Environmental Remediation of Contaminated Sites
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Lecture – 24
Introduction to Natural Attenuation and its Types

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Hello everyone, again welcome back to the latest lecture session, again a quick recap of what we have been up to, right, what have you been up to we have been looking at options for remediating contaminated groundwater, right and that context I think we looked at mostly pump and treat and then containment too and then I believe we looked at PRB's in great detail and now, we are going to look at the other major aspect here.

Again, we are dealing with contaminated groundwater and how do I remediate contaminated groundwater right, so in this context let us say, I am also going to discuss some other or non-technical aspects but you know it is relevant obviously because the education is not just about you know gaining technical knowledge but about understanding the relevant scenarios let us say where you have the human element, yes.

And try to apply your particular brains accordingly, right if I may say so, right so in this context I am going to talk about a particular scenario that I face there recently that is relevant in this particular context let us say, right so here, I mean root key right now, right and this particular

vicinity we have a river called Hindon and I believe that more or less ends up joining river Yamuna if I am not wrong.

But you know you can check that and Hindon river is one of the most polluted rivers in India now, let us say and I think sugar mills, indiscriminate use of pesticides and what do we say fertilizers, right say and you have different compounds let us say and this particular what do we say, contaminants that you know or different compounds in these particular parts that you are applying to either the land or discharging into water that act as toxic compounds or exhibit toxicity now, right.

So, again the key is that you know here we have what do we see I think recently let us say a 2000 hospital bed was set up and for primarily because you know exceedingly high not exceedingly, pardon me a remarkably high incidence rate of cancer in this particular vicinity or that particular area let us say, right so, you know to address this you know they set up this cancer hospital.

Again, obviously cancer is the symptom and you know we people at least to my knowledge have not yet identified the source of this problem but if you talk to people you know people who call a particular train as cancer train as and where you know this particular train is mostly filled up of you know these poor people suffering from cancer and the relevant people attending to the relevant particular cancer patient you know, taking the relevant patients to that particular hospital or from that right.

Again as most people know you know, people suffering from cancer I guess the treatment technologies are better right now, let us say but still it you know plays havoc with the economy of that particular family and also the social integrity of that particular family because you know the people you know attending to the relevant particular person are also going to be affected again that is some aspect.

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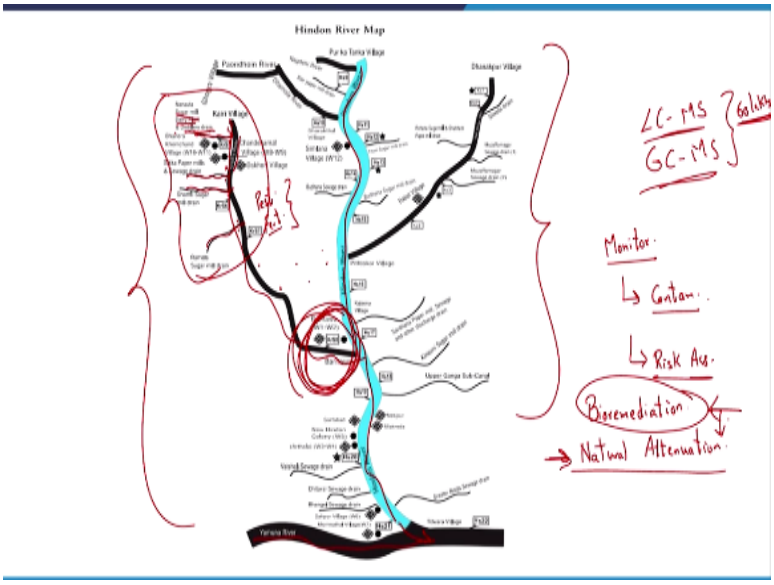

Because let us look at what I have here though, so here is the Hindon river right that is something we are talking about you know, you can search it to, look it up on Google map, right but one particular aspect that came to my particular attention recently was this particular tributary, I think it is called Krishna or such again, you can look that up right, this particular tributary, right.

Again, Hindon I believe ends up joining river Yamuna again that is something that we see out here, right and again all this particular location let us say that I have out here is typically remarkably polluted but it seems a lot of case of cancer were or higher or remarkably high case of cancer were; are reported from this particular area, this is still as of now in 2018 any way, you know burning issue here at least locally anyway, right.

So, again not much data that is available at least in the public domain but again it came to my attention because a few of my particular colleagues are from this particular area now, I mean they are biotechnologists, right and you know they are from this area and that they will looked at some preliminary studies let us say and they found that the concentrations of heavy metals, plasticizers and you know some of the other pesticides and such were high.

But they have not you know looked at that in great detail here though, right so, let us say you know if you have such a case or a scenario let us say, how are you going to try to remediate the particular you know, site now, it is not one particular village that is affected let us say, cluster of villages, wide swath of; or wide swaths of, large swaths of land here that are contaminated, how would you go about it; pump and treat na, it is not going to work.

PRB; not really right, again PRB let us say if you have a landfill let us say that some line and you have reach it coming in or you have relatively what do we say is the shape of the particular or size of the particular plume is relatively limited, yes PRB is applicable and so on here but what would you do when you have so, you know such a wide area that is contaminated and especially leading to you know, looks like carcinogenicity let us say, right.

Again, so here there are different aspects as you can see in this particular you know stretch, we have sugar mill, a dairy plant and a distillery dream and they are discharging into this particular Krishna river if I am not wrong and then again more such mills, paper mills, sugar mills discharging into this drain and widespread application of pesticides let us say in this particular area and fertilizers too, right, some of which can contain heavy metals or may be the heavy metals are inherent in that particular area with respect to you know, you have different strata sometimes you have arsenic let us say that is present in high concentration subsurfaced or relatively high concentrations.

Again, different aspects but you know this is what we have, so if you are the person what would you do right, so again for this obviously you need some background but you know the issue is that typically how it works is that though most industries have their effluent treatment plants you know all these kinds of industries, the either the efficiency is relatively poor let us say, sometimes, not sometimes most of them have affluent treatment plants at least at this stage for you know progress let us say but the efficiency is poor.

And typically, the reasons are because let us say you know not a great lot of what do we say incentive for maintaining the quality of water let us say for the relevant management of that particular company and again what is the reason because as of now, we do not have again in our; what do we say, I guess this is you know obviously, the case in developing country as in India, we do not have such a wide monitoring network of what do we say monitoring network that would give us an idea about the water quality let us say, right.

So, you know some issue crops up, there is a public outcry, people go take the sample let us say or then CPCB or SPCB steps in or such typically, SPCB you know the State Pollution Control boards depending upon the state, let us say they are undermanned as if 100 people are required

typically, they have 30 or 25 people obviously, you know to do the job you know the relevant manpower and again, you know that is something that is missing.

And again, let us say out here let us say you know, we have different kinds of compulsions too political or otherwise let us say, right so again, you know these are aspects that you need to keep in mind, this is the ground reality in general let us say and the issue here is that let us say even if the relevant management wants to get it done or as in treat the water to the proper extent typically, you know the relevant plant operator has limited understanding of the basic aspects let us say.

So, if something goes awry or goes wrong, you know they try to apply typically, anyway thumb rules and you know try to get things done but they typically, do not work, so again it ends up being the case that the efficiency is not great I mean, it is acceptable sometimes but again keep in mind that if you have so many industries that are coming in and you know and dumping their waste or treated wastes are partially treated waste into the relevant waters let us say, you are going to have remarkably what do we say polluted stretch of the river.

So, in monsoon you will have the river flowing in and you have a lot of volume of water or discharge let us say and so typically dilution but during the non-monsoon season more or less most of these rivers or streams are you know, most of these rivers as we are calling it are actually streams that just have the flowing wastes, if I can call that obviously, where is that going to go to let us going to seep into the groundwater, contaminate the soil and so on and act as reservoirs.

Let us say depending upon the type of compound you know, right that is something to keep in mind let us say. So, let us say you know this is a huge area now, you know I believe this is in Uttar Pradesh, hundreds of square kilometres or such let us say, so obviously you need to look at a multi-pronged approach at least in my opinion I am sure other people will have other opinions and so on and so forth right.

So obviously one aspect that we looked at recently or proposed was that let us say we are going to have to look at let us say upgrade; upgrades for the relevant effluent treatment plants such that even if the biological process that people use to treat these particular effluence do not work.

They will have other tertiary techniques that can be let us say relatively easily ramped up or such to be able to treat the water right.

So that is understanding or you know contain the source in a way, source in our context of the Indian context any way, right, the other aspect is obviously you already have contaminated or not obviously, most probably you have contaminated groundwater or and or soil now. How do I go about it and obviously, people are mentioned that they have more or you know higher incidence rates of cancer to my knowledge not a lot of study is done to see if the you know cancer rates are relatively higher than what you would expect in a particular control population but yes, here there is initial sufficient initial data to go by with that particular hypothesis.

Again, so what do we need to do; initially, obviously we need to look at monitoring study to understand what are the different compounds or contaminants, so upstream and downstream let us say as in I cannot go to each industry, you know get the relevant data analyse that that is way to humongous a job and we do not have the resources or the time or the manpower to be able to do that right you know and so we are going to try to identify the major sources let us say, upstream and downstream of the relevant locations maybe, right.

And then with distance and sampling at various locations of for groundwater and soil, so once we do that let us say we can understand what are the different contaminants present out there again, the issue here is that if I do not know what is causing the cancer, what are the typical contaminants; I need to look for you know, many types of compounds, heavy metals let us say limited set of heavy metals, I can start with I think 23 or so, right I can or I know the major heavy metals of concern.

So, I can look for those that is fine but with respect to let us say pesticides or fertilizers are there by products, there are many such what do we say compounds that can lead to toxicity let us say, right, how do I go about that so, obviously for that I need to have let us say LC MS, GC MS and so on let us say and typically, they are around 60 lakhs or so, depending upon the type of vendor, 60 lakhs each of them, right.

So, again the case here is that you know to get something done especially after you have relevant what do we say contamination you know, the costs add up especially in a country like India let us say where we are still developing the what do we say you know the government is

burden with what do we say not burden if I say it has many responsibilities yes, so again the funds available are limited, yes.

So, these are different aspects again but I am just giving you an idea about the different cost here again that is fine so, obviously we need to understand the have a monitoring campaign initially, right and from that I will get the data regarding the type of contaminants, right yes and then if I have relevant data about the toxicity well and good if not I will conduct the toxicity assessment and then what can I do; I can conduct the risk assessment let us say.

This is something we discussed, right so, risk assessment and then I can identify those locations within the stretch of area let us say and a generic what do we say analysis; generic analysis obviously because the data otherwise going into details for this stretch off or no large areas let us say in my opinion is relatively difficult to do so, so once you identify those areas that you know where the target population has facing greater risk or unacceptable risk or remarkably highly unacceptable risk let us say, you can target those locations for remediation let us say, okay.

So, now let us say we have targeted those locations for remediation, how do we go about that right because let us say if I am a researcher let us say if I want to go and get things done and that is not how it works, why; I need some money and how do I go about that I go to different funding agencies and ask for money let us say, right and say that I am going to propose this so on and so forth and based on that I am going to get things done, if the funding is approved let us say.

But again keep in mind that you know depending upon the priorities of that particular funding agency, is it groundwater, surface water or science or such each particular funding agency has their own priorities now, let us say you know I did approach or we did approach, one particular funding agency but they were receptive, yes but obviously, the experience that they were concerned with was one of the aspects was adverse media, what do we say coverage let us say.

So, typically in our context right now, we have a case where each and every aspect is drummed up and thus let us say people are very much apprehensive about you know let us say getting things done because if not getting things done let us say having adverse, what do we say data coming up or data that is not what do we say suitable to you, if I can call that or data that can

have issues down the line or will require the relevant government or the people let us say you know to take some action let us say, right.

So, if people typically want to avoid such situations, right so you know and we have many such containment sites or if not many considerable number of containment sites in India, so again it is an issue of priority, so how do they fund that so, you know these are issues that come up whenever you go to let us say funding agency or such too, so obviously these are aspects where the human element comes in as in you have the media involved.

And thus a local population, you have the NGOs involved let us say obviously, they play a very much worthwhile role, yes but they have their own limited resources too yes, so and again you know you have the relevant what do we say a political pressure right, so that is obviously a fine balance between all these aspects now right, again so those are aspect that I wanted to discuss because obviously, technical knowledge is relevant.

But you need to be aware of the relevant aspects on the ground here right, so that is my experience very recently and I want to just share that okay, so moving on though how do you go about this or how would you know get the system or make the system better, system as in at least from the technical point of view assuming you have a most of what you want let us say, so obviously you know we can have a multi-pronged approach obviously we are going to look you know containing the discharge of the relevant contaminants.

So, looking at improvements of the effluent treatment plants and secondly, you know in this large scale let us say if I have, identify the relevant contaminated zones remarkably containment zones, I look at PRB maybe pump and treat or some of the soil or sediment remediation techniques, we are going to discuss later, right but typically let us say if it has been constable time since it has been released.

And if the usage let us say of fertilizers or pesticides or let us say, discharge of these contaminants is over a wide area you know, you are going to have issues with applications of for most of these kinds of techniques, so what do I need to look at; I need to look at bio remediation let us say, bio remediation or understand or discuss natural attenuation let us say, yes, so first about natural attenuation, I will talk about bio remediation within the context of natural attenuation, right.

So, I guess it is self-explanatory, its natural attenuation; attenuation as in how could I understand that now, let us say reducing the effects of some aspect or variable let us say, so here let us say nature you know does its job typically given enough time, it is going to be able to degrade the relevant contaminants in that particular soil, now, right and again there are different mechanisms and such involved.

So, obviously one of the mechanisms is that you have the microbes in the relevant nature, right not in the relevant nature; in nature and they are obviously going to degrade the relevant contaminants, why is that because not obviously, they are going to have or you know they are going to try to degrade some of the contaminants, why is that because similar to us, they are as in the microbes also need sources of energy for growth and cell synthesis let us say, right.

They want to survive, they want to grow, they want to thrive too, right so, they keep looking for worthwhile sources of energy and in the soil let us say if you have the relevant electron acceptor and donor, one of which can be your contaminant you know the microbes will do their job and try to degrade that particular what do we say contaminant, so if I am not, you know adding anything to this particular system in this particular location and just trying to understand let us say or you know I have the relevant data if not understand.

And if I say that you know natural attenuation takes at such a rate that you know I do not need to do anything within a reasonable amount of time you know considerable swaths of the area will be you know, what do we say, well witness decrease in mass or concentration of the contaminant, right what can I do; I can obviously you know model the relevant case and then you know put forth data that natural attenuation is occurring at reasonably faster rates, right.

And also that what is it now; that I have you know if monitoring wells to be able to get this done right, so you know natural attenuation obviously, we just discussed in brief let us say, one aspect with respect to what do we say, degradation of the relevant contaminant by the microbes but there are other mechanisms obviously but in the context; in that context, I want to talk about bioremediation for a few more minutes.

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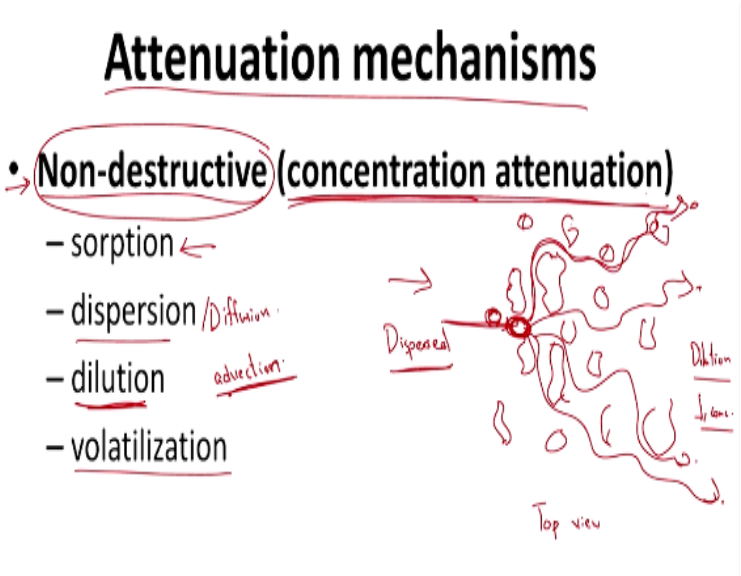

And then we will move on to the other aspects I guess, so let us see what we have here, so what are the different attenuation mechanisms though, right so, this is something we are going to discuss, so one is non-destructive obviously that means the next set of slides is going to be about the destructive mechanisms, so in that the concentration is attenuated or concentration is decreased let us say, right.

So, keep in mind that the compound is not being degraded, right but the concentration is decreasing, how can that happen that means, that you have dilution due to various reasons, right so let us say if I have 5 grams with in one litre, it is 5 gram per litre but then due to various reasons let us say if this 5 grams is now present in 100 litre, so obviously the concentration is less and the effects are less too.

And but keep in mind that the compound, the total mass of the compound is still 5 grams in the total system right, so here we are going to briefly look at some of the non-destructive what do we say mechanisms obviously, what are they; think of what we have there, so you have ground water flowing through the particular what do we say contaminated site let us say and if you what is going to happen; your groundwater is going to transport the contaminant, right.

So, you are going to have dilution of the contaminant, right because it comes in contact and you know you have a advection let us say, right so that is one particular aspect or let us say as groundwater you know transports this contaminant, some of the containment can be adsorbed onto the particular soil let us say, right again, so thus the concentration in the groundwater will decrease.

Why is that; because the contaminant is now adsorbed onto or can be adsorbed onto the relevant soil let us say, right and again you have dispersion because it is ground water not diffusion but if I am going to use the term dispersion let us say, right to understand the tortuous path or effects of dilution due to the tortuous path, we will discuss this later in greater detail or let us try to get this done.

So, if I have particle here and this is the top view let us say and all these are my soil particles let us say, soil and this is my contaminant let us say, right as groundwater you know, takes this containment through there are different paths that this containment can take, right or here, right so, you have a particular, so same containment starting at the same location because of the tortuosity out of this particular system let us say you know can be dispersed, right.

And thus, what do you see you know, it can end up at different locations, so thus again you see dilution or decrease in the concentration of the relevant contaminant, right again, what do we look at; this is my contaminant here, these are the different soil particles, this is the top view obviously, right and if the groundwater is taking this particular ground contaminant along with it because of the tortuosity of that system let us say, I am going to have dispersion let us say, right.

So, let us look at some of the other mechanisms out here, so sorption or adsorption on to the soil that is going to lead to decrease in concentration of the groundwater or concentration of the containment in the groundwater, I am going to have dispersion that is something we looked at diffusion and dispersion let us say can happen, so I will say due to diffusion too, right and then dilution.

Because you know you have advection let us say, typically, when I am talking about dilution, I am referring to the effects of advection as in ground water, what do we say is taking the containment over what do we say a larger area, then it was initially presented so, the concentration is going to be lesser obviously, volatilization. Volatilization, as in let us say you have let us say hydrocarbons or other such volatile compounds let us say, right.

So, they would; they are volatile obviously, what does that mean that they would want to stay in the gaseous phase rather than the aqueous phase, right so, if I have gas and some air out here

and the relevant not gas, pardon me, water and the relevant containment which is volatile here and I expose that to the gaseous phase what is going to happen to the volatile compound, it does not want to stay here, it wants to stay in the gaseous phase, right.

So, it is going to change phase by changing phase though, we have we see that the concentration in this particular water is decreasing, so obviously here we have different non-destructive mechanisms, keep in mind that there are non-destructive as in the mass of the containment has not changed, there is no degradation here, it is only that the concentration is decreasing, so that will have some effects as in let us say, if it is a wide area and I cannot treat it right now.

But I can see that after a few years or maybe months let us say, years maybe, right you know the concentrations are low enough in the groundwater that they do not pose a major threat let us say, right so again, natural attenuation takes place due to non-destructive mechanisms.

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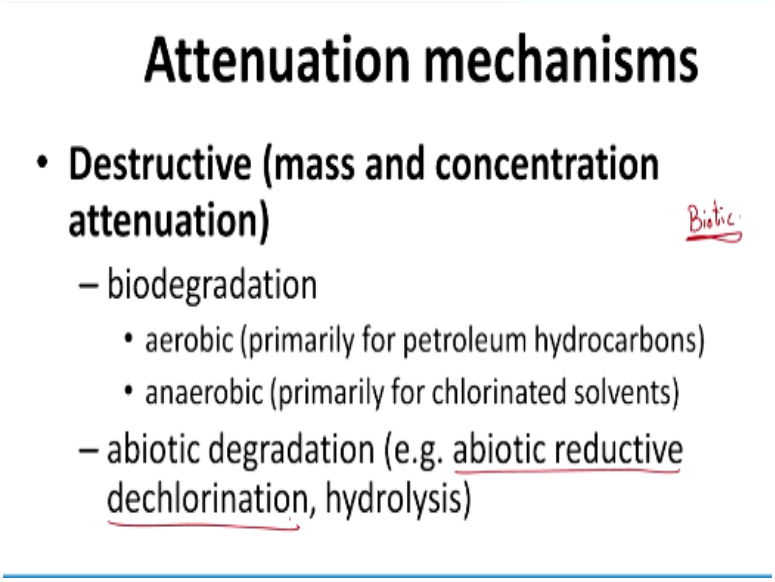

So, the other aspect obviously is going to be the destructive mechanism, in this case obviously I am going to witness both decrease in mass and thus concentration right, so destructive mechanism as in the compound is degraded let us say, right, it is not that it just change phase from aqueous to the soil, aqueous to the air or such, right so these are the aspects so, obviously how does that come about?

You have bio degradation which we are going to discuss in greater detail, right and again bio degradation, what is the thriving; not the thriving, the driving force pardon me, let us say the

microbes want to thrive, right and they need sources of energy and your contaminant will act as either the electron acceptor or donor as in when you have a redox process let say A + B going to let us say oxidized and reduced forms let us say products, you have energy released, right.

And this particular energy is used by the particular microbes and how do the microbes especially at this particular process though, they release enzymes that act as catalysts for this process to go through fast, right so, as in the A and B, you know can what do we say just A and B in contact with each other can lead to let us say, redox process going through but as you know redox process the issue is that time is an issue you do not know if they are relatively fast or relatively slow.

But typically, though they are relatively slow, right so, how do you want you know, how do you facilitate this particular process to go through faster or how do you facilitate this particular process by you know adding a catalyst, so that is what the role of the microbes are that they are you know the release enzymes let us say that act as catalysts to make this process go through faster.

And thus you know take the relevant energy for their growth and synthesis let us say, so by a degradation and there are 2 forms typically, aerobic obviously primarily let us say aerobic process, aerobic means you know in the presence, the redox process in the presence of oxygen let us say, right and what is oxygen obviously, it is an electron acceptor right, or an oxidizing agent.

So, obviously which particular compound will be degraded in aerobic conditions let us say, right, reduce compound or an electron donor, a redox process will go through only when you have both electron acceptors and electron donors right, it is not that the half reaction will go through, you need to have both the electron acceptor, right and also the electron donor, so in that context.

Let us say in aerobic conditions, if you have electron acceptor with kinds of compounds will be degraded those that can act as electron donors or which are reduced compounds let us say and obviously, you know petroleum are hydrocarbons, right hydrocarbons C and H that obviously can tells you that the carbon is in the more reduced form and thus can act as an electron donor right.

So, they are prime, these are prime candidates again we will come back to these aspects in greater detail and then obviously, we have the anaerobic conditions right, so here we see that you know I have the example for chlorinated solvents; chlorinated solvents as in you know they have Cl- let us say, or Cl pardon me, right and so, what is that typically indicate that you know CL is typically electronegative or one of the more electronegative compounds out there.

So, it is going to draw the relevant electrons towards itself or pull the electrons towards itself, so typically when you have chlorine let us say, what does it mean that the relevant compound are or is more oxidized let us say right, so typically when you have oxidized compounds, you need anaerobic conditions for their degradation, we are going to see why, okay and as we looked at in aerobic conditions typically, reduced compounds are degraded right that is something that we just looked at though, right.

So, let us move on and again then abiotic degradation as and you have 2 aspects out here, as in first let us say a biotic or bio degradation takes place biotic process and you have some by-products let us say typically hydrogen or let us say ferrous iron is produced let us say, right and what do they act as; they then can act as reducing agents to degrade the containments, so there is again a symbiosis between biotic and abiotic process, right that is something we have here as an abiotic reductive dechlorination, right.

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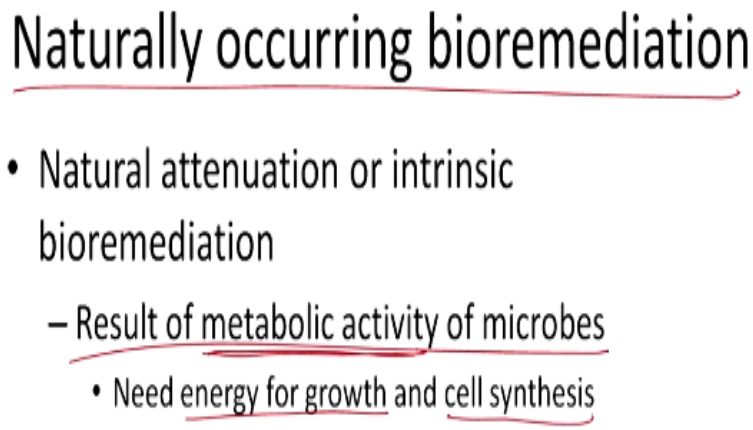

So that is something you know we are going to look at later, so next so typically, we are going to look at bio degradation for some time or bioremediation for a few minutes right, so obviously

as we discussed you already have microbes out there and you know you are going to have naturally occurring bioremediation, right so that is obviously within the context of natural attenuation but what are the issues though, right, what are the issues here?

And I think we discussed this result of metabolic activity of microbes, I guess in metabolic activity meaning the process that are involved in the production of energy required for growth or you know sustaining life, right metabolic activity, so we have our own metabolic process, the microbes have their own metabolic process and so on so, obviously the driving force is metabolic activity as we already discussed.

So, again what is the; what do they try to do; they need to get energy for growth and cell synthesis, right the microbes want to grow.

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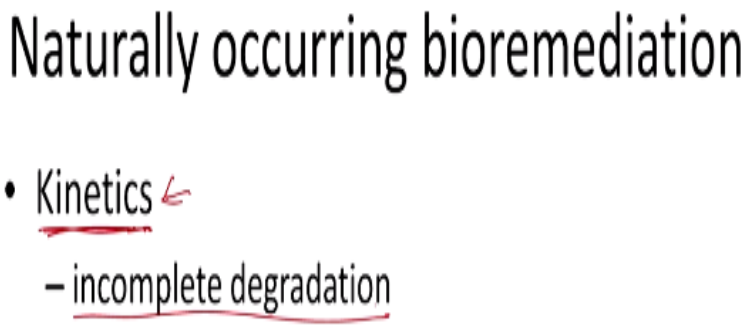

So, the key aspect that I was trying to hinted, early hinted earlier was that kinetics is an issue right, you know depending up on the concentrations of the relevant acceptors, electron acceptors or donors let us say are because of the type of redox process, the kinetics can typically be low even for not even, for natural attenuation let us say, right or it can also lead to incomplete degradation as in let us say if complete degradation is represented by A going to Z.

But it only ends up at A going to D, let us say right, so D might be more toxic or still toxic enough, so incomplete degradation is also a relevant aspect as in you will not have complete degradation.

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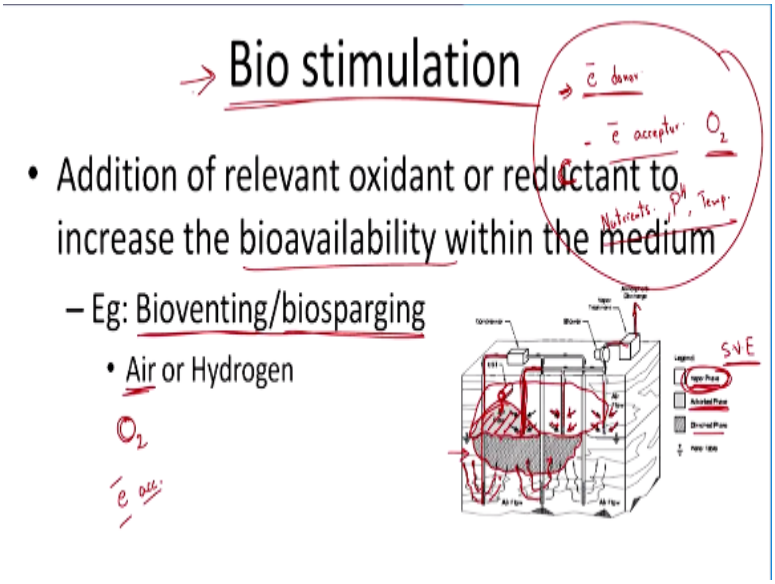

So, what do people typically look at; they look at bio stimulation, in this context what do they try to do; if you are compound let us say is the electron donor let us say, right for the relevant process to go through what do you need; you need an electron acceptor and typical electron acceptor out there what is that; out there is oxygen obviously, right or let us say similar to us the relevant microbes also need the nutrients let us say, nutrients.

The pH conditions should be you know, suitable for their growth and also let us say your temperature plays a considerable role here and obviously, they need a carbon source; carbon source either from the donor or acceptor typically, in this case obviously from the donor I guess, right, carbon, nitrogen, phosphorous the other nutrients and so on let us say, so if any of these are missing obviously, the process will not go through.

So, in bio- stimulation let us say you are to going to add or you know if there are any missing links you are going to provide those missing links, so that nature does its job, so obviously here what do we have; addition of relevant oxidant or reductant and such to increase the bioavailability within the medium, right and in that context we typically have bio venting or bio sparging, if it is in the vadose zone or such, bio venting, sparging.

And what do we say the groundwater and such and I believe I have a graph here okay, I have a particular schematic here so typically, what can we provide; we can provide air, when we say we are providing air, what does that mean; I am providing oxygen to the system which is an electron acceptor right, so if my particular containment is hydrocarbons let us say, you know petrol or diesel has leaked from underground storage tanks or such let us say.

And it is now an issue there, hydro carbons are relatively reduced forms of what do we say carbon let us say, right and now you need an electron acceptor for the process to go through but there is not enough dissolved oxygen in your particular groundwater let us say, so what can you do; you can provide the oxygen, so that the microbes present in that particular system can utilize the oxygen and this particular hydrocarbon.

And then you know facilitate this redox process you know, thereby meeting both the needs as in their need of you know, energy and our need of degradation of the relevant contaminant, so here let us say what do you have; you have I think an example here, an underground storage tank here of petroleum hydrocarbons and you have the relevant compound that is released, so 2 or 3 phases here, vapour phase obviously, hydrocarbons are volatile so that is what you see here.

I think this is visible, this is the vapour phase as you can see and then adsorbed onto the soil let us say in the ground water before it reaches the groundwater, let us say adsorbed on to the soil and that is something you know right, you know they are relatively more hydrophobic, so considerable fraction would be adsorbed onto the soil and if it reaches the groundwater table, it can also be you know have contamination of the relevant groundwater.

So, what do people do; so let us say we have a compressor you know, they have this particular wells put in and you pump air or typically oxygen in this case through the particular system let us say, right and obviously here they see that we see that there are 2 aspects here rather than just biosparging, where you are putting oxygen through to facilitate remediation of this particular or natural or bio remediation of this contaminated zone.

We are also pumping the gas out from this vadose zone or the vapour phase let us say, so that is typically let us say, soil vapour extraction that is something we are going to discuss again later in the context of soils or sediments as in here there are 2 aspects; one is you are providing oxygen to facilitate the growth of; not the growth, pardon me, the degradation of this particular what do we say the compound which is hydrocarbon.

And how do; how does that go about by the relevant microbes and the other aspect that is going hand in that in this particular non saturated zone, you have the relevant hydrocarbon which is in the gaseous phase, so they are pumping that out soil vapour extraction that is what you see here,

so vacuum conditions are created here and you pump the particular compound out and then vapour treatment and then the vapour is discharged, I guess right.

So, it goes hand in hand let us say, as we mentioned earlier, so bioremediation and in that context bio stimulation as in we are providing one of the missing links right.

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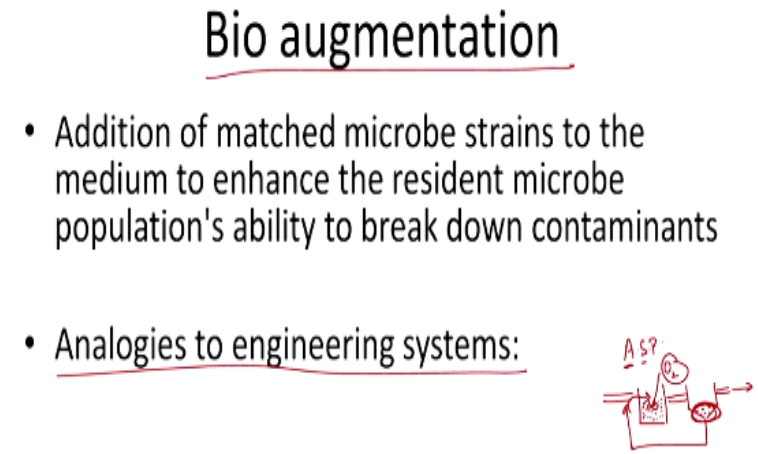

So, I am going to move on, so bio augmentation, say at least in the Indian context, I think rarely has been looked at but I think abroad or such there has been considerable what do we day, application of this bio augmentation, right and what is this about; Layman's terms let us say, right, so let us say depending upon where I have grown or such, I am acclimatised to a particular kind of environment let us say either maybe I can tolerate heat a pretty well compared to other person.

But the other person can tolerate the colder weather pretty well and so on, so if you take me and put me in relatively cold place initially or such or even generally let us say I am going to struggle let us say, right, so here I am talking about acclimatization, so here let us say you know you have relevant compounds; toxic compounds and toxic to us, there also at a high enough concentration, toxic to the microbes too right.

But they might not be toxic to all the microbes, there might be certain kinds of microbes that you know would want these particular contaminants or use these contaminants for their as their sources of energy let us say, right, so what would you do though, right so, here what can you

do; you can try to isolate the microbes from those locations where the contaminant concentration is very high let us say.

I think we looked at one example in Ghaziabad, right where we had chromium what do we say contamination, so what did people do; they looked at or isolated the relevant microbe strains from a particular site somewhere else let us say where the chromium concentration was very high, right that most other microbes were not thriving but a particular type of microbes were thriving.

So, they isolated those microbes, they cultured them, grew them, if I can use the layman's terms let us say and then introduce those cultures in this particular chromium contaminated groundwater in Ghaziabad, so you know that is more or less if I can say you know about bio augmentation as in I am going to introduce non-native species which have a preference let us say for degrading those particular contaminants into my particular contaminated site that is one way.

And the second way is to also engineer let us say or you know change the DNA of this particular microbes let us say such that you know, these engineered microbes can facilitate the removal or degradation, pardon me of the relevant contaminants, so they are the engineered microbes and you can engineer and put those microbes in but again it is a costly affair and from what I have known let us say the chances of success are relatively less.

And again, the reason is that obviously there is a particular reason why the microbes that are in that site are thriving, why is that because it is the principle of; if I may say, survival of the fittest right, so they are the fittest for those conditions now, so if you put some other particular microbes in, it does not necessarily mean, they will thrive there again right, so again you might need to change the conditions or such or these microbes let us say can feed on these other non-native species or the engineered microbes let us say.

Or these engineering microbes which do well in the lab conditions, might not end up doing well to or you know might not acclimatize themselves to these particular site conditions, again bio augmentation in a nutshell if I can say right so, analogies to engineered systems though right again, as in what are we doing in this bio augmentation; we are bringing in microbes let us say if I can use the layman's terms, you know and introducing them here.

So, engineered systems as and you have your effluent treatment plants, so where do you see the relevant analogy though as in you have your activated sludge process ASP, so what is that about; you have your wastewater coming in and you had oxygen here which is your electron acceptor, right and you know this is your aeration tank that is what we typically call and then your secondary settling tank and the sludge is again recycled right.

It is activated sludge as in this activated sludge is recycled again and then the supernatant which is the water is the cleared water or the treated water, so what is happening here; this sludge contains the relevant microbes let us say and these microbes are now again recycled into the system such that you have a relatively high concentration of the microbes or those microbes which can treat your or degrade your waste and oxygen is your electron acceptor.

So, you can think of these as analogies let us say, right so, in the engineered systems as in our ASP or SPR, we are already looking at these case as in promoting the growth of a certain kind of microbes let us say that would promote degradation, so you can try to understand that in terms of bio augmentation, I guess right.

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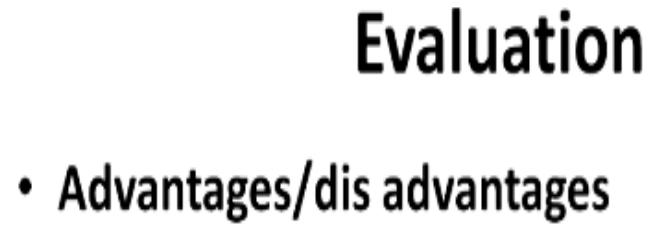

So, moving on let us say and we are going to move on to looking at the evaluation, advantages and disadvantages let us say, obvious advantage is that let us say you know costs are relatively less right but obvious disadvantage is that the kinetics are typically slow especially for only natural attenuation that is why you either try to stimulate it or you know introduce the non-native species.

But there are some other advantages or disadvantages we are going to discuss that in the next session because looks like I am out of time and then we are going to look at the mechanisms let us say, some of the mechanisms and then move on to the relevant models with respect to how do I predict you know what is going to happen to the system right for example, I cannot just say you know okay, this looks like a good candidate for natural attenuation.

And I am not going to do anything and just to wash my hands right, obviously I need to be able to predict what is happening and then show that okay, natural attenuation is occurring or if that is not good enough or the rates are not good enough for such then I am going to look at providing the stimulus let us say or stimuli to you know fast in the process, right so, I guess with that I am going to end today's session and thank you.