can bio augment we can biostimulate in bioaugment, what we do is we isolate strains.

So, we study some strains that are very good at removing a contaminant from environment. And once we have induced them in the lab and we have tested their efficiency we put them in the environment and we allow them to degrade. Their limitations with bioaugmentation in one of the previous lectures I have shown you a cartoon of this wonderful beautiful pseudomonas putida, going out in the real world and realizing that degrading hydrocarbon in the lab is very different from degrading in an environment.

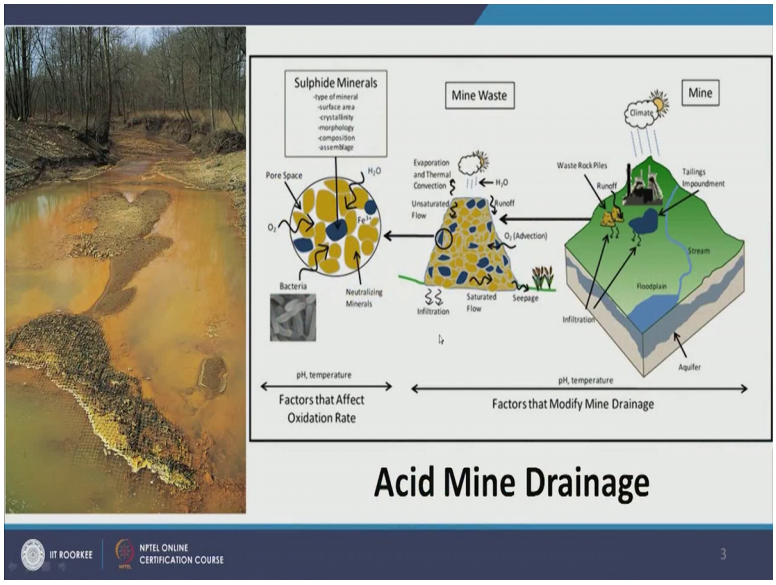
So, this is what usually happens with bioaugmentation in certain cases, it works very well especially when you are talking about perticular rate for remediation.

And biostimulation we create conditions suitable for microbes to remediate the problem to get rid of the contaminant. So, if we want more sulfate reduction to happen they add biomass or we will add the nutrients. So, that sulfate reducing microbes can be enriched.

So, biostimulation involves addition of. So, in biostimulation we do not add microbes. We light electron donors, will add nutrients, will add surfactants and I will talk about bio bio invent surfactants are important and helpful. We add electrode acceptor electron donors or anything are there any other chemical that will help accelerate the remedial process.

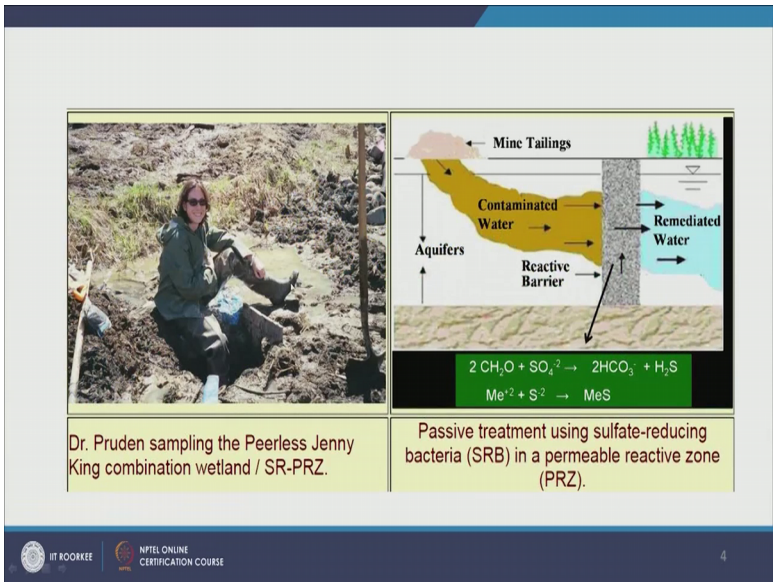
So, the chief difference with mean bioaugmentation and biostimulation is that in bioaugmentation, we add microbes, we augmenting the existing microbes in accuminary in bio stimulation, which is stimulating their existing maximal community either ways we are trying to get rid of the contaminant.

(Refer Slide Time: 05:09)




And the previous class I talked about acid mine drainage, but it is a problem as I mentioned in the introduction, this stay was the solution offered by doctor prudent means she was working in Colorado state university.

(Refer Slide Time: 05:11)




So, here she is sampling one of the acid mine drainage problem very she is a pioneer in environmental microbiology, I if you are interested in take a doing research further in environmental microbiology and it is a quite a promising field by the way I highly encourage you to follow her research, she is currently the global leader in environmental and public health.

So, in Colorado State there was a big problem with acid mine drainage. So, the water PH was very low and very rich in heavy metals and usually it would work this way these are the mine tailings. So, this is the rejected stuff from the mines or this is just, where the mine is happening and then this is the flow this is your aquifer this is the flow of water.

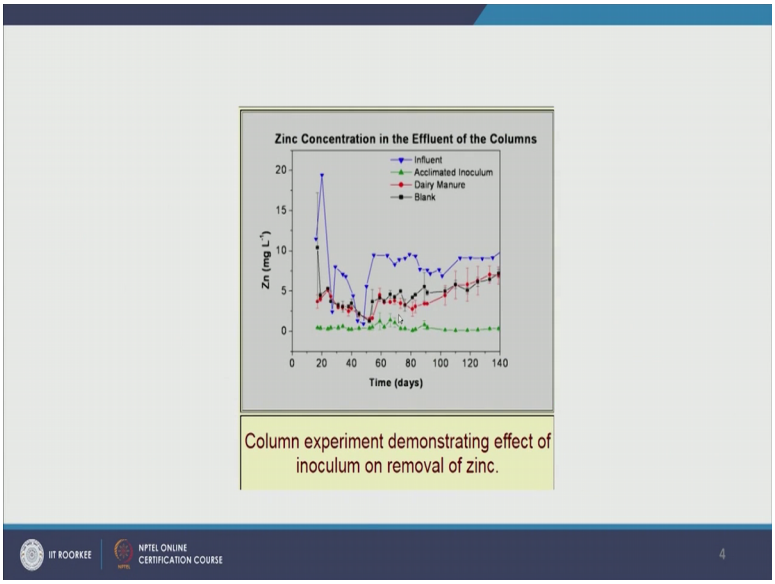
The contaminated water flows and it destroys the vegetation destroys the ecosystem. What she offered was let us add a reactive barrier. So, wherever in the permeable reactive zone she created this permeable reactive zone. So, it is permeable allows the water to go, it is reactive zone instance that is the reaction happening and these are the reactions happening.

So, the 2 important things that are happening in this is that the sulfate is getting reduced to sulphide. And the metal sulfate is getting metal that is dissolved in the water is getting precipitated as metal sulphite.

So, metal is getting precipitated as metal sulfite and sulfate is getting reduced as sulfide most she has added here is lot of electron donors and these electron donors will encourage once oxygen is depleted in this reactor column. They will encourage the microbes to eat reduced sulfate and this this becomes a sulfate reducing zone.

So, the water that comes out from here from the other end of the permeable reactor zone is remediated water it is good in PH normal PH does not have heavy metals lot of heavy metals and the vegetation is saved. So, this was her very highly celebrated work that and she did some really cool research on this and developed some microbial techniques for us to be able to analyze the remediation process.

(Refer Slide Time: 07:13)




And as a result she showed that the concentration of heavy metals in remediated environment was very low. So, what you are see here in blue is the influent is a concentration of zinc in the influent, it is pretty high. And if we just add if you do nothing and just put a reactive barrier here. So, in some places she put you at the barrier, in some places she put reactive barrier, but she added cow manure cow dung.

Now, cow manure or cow dung is very rich in microbes. So, biomass and it is very rich in electron donors, but it is lignocellulosic material. So, it is not it does not degrade readily, but it does degrade over time. So, she put cow dung and she noticed that not adding anything and adding cow dung did not have much significant difference.

In certain after certain days of cow dung added P R Z showed some reduction in zinc, but overall there was not much difference. And then in some she added acclimated inoculum. So, these are sulfate reducing microbes that have been acclimated to the severe conditions of the acid mine water.

So, usually cow dung should work really well cow dung is very rich in microbes very rich in electron donors; should be able to deplete oxygen very rapidly, should be able to switch to sulfate reduction very rapidly, but remember the water that is coming here is very rich in metals and many microbes are susceptible to metals and it cannot survive in metals rich in water.

And many microbes that live in cow dung cannot live in such acetic water. So, when they are exposed to acid water they die there is no point of carrying out sulfate reducing anymore. So, in the lab what she had done was she had acclimated some of the inoculum to the low PH and heavy metals.

So, enough acclamations it is a very interesting dough and we will talk about it we just talk about it in a bit and I briefly, I can tell you acclimation is giving conditions to the microbe so that they can get adjusted to the new environment.

So, we exposed them to the new environment and once they have been exposed they are used to it. So, now, these microbes in the PRZ they were exposed to low PH, high metal, concentration will water, in that and then the micro community had selected for microbes that are can thrive in low PH and high heavy metal laden waters and carry carryout sulfate reduction.

So, the microbes that were acclimated they showed the most consistent and definitely look at the values are dropping from high of 20 all the way to near 1 2 milligram per litre of zinc. So, they had calls the most consistent the highest amount of dropping in the levels of heavy metal in the water.

So, these were the column experiments that she first did in the lab and then eventually went out in the field and did experiments. Now if you were given this problem and this is the problem in many parts of the country how would you go about; treating acid mine drainage well. Now we know that this is an established approach. So, what we can do is we can take our cow dung we can take other electron donors our biomass that are cheaply available in India readily and cheaply available in India. And then we can acclimate them to the particular acid mined water that from the mind that we are talking about.

So, if the mine is rich in not in zinc, but let us say an iron or copper or something else or whatever heavy metals are uranium, we can expose this cow down to these metals and in the PH that they have an environment in the lab. Once they have acclimated and they can carry out sulfate reduction in presence of low PH metal related in water, then we can inoculate them in the la in the field.

You have inoculated them in the field now how do you know it is working well; obviously, you need to have some means way to measure the water before the reactive barrier and after the reactive barrier. So, you can see the drop in the metal concentration you can see the increase in PH and you can know whether this water remediated water meets your quality standards or not.

And if it does not meet your quality standards and you need to make some changes in your reactor barrier and if it meets a quality standards well and good, now the other thing is you know that there is remediation happening, but how much of it is remediation is just adsorption of metal or chemical driven reactions, because the oxygen has been depleted, but the microbes are dead, but because oxygen is deeply for sulfur dioxide sulfate is turning into sulfide chemically and the metals are precipitating chemically. And was the chemical onset happens, we know that the reactive barrier is not going to last very long because the microbiological processes are very important for it to be consistent.

So, in order to try the microbiological process now think about what are the tools that you can use to track? If my groups are still alive, if they are still thriving and what their community structure is who are the best sulfate reducers? Because here you are doing bio stimulation, but in other mine you can use these best sulfate reducers and then bioaugmentation.

In US boiaugmentation is illegal in India we are still in the experimental stage for example, right now we are using some microbial strains to sequester chromium from the groundwater in (Refer Time: 12:11) already. So, how what tools would you use to monitor your degradation and your microbial community in the reactive barrier before reactive barrier after reactive barrier. So, maybe pauses it pauses video for a minute and think about it and then you already come back and listen to what I have to say about it.

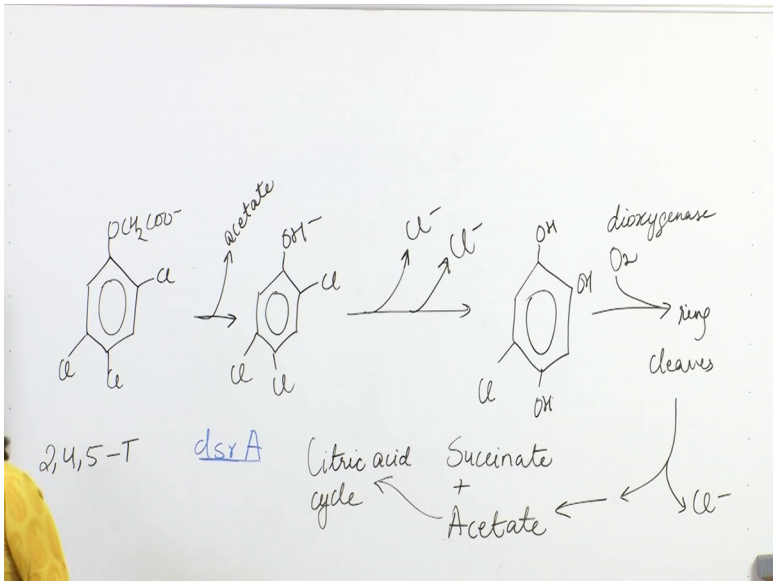
So, now, that you are back I am and I hope that you have some ideas some solution on how to track the microbial communities typical approach is first to understand, how many microbes are thriving? So, if we notice that the number of microbes is going down, number of bacteria is going down, we know that our microbial community is diminishing.

It is not doing very well and it might die out and then after some time the reactive area will bead and reduce this. So, definitely you want to measure the number of 16 s R R N A, because 16 s R R N A is a universal gene that will tell you the number of total bacteria present in a micro community.

So, the first approach that you should use is do quantitative polymerase chain reaction QPCR and target 16 s R R N A gene. So, what you can do is at different distances at right, where the contaminated water meets the reactive barrier and then some distance from here and so on and so forth until remediated water. And even beyond you should measure, if you take samples, again with depth also take samples and measure number of 16 s R R N A gene and that would be your total bacterial count. Now you have done 16 s R R N A gene, now you know total bacterial count what else can you do?

Using a QPCR, now you can target the genes that are specific to sulfate reduction, because the major criteria for this the major driver for this reaction is sulfate reduction. So, there are there is a particular genetic markers called d s r A.

(Refer Slide Time: 14:01)




So, you can use this genetic marker d s r A this gene which is specific for dissimilatory sulfate reduction a, which is an enzyme it codes for that enzyme and this enzyme is crucial for reduction of sulfite to sulphide so not sulfite to sulfide, but sulphide to sulfide.

And once you have one and once you have detected the gene you know that sulfate reduction all the way to sulfide is happening, because not only are we interested in sulfate reduction to sulfur or to sulfite, but we introduce a very interested in making hydrogen sulphide, only when this is present the metal will precipitate a precipitate readily.

So, you can do QPCR and tar targeting gene d s r A and again at different defth. So, you know at which in this way you can also know is this very sufficient for the reactor barrier or should it be more white or is it too much. We do not need to have such wide reactor barriers all this information you can get by tracking with which the reduction in d s r A in the gene that is specific to such a reduction what else can you do?

Once sulfate has been exhausted methanogenesis can certain. So, you can look into MCRA. MCRA region is specific for methanogenesis what was can you do? So, these are based on electron acceptors electron oxidative gradient. Now on the electron donor site will have oxidation of biomass, oxidation or biomass, sorry oxidation of cow dung, because it is cow manure here in India also. Buffalo manure common here are very easy to find.

So, in order to understand oxidation of cow manure you can use markers that help you understand, how to attract degradation of complex carbohydrates? And for example, for aromatic the hydrates you can target the catechol based proteins the enzymes that degrade catechol intermediate. And then so when you track them with depth when you track them with width so, both with depth and with it you can get an idea of the functional characteristics of microorganisms.

Now coming back to the one of the questions that I mentioned earlier, if I know what microbes are the best when it comes to sulfate reduction. In this particular case next time I do not need to add come in your I did not have such wide reactive barriers all I need to do is add those sulfate reducing microbes and they will take the care of the job, or let us say this reactive membrane this reactive barrier it stops working as well as it is doing right now what I can do is? I can just add inject by augment those excellent self-reducers they resuscitate the self-introduction Micro Billy driven sulfate reduction process.

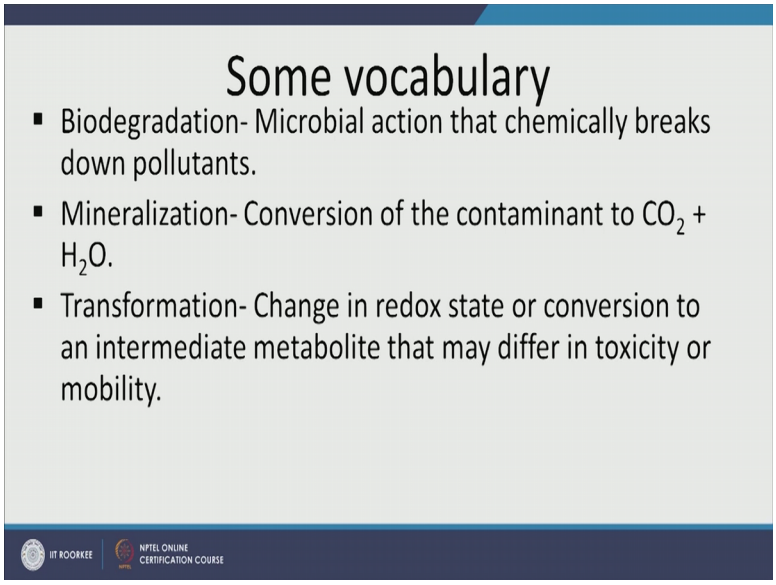
In order to isolate them what I need to do is I need to take multiple samples I need to take them to large and then I need to culture the microbes that are present there and then when I have cultured them, I everything to isolate them and I need to see how well they are doing at sulfate reduction?

The other way is that over time, because the microbes that are better at sulfate reduction over time they will be enriched in the community. So, what you can do is you can collect samples from select sampling sites and over time and when you do that you can see how over time the microbial community is changing.

So, you can profile the microbial community and thankfully for you now we have fourth generation sequencing techniques, third generation sequencing techniques. So, you can do sequencing of the micro community using ion current platform, when the nanopore sequencing becomes more common and popular in India, you can use nanopore based sequencing or you can use the same old illumina sequencing, which is very very useful for pyral sequencing, which has very low error rate and sanger sequencing will be very expensive and tedious so and less informative so do not go there.

So, you can use this next to next generation sequencing techniques to sequence profile the microbial community and note how the structure of microbial community is changing over time under the assumption that over time, the better substrate reducers will be enriched as long as there is sulfate present. So, you need to use this microbiological technique in order to answer acid mine drainage problem in the country.

(Refer Slide Time: 18:13)




So, let us go through some brief vocabulary and then move on to other environmental challenges. So, biodegradation biodegradation is when microbes they degrade chemically degrade your pollutants mineralization when finally, the microbes have degraded your contaminant to an extent that now you are producing minerals gases like carbon dioxide water.

So, they cannot be degraded for the most degraded version of pollutents possible, in transformation what we do is we transform? The redox state or we transformed to some other metabolity to some water product, which is which has reduced toxicity or reduced mobility.

So, if you talk about acid mine drainage we transform the oxidized metals metal sulfides to meta sulphide, which will precipitate, which are more stable have low in mobility. So, this case we are changing the redox state of the metal and converting it into an metabolite that has low mobility. So, this is biotransformation then you have another term called xenobiotic xeno means unfamiliar.

So, any compound that is not very familiar to life is xenobiotic nowadays not. Nowadays, but in past few days definitely nowadays also, we use many chemicals in our day to day life that were not present on earth before mankind invented them and started producing them in labs and in industries.

So, these are contaminant that is entirely foreign in nature and thus less amenable to bio remediation. Now over millions of years the microbes in our environment have gotten used to certain compounds and certain contaminants and they are very nice integrating them.

For example, wherever there is an oil well and oil routinely seeps in even before man started exploring oil and taking it out from the earth, the oil naturally would seep in. So, in for example, in the deep vents in the oceans and the seas. Then in those 8 years the microbes in the vicinity of the oil sea would be quite used to degrading the contaminants over time degrading the petroleum over time. And this is not as xenobiotic because in this microbes are used to the presence of petroleum and they know how to degrade it and they are very good at it and they have evolved over many many generations to be used suitable for living their xenobiotics.

Because they are new on the face of earth the microbes are taken by surprise they do not know what to do with it, many a times they are they die because the xenobiotic interferes with their life processes many times they just ignore it and move aside. Sometimes the xenobiotic resembles the, resembles our compound that microbes are familiar with and they know how to degrade it and how to use it for food or energy. And then our electron and then the microbes will actually degrade it try to degrade it similarly and if it works out well for them they will be able to degrade otherwise they will not be able to degrade. So, this is the bue challenge of xenobiotics.

(Refer Slide Time: 21:14)

# Some Important Topics

- Gene Regulation
- Metabolism
- Metabolic Control
- Aerobic and Anaerobic Pathways of Contaminant Degradation/Transformation
- Enrichment Cultures
- Bioremediation Technologies
- Molecular Fingerprinting Tools

Now, some important topics that we need to cover when you are talking about bio remediation, we need to understand gene regulation. So, we need to understand how the genes are regulated. So, remember in the acid mine drainage I was giving you an example of quantitative polymerase chain reaction, you can do QPCR here and find out whether the genes for the sulfate reduction are present for meccano genesis are present or not and that will give you an idea of functional characteristics.

Now if the gene is present I have mentioned this before it does not mean that it will eventually, we transcribe into RNA. Even if RNA is present does not mean it will be translated into protein, if protein is present does not mean that protein is actually active protein.

So, at each step there is regulation we need to understand what things trigger gene regulation, what things trigger these regulatory processes. So, we need to understand them in this study for bioremediation, we need to understand metabolism. Some contaminants are very well as electron donors, some contaminants are very well as electron acceptors.

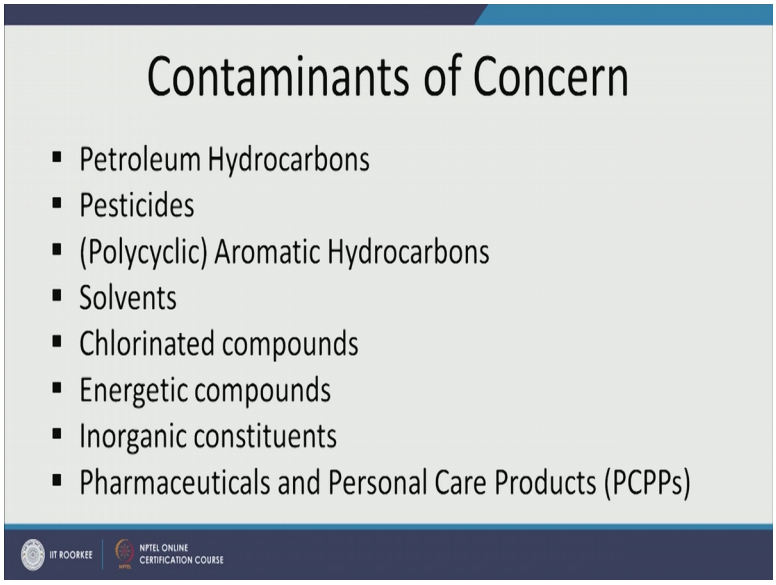
For example, the metal sulfate or the oxidized version of metals they act as electron acceptors right, on the other hand petroleum another contaminant will act as electron donor.

So, we need to understand where and how in metabolism we also need to understand, how the microbes will eventually degrade a contaminant? What are the different steps is going to go through it? Will it be in assimilatory degradation or dissimilatory degradation in assimilatory, they actually assimilate that the daughter products of the degradation into their body. The user for making them biomass in this assimilatory the only degraded to get energy or electrons. They metabolic control, they have everything in line for metabolism, but what is affecting, what is regulating their metabolism? Then we need to understand the both aerobic and anaerobic pathways of contaminant degradation and transformation.

So, same compound like hydrocarbon when degrading aerobically it will have different end products versus if it is being degraded an aerobically. So, we need to understand both anaerobic and aerobic pathways of contaminant degradation or transformation. Then we will talk about enrichment cultures why they are important in bio remediation biodegradation and how do we use them?

And then we will talk about certain bio remediation techniques followed by molecular fingerprinting techniques, which nowadays have to be next generation to tecque sequencing techniques.

(Refer Slide Time: 23:26)




Now what are their contaminates are concerned, we are very concerned about petroleum hydrocarbon; not very long time ago there was a major oil spill near Chennai, in Northeast India many we have many oil wells and many of them are routinely caused oils spills are destroying the local environment there. It is just very unfortunate that this is not making news in our country, the number of oil spills major or minor that are happening in the country different parts of the oil fields in our country and are affecting the water affecting the soil and the local flora fauna and public health.

So, better lime hydrocarbons are very interested in the other thing is some petroleum hydrocarbons depending on the well they are coming from the edge of the world, and also the process the refining or the processing of the petroleum hydrocarbon that has happened, whether it was raw refined. They might have certain components which are very very toxic for example, arom if the petroleum hydrocarbons are rich in aromatic components from a particular well and it undergoes a spillage in the environment or it is exposed to the environment, but the environment is exposed to the aromatic rich petroleum hydrocarbon.

Now these aromatic components they are more soluble in water, because their aromatic and the electron rich they usually form very good ionic bonds and ionic bonds are usually more soluble in water. So, the aromatic compounds and they are also very toxic. So, not only will not only are they more toxic, but they are more likely to be present at a higher in water. So, they will affect the aquatic life and human life more.

Then we are very interested in pesticides in India this is a major problem. Why is it a major problem, because most of our Indian citizens are still involved in agriculture which is the back actually, I because it is the backbone of our country and we need to help them help our farmers and agriculturist.

And one way we are trying to help them is by giving them more and more freely available not freely, but easily available pesticides. The pesticides what they do is they kill the pests; obviously, many of these pesticides xenobiotics. They are poisons because they kill eukaryotes for us also, for environment also and for helpful insects also.

So, in agriculture like in human body we have good insects, we have bad insects, pesticide tries to wipe them all thus disrupts the ecological balance in natural ecosystems; not only that these pesticides are water soluble. So, they flow through our surface water runoff they seep into the groundwater and they form quite substantial they straight contaminate quite substantial number of drinking water and water surface water across the country. So, pesticides and many of them are recalcitrant. So, they are very hard to degrade the other thing we are interested in is aromatic hydrocarbons.

So, the components of petroleum hydrocarbon that I told you are aromatic and we are very interested in polycyclic aromatic hydrocarbons or PAHS, because they are not just a benzene ring hydrocarbon, but they have multiple hindrance in rings. So, they are toxic they tend to be slightly more soluble than other kinds of hydrocarbons such as aliphatic hydrocarbons.

And because their polycyclic they are highly stable very recalcitrant they are not going to degrade easily. So, PH is degradation remains a major problem across the globe, we have a interested in solvents. So, we use solvents all our day we like where we are painting a car, painting a house, we use solvents and these solvents what happens to them? We just when they are done using them, we just dump them on the ground or dump them in the dump yard and when we do that they infiltrate our groundwater and then we have a major issue .

Now, again there are certain shops that are industry that use more amount of solvent than how typical household would and they are the major sources of solvent contamination of groundwater.

Then we have chlorinated compounds such as perchlorate such as bleaching powder. And hence we use a lot of chlorinated compounds and many of them are recalcitrant like perchlorate based compounds and when they infiltrate groundwater, they create a big nuisance and they have to be treated.

So, these are again what we are very interested you see the global problems pesticide is certainly a big in India, the other beginning India is fertilizer. And some fertilizers are not a major issue, because microbes uptake them, algae uses them, which becomes an issue if it is the lake trees take them, plants take them, but some fertilizers are not good for environment and they are recalcitrant as well.

Then we have energetic compounds these are very rich in energy. So, they usually degrade very fast, we have inorganic constituents such as metals and then we have pharmaceuticals and personal care products in recent decades, pharmaceuticals and PCBS personal care products have emerged as a major source of problem why? Because the medical care is now more readily if they available to India.

For example, for most medicines in India you don t even need a prescription from a registered doctor, just go to a medical store ask for some pharmaceuticals ask for medicines and they give you. Sometimes you do not even know what medicine you need to get, but you just ask the medical store person and he will give you some medicine that he thinks is best for you.

So, that like see doctors. The one of the major disadvantage of this is that the human beings we have a tendency to eat medicines just, because it makes us feel better thanks to a placebo effect. So, even though it is a headache and does not require any microbial antibiotic, I will definitely go and get an antibiotic from store so that I can feel better thanks to placebo fact.

Now because this lot of antibiotics and anti microbials and pharmaceuticals in general are being consumed by human beings, I registered doctor who is well trained will tell you used his medicine for 5 days for 10 days or how much ever longer it takes, but when you have free access to pharmaceuticals we soft drug ourselves we self-administer, the drugs and in this way we more they more often than not we are abusing the drugs misusing them or overusing them. And as a result the concentration of pharmaceuticals in the environment increases a lot.

Now what the pharmaceuticals do they kill microbes, they kill they are proxying to many different life forms and they also affect the, they create other problems to affect my rural communities in ways that hit back to us.

So, in short the pharmaceuticals are now a major major problem in our country and across the globe where, because the levels of pharmaceuticals have increased and in the environment. And not all that pharmaceuticals are not very good if their present environment for many reasons because some pharmaceuticals are in decline disruptors.

So, the harmon therapies for example, we give steroidal pharmaceuticals to relieve allergies right and autoimmune diseases. Now in these cases steroids are very good for them, but they are very bad for us the corticosteroids not the muscle building steroids. So, that these carting asteroids are very bad for healthy people. So, if they are high of them in my drinking water and I am drinking them regularly they will affect my body’s production of corticosteroids.

And that will affect my hormonal cycle and then we have many hormones that are actually administered as pharmaceuticals, when they levels increase in environment they affect public health and most of these pharmaceuticals are soluble in water or to some degree and then their deaths transported to aquatic systems.

The other problem is when we have higher pharmaceuticals present in water or in environment microbes, they are very clever they develop resistance to it. So, they develop a antimicrobial resistance.

So, they are resistant to all that known antimicrobials or some antimicrobial or few antimicrobial; however, it works our particular antimicrobial. Which is not good for us, because when microbes stop dying because of when there are exposed antimicrobials, sooner than later the pathogens in our body who infact a once stop dying, when we eat the medicines?

So, pharmaceuticals are a major major contaminant of concern and personal care products big big issue and will be slightly talking more about personal care products than I have done in previous years. Because now again in philosophy decades the consumption the humanism in our country has increased a lot.

So, now, we have more people using fancier shampoos more of an fancier soaps and more often again, we do not use the herbals ones that that is just treat our the natural root powder that allow us to clean our bodies without using the carbon rich soaps. Not only that not only the essentials, now essentials just soaps detergents, but we are also using other personal care products things that we do not biologically need. So, is a different kinds of makeups and creams and products that have micro plastic in them.

Now, this is a big nuisance because most of these PCPS are against xenobiotic they very rich carbon source. So, they are very good for microbes, but many of them are recalcitrant or they have preservatives in them. So, they do not degrade very easily. The other thing is many of these personal care products; they have microbeads of plastic in them. So, you might have seen advertisements of toothpaste or I must have used those toothpaste it, show some glitter inside them and they claim that this glitter will scrub your teeth and lean the teeth better.

So, many a times these are micro plastics and then these micro plastics enter the environment, because when you brush we spit the toothpaste out eventually it destroys the environment and they live very long and they are very hard to remove because they are. So, small in size and because they are plastic they imposed a li impossible to degrade in environment and there are big big nuisance environmental and public health from environmental and public health perspective.

So, these are the various contaminants of concern currently and in the next few lectures we will be talking more about them, how to degrade them what are different studies that have happened, what are different pathways we will be looking a little bit more in detail about these important topics the gene regulation metabolism metabolic control aerobic and anaerobic pathways, enrichment culture, the biotechnology, technologies we use for bio remediation and I have already talked about next generation sequencing. So, I will be just touching briefly on when invert is applicable.

So, dear students this is all for today be tune for the next lecture when will dive more deeply into these important topics or bioremediation.

Thank you very much.