Soil Science and Technology
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Lecture – 48
Removal of Toxic Inorganic Substances

Welcome friends to this third lecture of week ten of Soil Science and Technology and in this lecture we will try to first finish the inorganic contaminants in the soil which is started in the last lecture.

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And then will be discussing about different methods for remediating the inorganic contaminants from the soil. So, in the last two lectures of week 10 we discussed about how to remediate different organic pollutants in the soil, we talked about bioremediation. And we talked about the different types of bioremediation we talked about natural bioremediation as well as the engineered or enhance bioremediation and you know that enhance bioremediation can also be divided into biostimulation as well as bioaugmentation.

And we discussed about so we will other chemical methods and then we started with the different types of inorganic substances specially the heavy metals, we talks about several heavy metals. Now we will discuss them one by one, so we started with arsenic and let us see what are the problems which process in the environment. So, arsenic problem is an you know the problem of arsenic is it's accumulation in certain orchard soil following years of application of arsenic containing pesticides.

And being present in an anionic from this element is absorbed by you know hydrous and iron and aluminum oxides especially, in acid soils. And in spite of the capacity of the most soils to tie up the arsenates long term addition of arsenate sorry arsenical sprays can lead into toxicities for sensitive plants and earthworms and remember that that arsenic toxicity can be reduced by application of sulfates of zinc and iron and aluminum which tie up the arsenic in insoluble forms.

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So, these map basically shows the groundwater arsenic contamination scenario of West Bengal and if you look at it you will see that the mostly this arsenic contamination of the groundwater in West Bengal is considered in the lower in the indo gangetic zones and this lower indo gangetic zones and nearby areas has suffered most for this from this arsenic toxicity and you can see turtle of human health hazards pictures which is occurring from this which already occurred from this arsenic toxicity in the groundwater.

And their respective up uptake by the human being and; obviously, these leads to the ultimately to different carcinogenic effects and that is why it is important to remediate the arsenic from both ground water as well as the soil.

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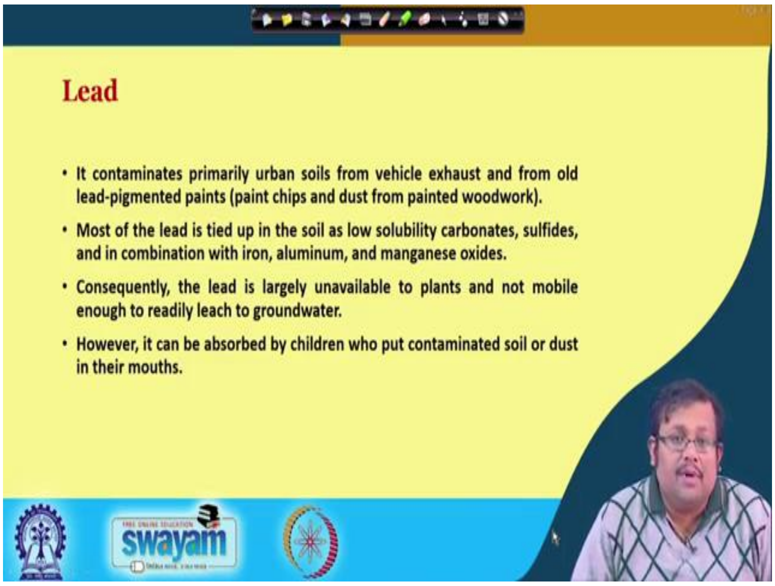

Now, the next important heavy metal is lead; obviously, it contaminate you know it you know it contaminates primarily the urban soils and from different types of vehicle emissions and exhaust and from old lead pigmented paints from paint chips or different types of painted wood works and most of the lead is tied up with the soil as low solubility carbonates sulfides and in combination with iron aluminum and manganese oxides.

And consequently the lead is largely unavailable to the plant and not mobile enough to readily leach to the groundwater; however, you should remember that these lead can be absorbed by the children who pore different contaminated soils or dust in their mouth. So, that is why it is becoming nowadays important pollutant and it is gaining importance for environmental contamination.

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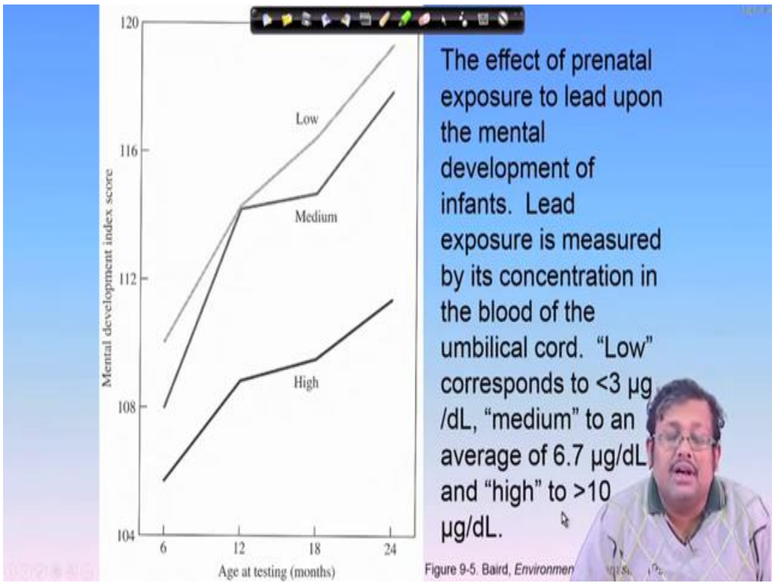

So, next slide will show a graph which shows basically the effect of lead in prenatal expose you know effect of prenatal exposure to lead upon the mental development of infants and lead exposure here is you know measured by its concentration in the blood in umbilical cord and you can see there are 3 grade is one is lower than medium and high. The low corresponds to the less than three microgram per deciliter and medium to an average of 6.7 microgram per deciliter and high correspond to greater than 10 microgram per deciliter.

And obviously, it is quite you know quite evident then when the there is high concentration of lead in the blood; obviously, that returns the mental development. So, mental in development index score is low, in case of high following by medium and low and now different edges of testing or mass. So, that shows the importance of lead then it's remediation from you know from our environment for better you know for better you know for cleanliness of the environment.

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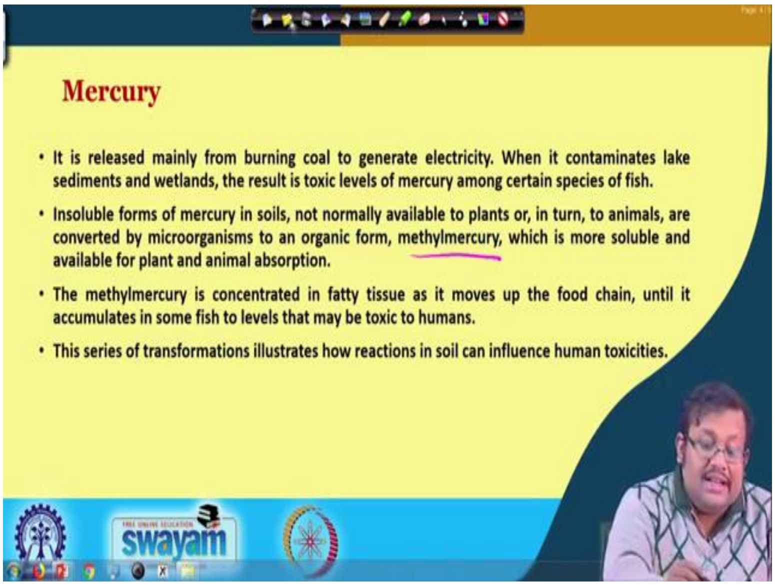

So, the third important and one of the most important is mercury, remember that it is release mainly as a burning coal to generate the electricity when it contaminates lake sediments and wetlands the result is toxic levels of mercury among certain species of fish and it's shows different types of biomagnification I will talk about this in a couple of slides.

And insoluble forms of mercury in soils and not normally available to the plants or in turn to animals are converted to microorganism to an organic form that is called the methylmercury we it is very important this methylmercury and which is more soluble and available for plant and animal absorption will see that.

Then the methylmercury is concentrated in fatty acid in fatty tissues and it moves up to the food chain, until it accumulates in some fish level that may be toxic to humans of shop and consumption. And the series of transformation illustrate how reaction in soil can influence human toxicities.

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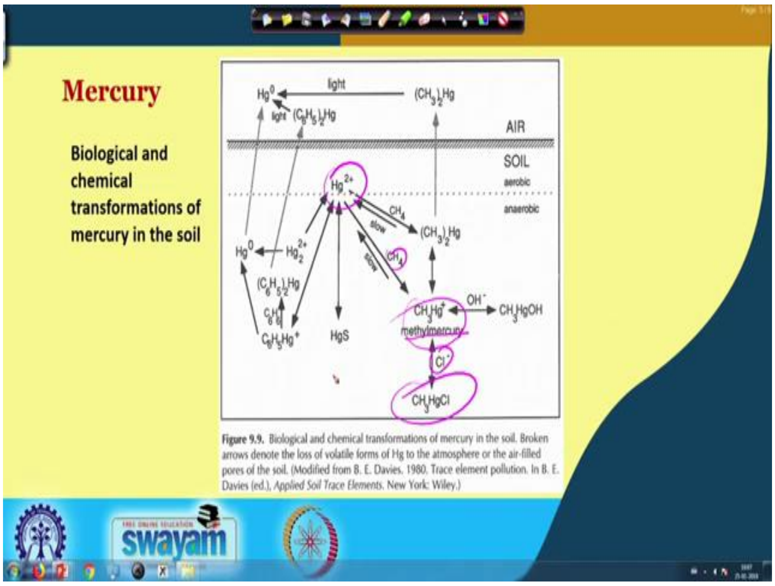

So, let us see couple of ways through which you know there are biological and chemical transformation of mercury in the soil you can see that how this mercury moves through the aerobic zone of the soil as well as anaerobic zone of the soil and also in air or air filled pores spaces. So, we can see here that you know this is the mercury which is the starting point and; obviously, in the anaerobic layer it you know it goes you know it ultimately released the methylmercury of reaction with the methane.

And the conversion of methylmercury to you know the mercury is very much slow and this you know methylmercury can also add you know chlorine to produce this compound and ultimately; obviously, this broken arrows are basically shows the movement or the volatilization the loss of volatile forms of mercury to the atmosphere or the air filled pores of the space.

So, you can see how this mercury and is different components, different harmful components especially market this methylmercury can moves you know throughout the environment as well as you know aerobic and anaerobic layers of the soil and how transform in the soil.

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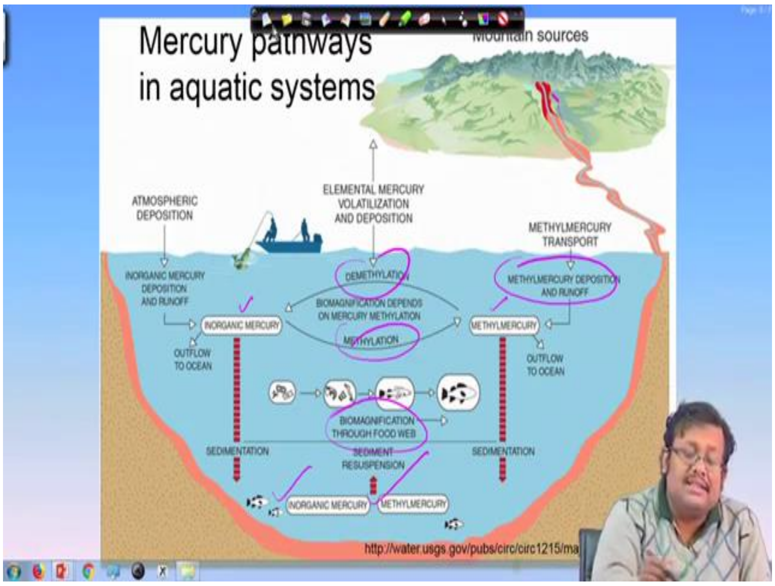

So, another is mercury pathways in aquatic system you can see here you know how mercury ultimately pollutes the aquatic systems. So, if there is a mountain source; if there is a mountain source the you know there is a in transportation of mercury an ultimately the methyl mercury transport an ultimately deposits and you know methyl you know through methylmercury deposition and runoff.

And ultimately this methylmercury goes out flow to the ocean and you can see here this how this biomagnification through the food web is going on from smaller organism to larger organisms like fish. So, this you know biomagnification is very very important in the through food web is very very important for eventual accumulation of this mercury in the human body parts.

And you can see you know a significant amount is getting sedimented and you know and further the sediment resuspension is occurring from this inorganic mercury and methyl mercury and this inorganic mercury basically get sedimented and you know resuspension or sediment resuspension basically occurs from inorganic mercury as well as methylmercury and you know and you can see here the two major factors here or two major determinants here inorganic mercury and methyl mercury and they when the inorganic mercury undergoes methylation it produces the methylmercury and when methyl mercury undergoes demethylation produces the inorganic mercury and this biomagnification basically depends on mercury methylation.

And so, you can see how this mercury is getting converted into different froms inorganic farms to organic farms and then back into the inorganic forms and how these inorganic and organic transformation affecting the biomagnification and ultimately it is depositing in the environment and then further moving back to the water from the deposited you know from its deposits. So, you can see here you know this is a mercury pathways in aquatic systems in ultimately its get accumulated in the human body parts.

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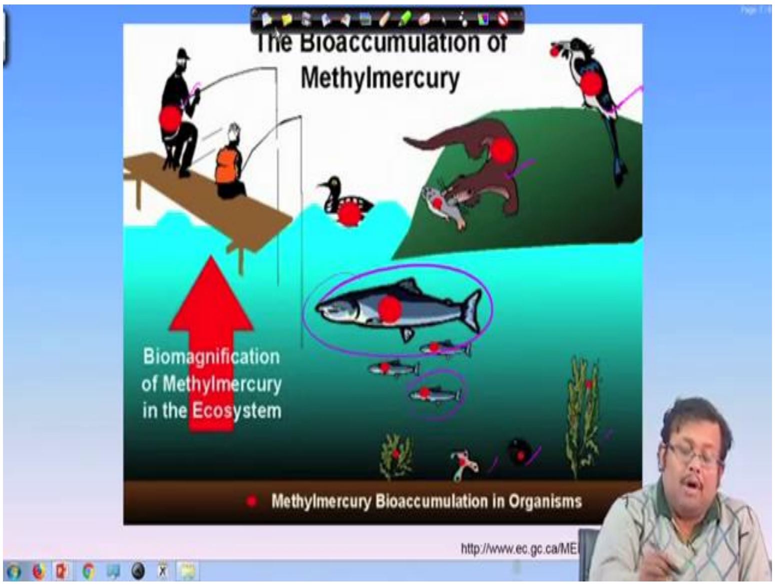

And; obviously, this was the bioaccumulation of methylmercury; obviously, is see here biomagnifications of methylmercury in the ecosystems. So, it starts with the you know the plants which are present in the naquatic environment and then the micro you know different types of planktons and other microbes which basically this eats this methylmercury.

And it accumulates in their body, ultimately the smaller fishes you know pray on this planktons and ultimately this methylmercury get accumulated in their body and subsequently to the larger fish and from this larger fish to the different types of birds which are present in the water and ultimately their getting accumulated in the animal tissue as well as other you know among the human tissue and you know other animals and bird tissue.

So, that basically shows the bioaccumulation of methylmercury in that is why you know mercury is a very important you know environmental you know mercury is considered is an very important environmental contaminant.

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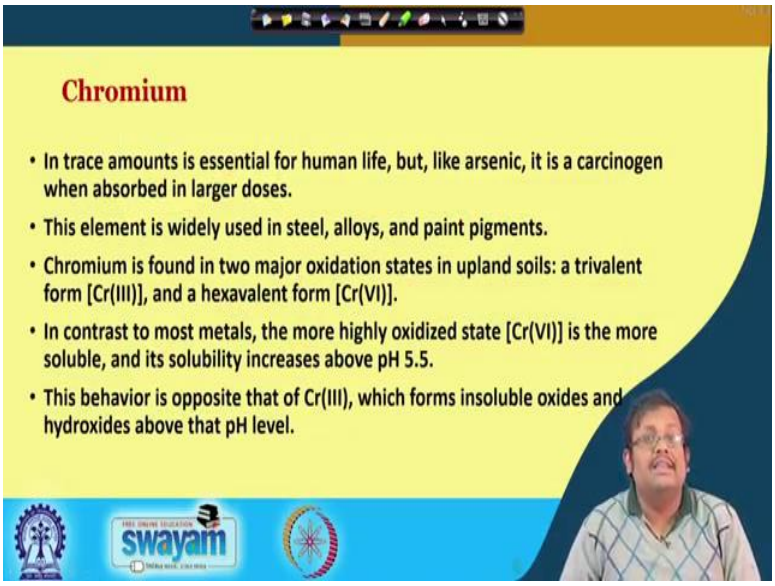

So, guys let us move here in see the chromium; chromium is also a very important it is because in trace amounts is essential for human life, but like arsenic it is in carcinogen which when absorbed in large doses and this element is widely used in steel alloys and paint pigments and chromium is found in two majore oxidation states trivalent form and hexavalent form. In contrast to most metals the more highly oxidized states is more soluble and its solubility increases above pH 5.5 and this behavior opposite to that of chromium three which forms insoluble oxides and hydroxides above the pH level.

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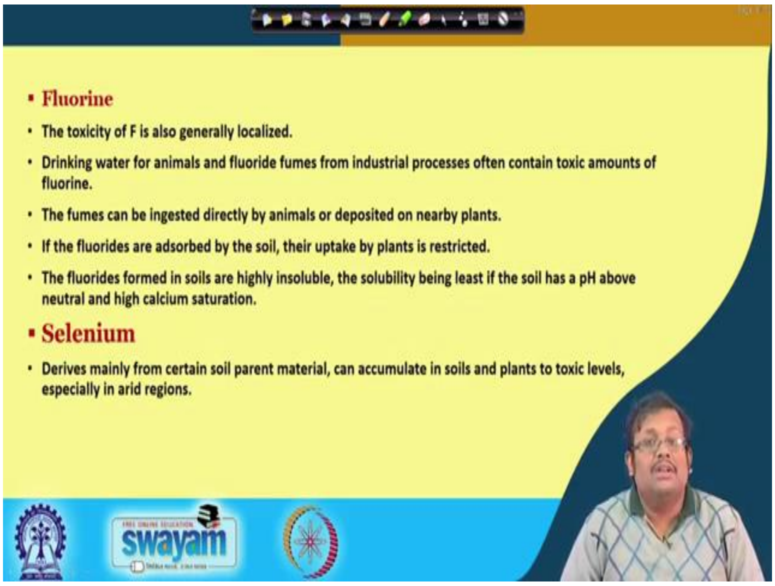

So, another important are you know element is fluorine and the toxicity of fluorine is also generally localized and drinking water for animal you know drinking water for animals and fluoride you know fumes from industrial processes often contain toxic amounts of fluorine and the fumes can be ingested directly by animals are deposited in the nearby plants.

So, that is why it is creating several problems and if the fluorides absorbed by the soil their uptake plant is restricted and the fluoride forms of the soil is highly insoluble at the solubility being released if the soil has a pH above neutral and high calcium you know saturation. Another one is selenium it derives mainly from certain soil parent materials and can accumulation in the soil and plant to toxic levels especially in arid regions.

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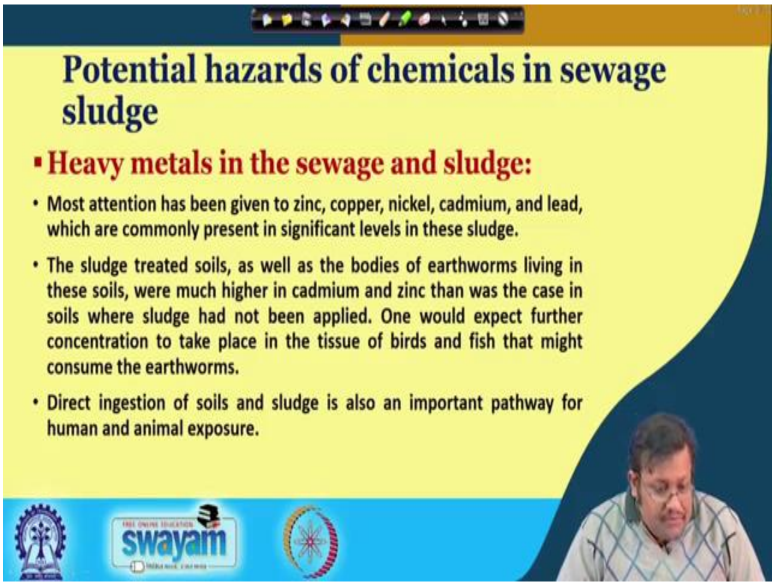

So, what are the potential hazard another potential hazards of inorganic substances can come from application of sewage and sludge and heavy metals in the sewage sludge you know you know sludge and sewage is loaded with heavy metals and most attention has been given to zinc, copper, nickel, cadmium and lead which are commonly present in significant levels of these sludge.

So, whenever we apply the sludge into the soil we must be very very careful about the heavy metal load of these sludge and sewage thing. So, direct injection of soil and sludge is also important pathways for human and animals exposer. So, you know it has to be remediated carefully you know when we apply you know the chemical sewage and sludge in the soil.

So, guys you know this you know that you know let us wrap up this lecture not let us wrap up this topic which gives you basic overview of different inorganic substances and then we move ahead to new topic that is remediation of soil inorganic pollution.

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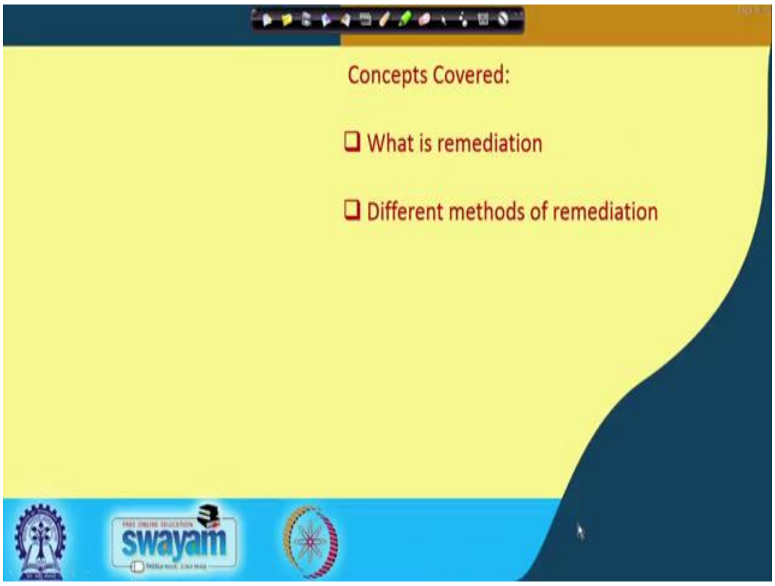

And the basically will be covering this following concepts what is remediation and what are the different methods of remediation organic or inorganic remediation?

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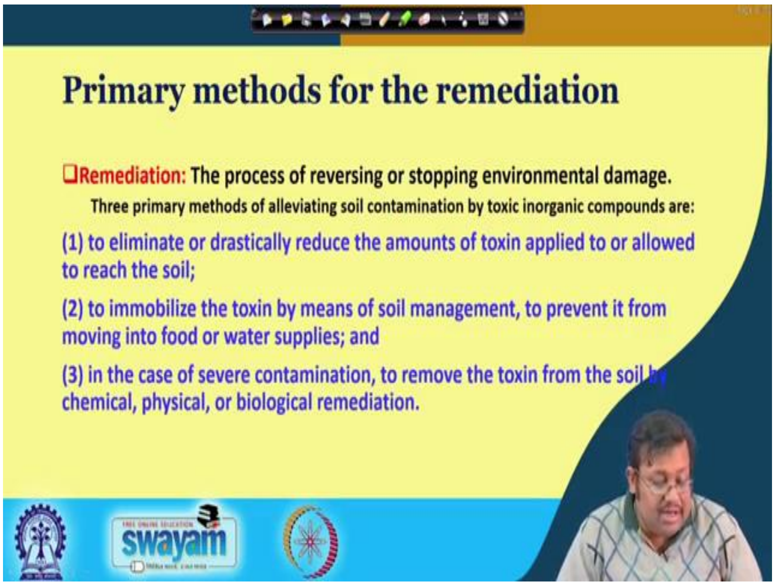

And so the definition of remediation says that it is a process of reversing or stopping environmental damage and there are three primary methods for alleviating or soil contamination by toxic inorganic compounds are there are three major strategies for you know for remediation from soil, first of all to the first of all to eliminate or drastically reduce the amount of toxin applied or to or allowed to reach in to the soil.

Secondly, to immobilized the toxin by means of soil management to prevent it from moving into the food or water supplies and thirdly in the case of severe contamination to remove the toxin from the soil by chemical physical biological methods. So, basically there are three steps first steps you know first of all will reduce or drastically cut down the amount of toxin which we generally applied or allowed to reach into the soil.

Secondly so it is the kind of prevention method preventive method. Secondly, once it reaches the soil will try to immobilize a toxin by means of soil management. So, it is a management aspect and final in case of severe contamination to remove the toxic from the soil by different types of chemical, physical and biological remediation. So, it is a corrective measures. So, we can see there are three major aspects of you know soil you know inorganic contaminant remediation.

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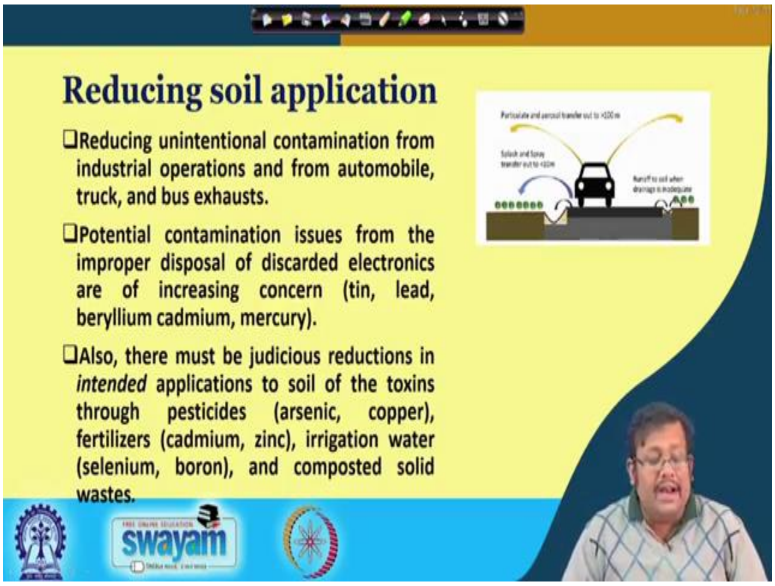

So, if we go ahead and see what are the different types of ways of cutting down the application you know or the soil application of the heavy metal. First of all we can reduce the unintentional contamination from industrial operation and from automobiles trucks and bus exhaust. You can see here when there is a large number of automobiles moves towards a road; obviously, there is a you know there is a way with you know the heavy metal contamination chances are there from you know from different different parts wearing of their tires.

and their exhausting or burning of the fossil fuels and you can see the particulate aerosols can transfer out to the nearby areas greater than 100 meter you know distance and also different types of run of circles when the drainage it inadequate and these heavy metals which are deposited over the road surface due to the movement of automobiles they get move from one place to another place with the run of water and then contaminant the surrounding place.

So, this is an way of contaminating the environment soil environment. So, we can reduce the at this unintentional contamination from we can cut down the industrial operations or industrial exhaust and automobile and we can manage the automobile and bus and truck exhaust. The second way is to potential contamination issues from the improper disposal of discarded electronics, are of increasing concern you know that you know tin lead beryllium cadmium mercury these are important parts of this electronic.

So, when you are disposing it ultimately it goes to the environment and contaminate. So, it must be very we much deal it with very we much deal it very carefully. Also there must be judicious reduction in intended applications to soil of toxins through pesticides. So, there is a worldwide drive for reducing the pesticide application of pesticide and their promoting the integrated nutrient management, where the application of inorganic pesticides is you know is being replaced by application of organic pesticides we does not contain these heavy metals.

So obviously, like arsenic copper cadmium zinc and all this things and also inorganic fertilizers also. So, these are some of the strategies for reducing or cutting down the heavy metals which can reach into the soil environment.

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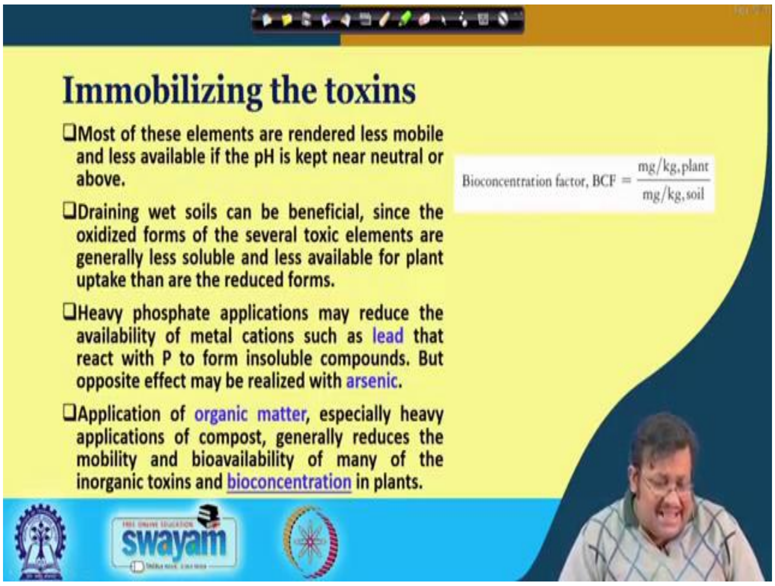

The second important is the management aspect that is immobilizing the toxin, now most of these elements are rendered less mobile and less available if the pH is kept near neutral and above and draining wet soil can be beneficial since the oxidized form of the several toxic metals are generally less soluble and less available for plant uptake and then are the reduced form.

So, remember that heavy phosphate application may reduce the availability of metal cation such as lead; however, it does the opposite with the arsenic because you know you know it increases the availability of the arsenic when we apply the heavy metals sorry heavy phosphate and remember that when we apply the organic matter especially heavy application of composed generally it generally reduces the mobility and bioavailability of many of the inorganic toxins and bioconcentration in the plant.

Now bioconcentration factor you can calculate by using this formula bioconcentration factor is basically the magnesium I am sorry the milligram of any heavy metal per kg of plant tissue over milligram per kg of soil. So, this by using this you know bio concentration factor we can determine what is the you know what is the toxicity level?

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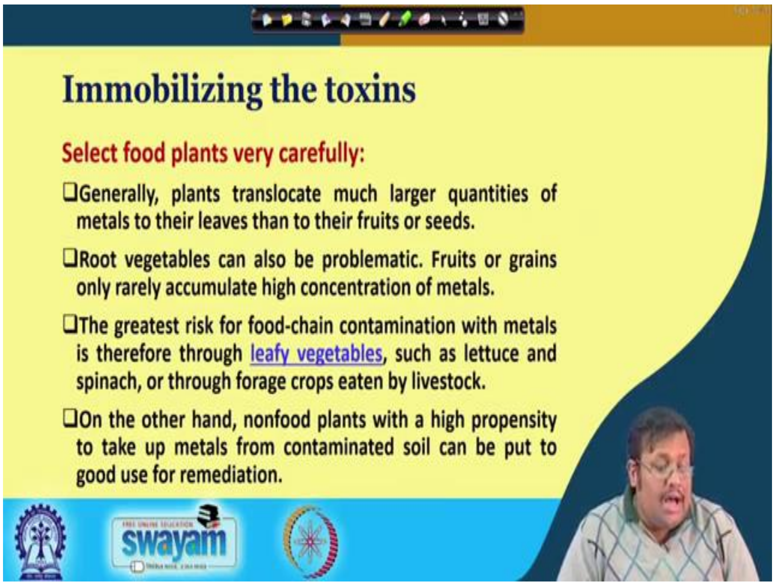

So, also we can select food plants very carefully remember that generally plant translocate much larger quantities of metals to the leaves than their fruits or seeds and only vegetables can also you know root so remember that root and root vegetables can also be problematic because fruits and grains only rarely accumulate high concentration of metals; however, this is a most important.

The greatest risk of food chain you know contamination with metals is therefore, through leafy vegetables such as lettuce and spinach or through forage crops even by eaten by livestock because it gets highly accumulated on this leafy vegetables. On the other hand non food plant with a high propensity to take up metals from contaminated soil can be put to use good use for remediation when we call it phytoremediation we will discuss it.

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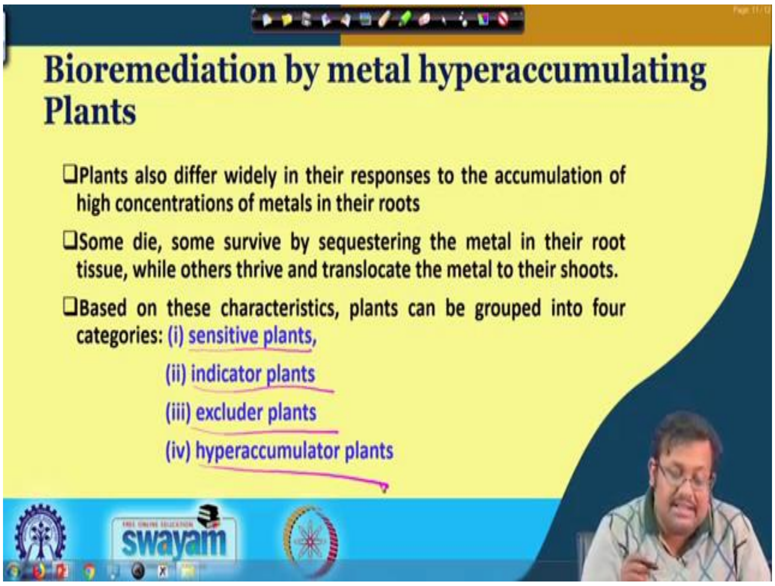

So, bioremediation can also be done as I have told you in the last slide bioremediation can be done by metal hyper accumulating plants. So, plant to remember that, plant differ widely in the responses to the accumulation of high concentration of metal in their roots. Some die some survive by sequestering the metal in their root tissue, while the others thrive and translocate metal to their shoot.

And based on these characteristics we know plants can be grouped into four categories, these are the four category first of all the sensitive plant, second is the indicator plant, third is excluded plants and finally, the hyperaccumulator plant. So, we will discuss them one by one.

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So, basically sensitive plants are the most of the most of the plants are basically sensitive plants. So, by the definition of sensitive plant it tends to take up metals readily, but then cannot tolerate the resulting high metal concentration in their tissues. So, they become poisoned by the metals their growth is inhibited and they are likely to die if grown in even moderately metal contaminated soils. So, majority of the crops are basically you know heavy metal sensitive plants and they basically cannot with stand these you know these heavy metal concentration in the tissue.

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The second type is call indicator plants, the indicator plants steadily takes up you know the metal in proportion to how much is available to the soil at this trait they you know this trait make them useful as indicator of soil metal concentration and this survive from very low to quite high soil metal concentration. But they do not accumulate concentration of the metals in the tissue that exceed the concentration in the soil and they manage and they manage to tolerate moderately high levels of metal taken up by the sequestering the metal nonsensitive plant parts or by binding the metals inorganic compound that reduces the toxicity.

So, this is important they manage to tolerate moderately high levels of metal taken by the sequestering of the metal non sensitive plant parts or by binding the metals into organic compound that reduces the toxicity. So, these are the traits of indicator plants.

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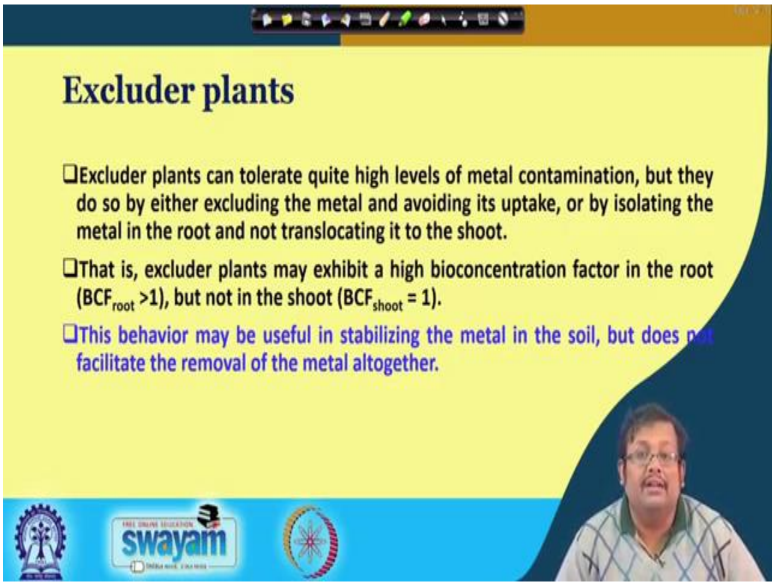

The third one is call excluder plants; a excluder plant can tolerate quite high level of metal contamination, but they do so by either excluding the metal and avoiding its uptake or by isolating the metal in the root and not translocating into the shoot. So, it takes some measure. So, that these heavy metals can you know can be avoided to you know the uptake of the heavy metal can be avoided or even that even they have up taken it they are concentrated in the root and not translocated into the shoot.

So, that is the excluder plants this excluder plants has you know may exhibit high bioconcentration factor we have already talked about this bioconcentration factor. So, they may show high amount of bioconcentration factor in the root greater than 1, but not in the shoot which can be equal to 1.

So, this behavior may be useful in stabilizing the metal into the soil, but; obviously, this does not facilitate the removal of the metal from the soil altogether, so this is the disadvantage of this excluder plants.

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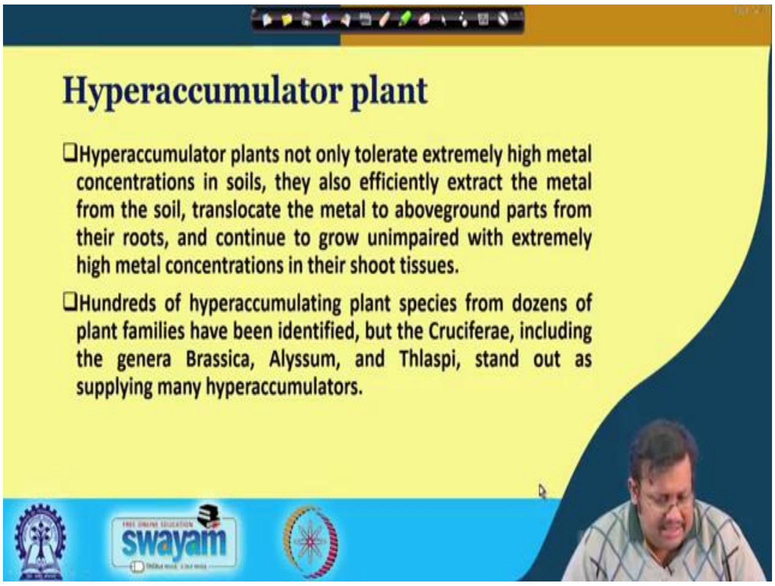

Hyperaccumulator plants, the hyperaccumulator plants not only tolerate extremely high metal concentration in soil, they also efficiently extract the metals from the soil translocate the metal to aboveground parts from their roots and continue to grow unimpaired with extremely high metal concentration in their shoot tissues. And remember that hundreds of hyperaccumulating plant species from dozens of plants families have been identified, but the cruciferae, including the genera Brassica, alyssum and you know Thlaspi, stands out as the supplying many you know supplying many hyperaccumulator.

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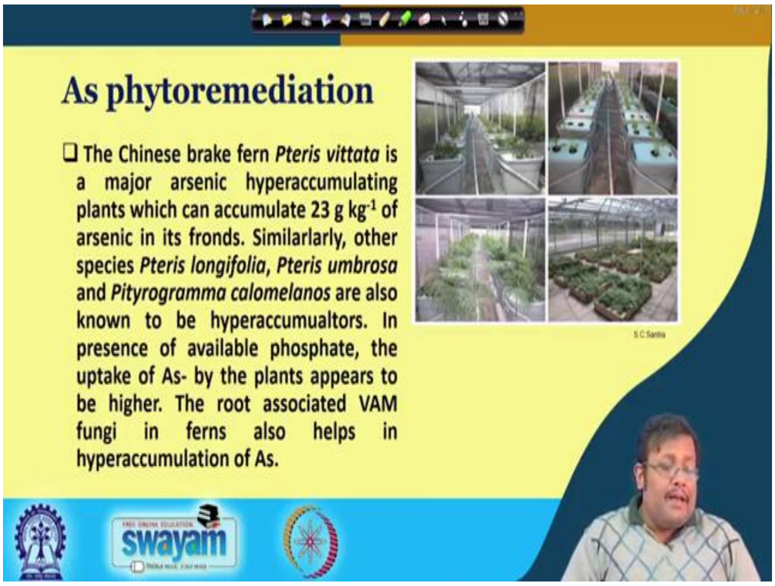

So, you can see I am showing you one example of arsenic phytoremediation at the Chinese break fern Pteris vittata is a major arsenic hyperaccumulating plants which can accumulate 23 gram per kg of arsenic in its fronds. So, similarly other species like Pteris like Pteris longifolia Pteris umbrosa and this Pityrogramma this calomelanos are also known as the hyperaccumulators and in the presence of this of available phosphate the uptake of arsenic by the plant appears to be higher.

So, the root associated you know also the VAM fungi that is basically arbuscular mycorrhiza in ferns also helps in hyperaccumulation of arsenic. So, these are this is an example of hyper accumulation of arsenic. So, guys we have covered this basically this different types of inorganic substances or inorganic heavy metals which are present in to the soil and we talked about different types of the you know specific heavy metals like arsenic and then lead and how they how they impact the environment as well as human health.

We also talked about chromium you also talked about selenium, we also talked about you know so as you know we also talked about florin. So, now I have shown you how we the phytoremediation can help in remediating these heavy metals from the soil as well as you know what are the different types of plants we talked about sensitive plants, we talked about indicator plants, we talked about excluder plant and then hyperaccumulator plant remembered that phytoremediation has become a very important issue now a days and it’s in a important area of research for those who want to do research in soil and environmental chemistry I must encourage them to do more research in hyperaccumulation. Because I mean this is one of the way through which we can we can remediate our environment in a more sustainable manner as well as more environmental friendly way.

So, guys I hope that you have got basic overview I would encourage you to go ahead and do some more research and more studies refine studies in you know phytoremediation as well as bioremediation. I have not touched about the microbial bioremediation, but remember that microbial bioremediation is also very very important for remediating these heavy metals from the soil there are certain bacteria and which can remediate these heavy metals when they can take up this heavy metals in their body.

And they can we stand high concentration of the high concentration of different heavy metal there are certain bio you know there are certain bacteria which can convert this arsenic which is an important heavy metal to some other you know immobile compounds and that is why they are concentration and with their toxicity in the environment can be reduced.

So, there are several ways; obviously, it is not possible to cover each and everything, but hopefully have got some basic ideas about this bioremediation, I would encourage you to go ahead and do some more research thank you and let us meet in the next lecture to discuss our next topic that is soil survey.

Thank you.