Environmental Soil Chemistry
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Lecture – 55
Modeling the Fate of Pollutants in the Soil, Risks and Remedies Continued

Welcome friends to this fifth lecture of module 11 of this online certification course of environmental soil chemistry and in this week we are talking about the modeling the fate of pollutants in soil and risk and remedies, and in our previous lecture, we have already discussed about different types of risk assessment, what is diagnosis, what is prognosis, what is the difference between diagnosis and prognosis.

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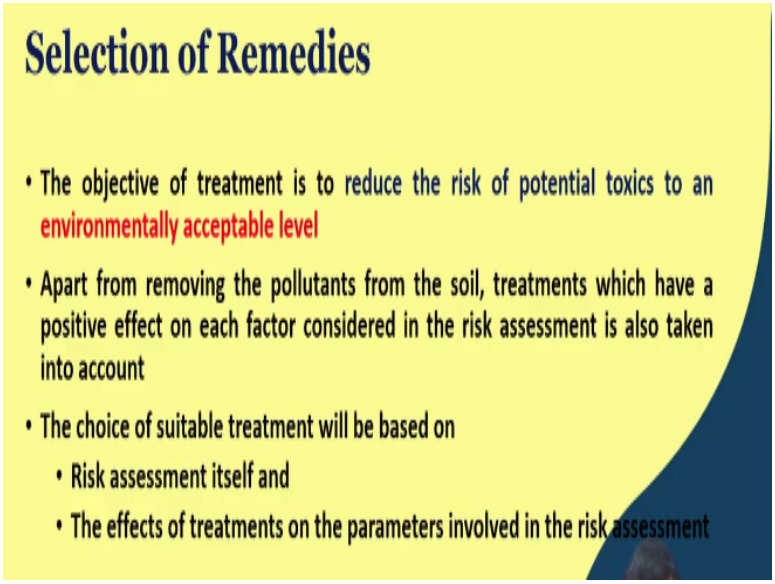

Today, we are going to start with the selection of the remedies. So, today we are going to discuss in details about different types of remedies of pollutions. Now, remember that the objective of treatment is to reduce the risk of potential toxics to an environmentally acceptable level. We always try to reduce the contamination level below the environmentally acceptable level.

Apart from removing the pollutants from the soil treatment, treatments which have a positive effect on each factor considered in the risk assessment it also taken into account. Remember the choice of suitable treatment will be based on 2 factors. First of all, the risk assessment itself and the effects of treatment on the parameters involved in the risk assessment. So, this

is very important. These 2 factors are very, very important and we will be discussing them in details.

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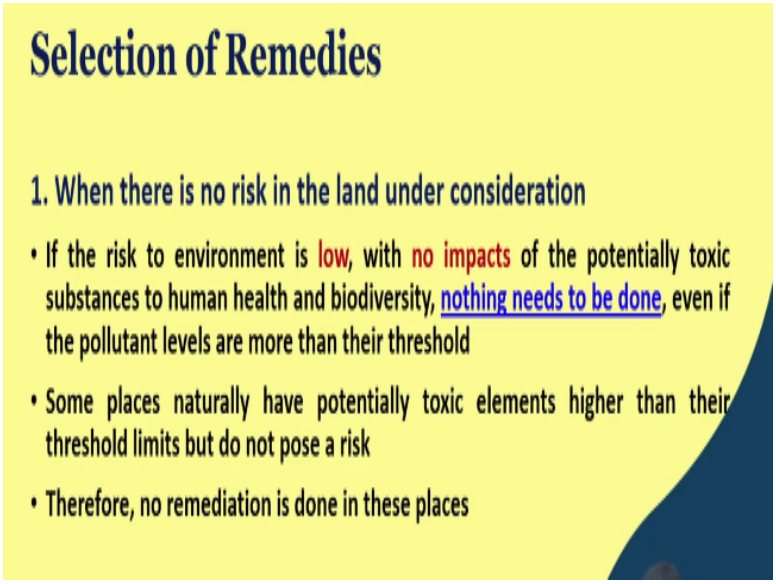

So, first of all when there is a condition when there is no risk of land under consideration. So, if there is a condition that there is no risk in the land under consideration, what will be our remedial tactics. So, if the risk to environment is low with no impacts of the potentially toxic substances to human health and biodiversity, we do not have to do anything. So, nothing needs to be done even if the pollutants levels are more than their threshold. So, this is very important.

The potentially toxic pollutants level should be high enough to cause damage to human health and biodiversity, otherwise we do not have to worry about their contents, so we do not need to do anything. So, some places naturally have potentially toxic elements higher than their threshold limit, but do not pose any particular risks to human health. So, therefore in this case, we do not need any remediation for this to remediate those pollutants.

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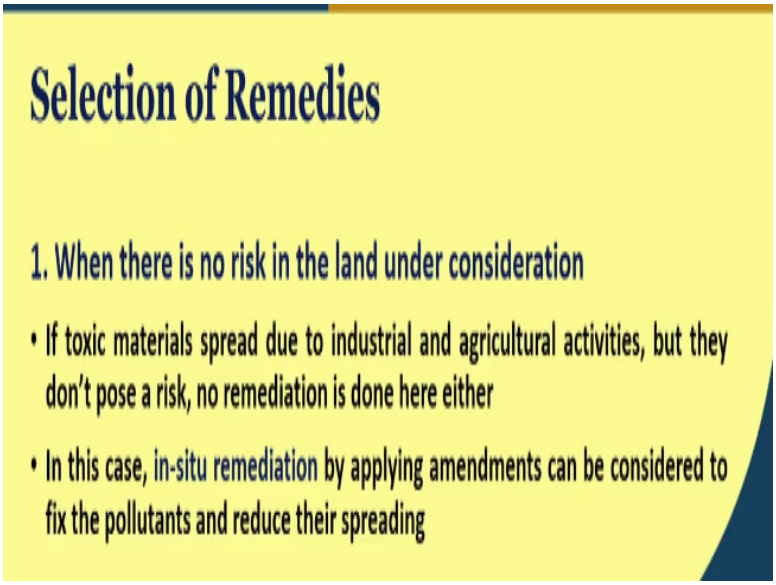

So, if the toxic materials spread due to the industrial and agricultural activities, but they do not pose a risk, then again no remediation is done here either. Now in this case, in-situ remediation by applying amendments can be considered to fix the pollutants and reduce their spreading. So, this is the condition where there is no risk in the land under consideration.

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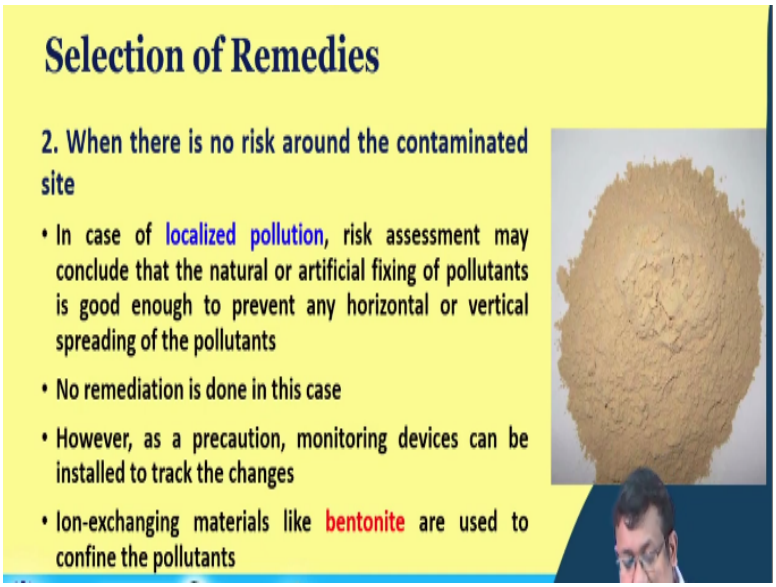

Now, the second condition when there is no risk around the contaminated site. So, we have a contaminated site, but there is no risk around that contaminated site, so in case of localized pollution the risk assessment may conclude that the natural or artificial fixing of pollutants is good enough to prevent any horizontal or vertical spreading of the pollutants.

So, whatever measures we are taking in the localized pollution if it is sufficient to contain the pollution movement vertically or horizontally or the spreading of the pollutants vertically and

horizontally, then no remediation is done in that case. However, as a precaution, monitoring devices can be installed to track the changes whether there is any spreading in the vertical direction or horizontal direction.

Now, different types of ion exchange materials like bentonite are used to confine the pollutant. You can see here the photo of a bentonite. So, basically, this is an ion exchanging material and we generally use to confine the pollutants.

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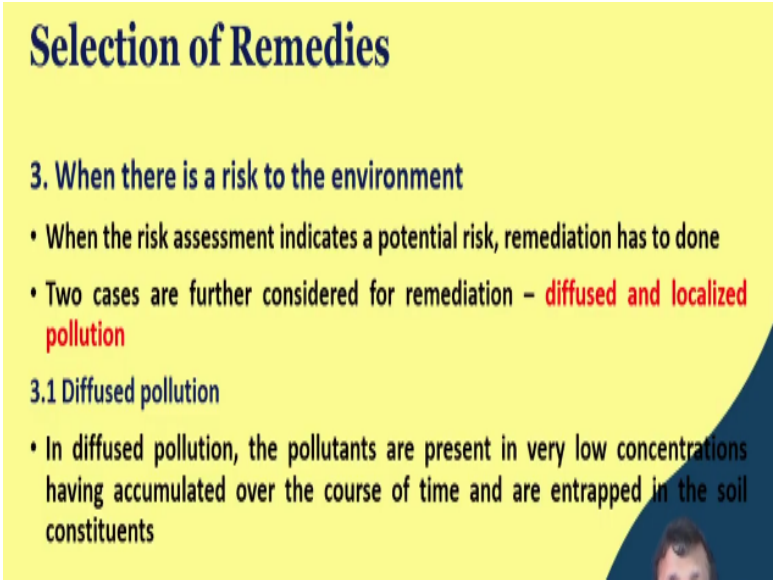

Now in the third condition, when there is a risk to the environment. So, when the risk assessment indicates a potential risk remediation has to be done in that case. Now, two cases are further considered for remediation. First of all, one is diffused and the second is localized pollution. So, what is the diffused pollution?

Now, in case of diffused pollution, the pollutants are present in very low concentration and they have accumulated over the course of time and are entrapped in the soil constituents. So, this is called diffused pollution. So, diffused pollution differs from a localized pollution.

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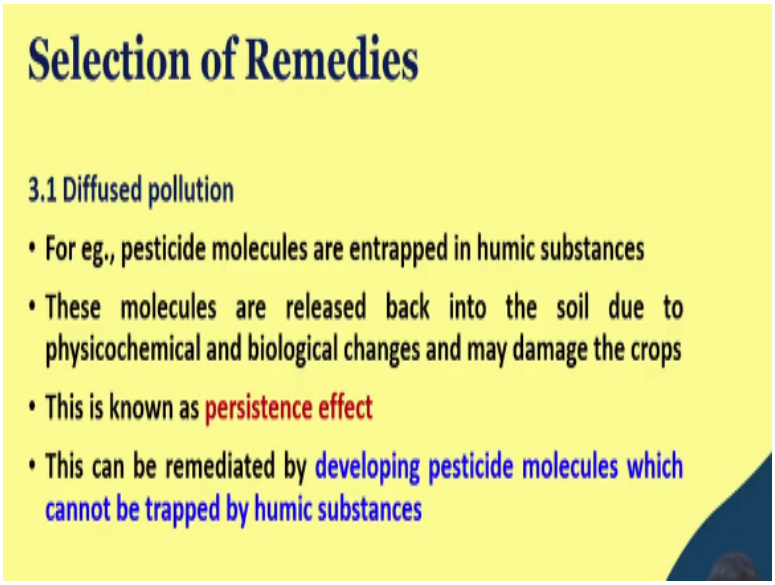

Diffused pollution examples are pesticide molecules. When the pesticide molecules are entrapped in humic substances that is called a diffused pollution. Now, these pesticide molecules are released back into the soil due to the physicochemical and biological changes and may damage the crops and this effect is known as persistence effect, and this persistent effect is the reason that is why certain chemicals are banned for applying in the crop fields.

Now, so the pesticide has the property to remain persistent throughout a long period of time and they can be entrapped into the humic substances. So, this can be remediated by developing pesticide molecules which cannot be trapped by humic substances.

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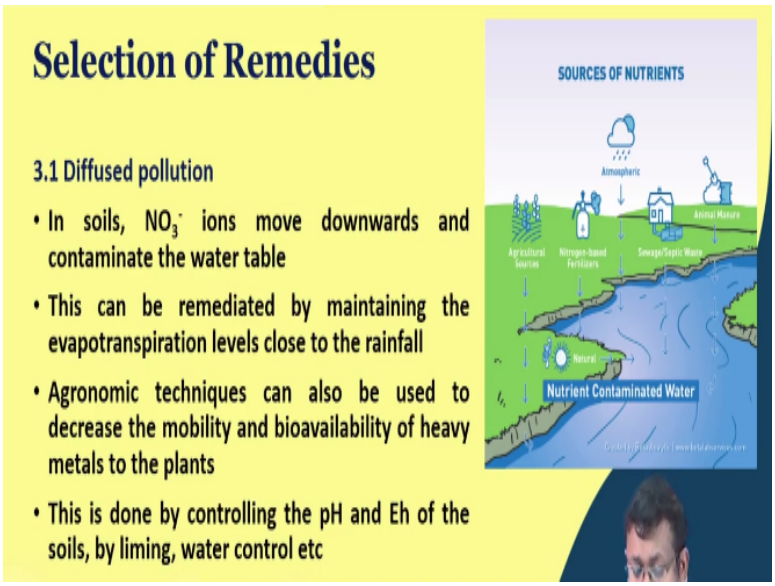

Now, in soils when we talk about the diffused pollution nitrate ions move downwards and contaminate the water table, already we know that the nitrate pollution in the water bodies.

Now this can be remediated by maintaining the evapotranspiration level close to the rainfall. So, if the evapotranspiration level remains close to the rainfall, there will be no downward vertical movement of nitrate ions.

Now, agronomic techniques can also be used to decrease the mobility and bioavailability of heavy metals to the plants and this is done by controlling the pH and Eh of the soils, by liming, water control, etc. You know that in case of a submerged soil, due to the change of redox potential, some elements like iron and manganese their solubility differs, their solubility generally increases, and as a result there is change in the pollution status in those conditions.

So, changing the different types of agronomic practice have a profound influence on controlling the pH and Eh of the soils and it can be done by liming, water control, etc. and thereby we can control the movement of these ions in the soil and water bodies.

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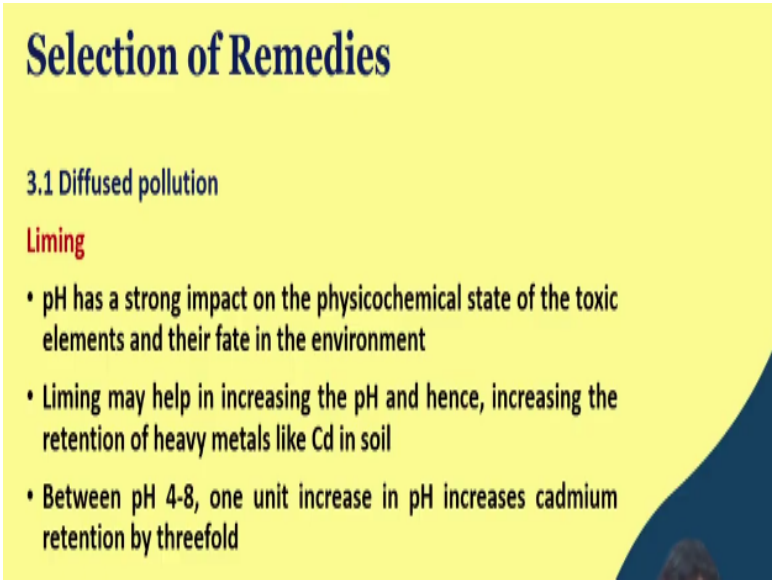

Now liming. You know that pH has a strong impact on the physiochemical state of the toxic elements and their fate into the environment. Now liming which is basically application of calcium carbonate, which helps in increasing the pH, so when we apply the lime, generally liming is done in case of acidic soil. In case of acidic soil, the pH is low, so to increase the pH we generally apply calcium carbonate.

So liming may help in increasing the pH and thereby increasing the retention of heavy metals like cadmium into the soil. Now, between pH 4 to 8, one unit increase in pH increases

cadmium retention by tenfold, this is very important. So, this is how by changing the liming condition, by controlling the liming condition you may potentially increase the retention of different heavy metals. So, that is very important to note while calculate the liming materials for applying in the field.

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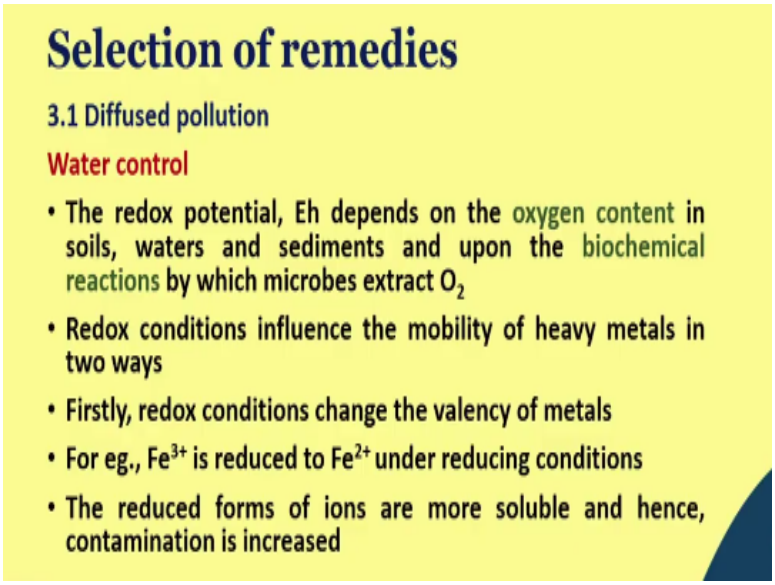

Now, what about the water control. Now, the redox potential Eh depends on the oxygen content in the soils and waters and sediments and upon the biochemical reaction by which microbes extract oxygen. We have already discussed this in the redox chemistry in our previous chapters. Now, redox condition influences the mobility of heavy metals in two ways. Firstly, redox conditions change the valency of the metals.

For example, in case of iron and manganese by changing the valency of the metals, it basically converts the lower soluble ions to higher soluble ion. For example, Fe^{3+} is reduced to Fe^{2+} under reducing condition and thereby their solubility increases and the reduced form of ions are more soluble and hence contamination is increased. So, that is why changing the redox condition can increase the solubility and thereby changing the contamination.

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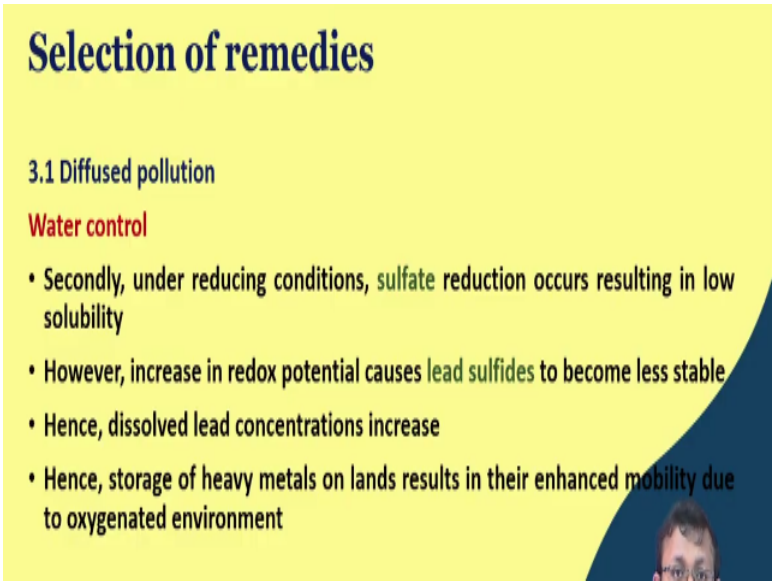

Secondly, under reducing conditions, sulfate reduction occurs resulting in low solubility. So, sulfate is there in the soil. So, sulfate reduce under reducing condition. However, increase in redox potential causes lead sulfides to become less stable. So, hence dissolved lead concentration basically increases when we increase the redox potential.

So, the storage of heavy metals on lands in their enhanced mobility due to the oxygenated environment can be justified by changing in their Eh or redox potential. So, this is how the redox potential influences the mobility of different heavy metals and pollutants in the soil.

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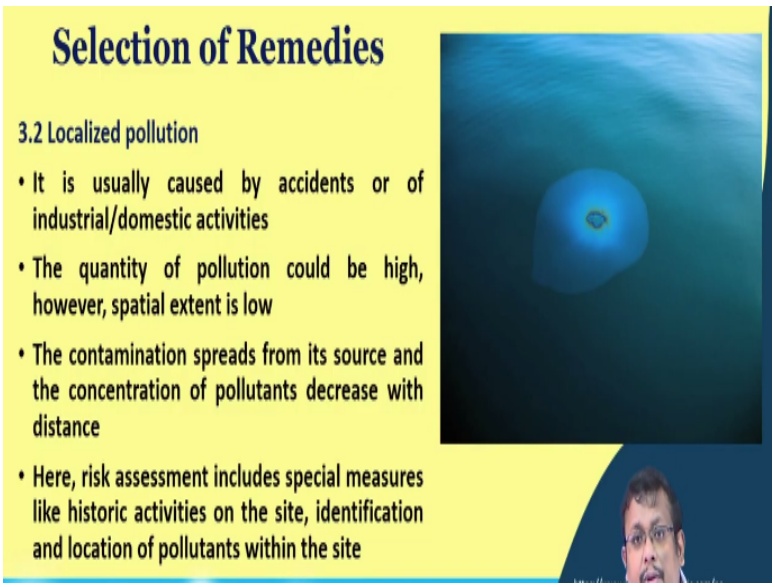

Now, we have covered that diffused pollution. Now, let us cover the localized pollution. Now, as you can see in this picture, this is an example of localized pollution. So, it is usually caused by accident or of industrial or domestic activities. Now, the quantity of pollutants

could be high, however, spatial extent is very low. So, that is why it is called the localized pollution, it has not spread enough.

So, that is why it is called localized pollution. So, the contamination spreads from the its source and the concentration of the pollutant decreases with the distance. So, the risk assessment includes special measures like historic activities on the site, identification and location of pollutants within the site. So, this is an example of localized pollution and localized pollution for example is petroleum spill in the ocean.

So, this is petroleum spill in the ocean from a tanker. So, this is an example of localized pollution and in this localized pollution, the spatial extent of pollution is less. So, the remedial measures which you have to take for controlling the localized pollution is different than that of the diffused pollution.

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Now, technologies to the remediate localized pollution sites basically includes hard and soft techniques. So, we will discuss both hard and soft techniques now. Now, hard techniques with excavation, also known as surgical operation. So, if a small area is highly contaminated, now presenting a risk to the environment, the soil should be clean. Let us consider that there is an area where the soil is highly contaminated and we have to clean the soil.

So, this is an example of localized pollution and we have to clean, the simplest way is to excavate the contaminated soil and put them in the waste disposal sites. So basically, we excavate the contaminated soils from the localized pollution site and then dump it into some

waste disposal site. However, in this case, excavation simply displaces the problem. So, we are basically excavating the pollutant soil and then we are putting it somewhere else.

So, the excavated material can be treated in-situ or in mobile plants. So, this is the problem with this excavation treatment.

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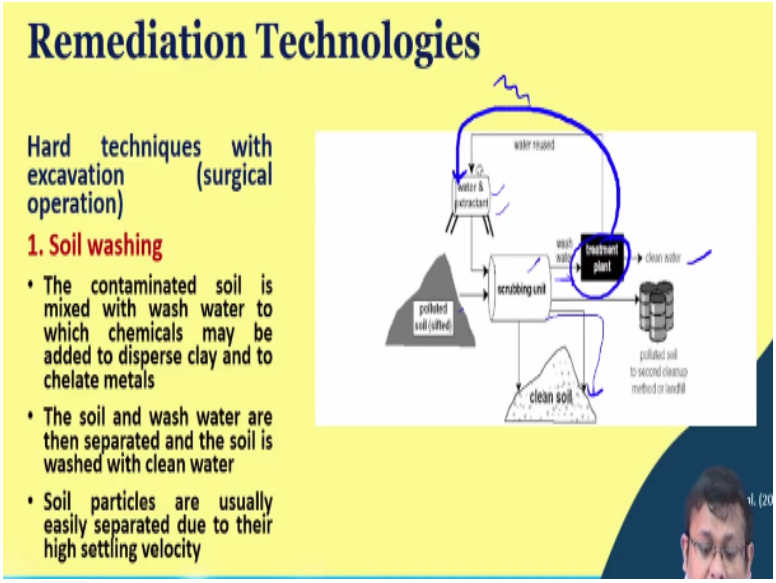

Now, another treatment is known as soil washing. So, soil washing basically the contaminated soil is mixed with wash water to which the chemicals may be added to disperse clay and to chelate the metals. So, the soil and wash water are then separated and the soil is washed with clean water and the soil particles are usually easily separated due to their high settling velocity. So, this is basically shown in this diagram.

So, basically let us consider this is a polluted soil. So, this polluted soil is basically you know placed into the scrubbing unit and in this scrubbing unit basically we are adding this water and extractant okay. So, when we add these water and extract in this turning unit and mixed with this polluted soil basically that dispersed the soil clay particles and then chelate the heavy metals and then this clean soil, the resultant clean soil we basically use for other purposes.

However, the polluted water will be basically directed to a treatment plant where they will be converted to clean water or they can be further reused. So, this is an example of the soil washing technique. Sometimes the polluted soil basically goes to the second clean up method or sometime in the landfill. So, this is an example of the soil washing technique. So,

remember that both this excavation and the soil washing are the basically hard techniques or surgical operations.

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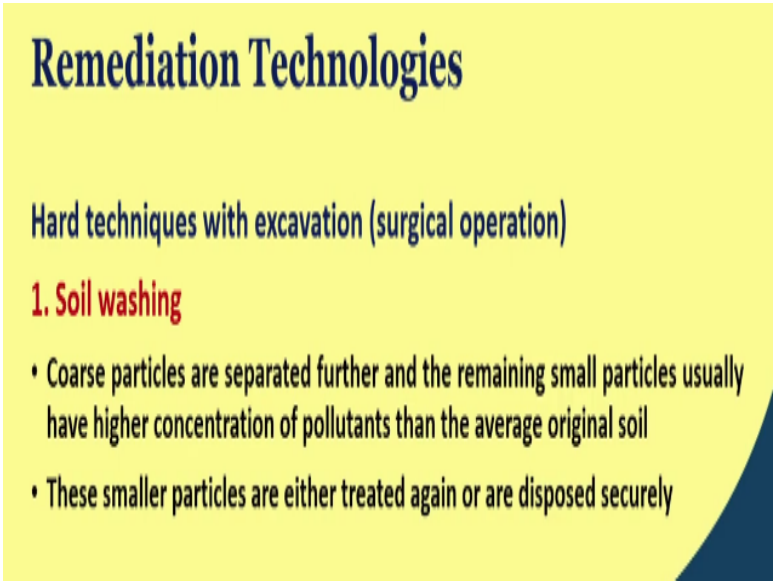

Now, coarse particles are during soil washing procedure, you know the soil particles have settled down, now coarse particles are separated further and the remaining soil particles usually have higher concentration of pollutants and the average original soil. Now, these smaller particles are either treated again or are disposed securely. So, this is how the soil washing basically executed.

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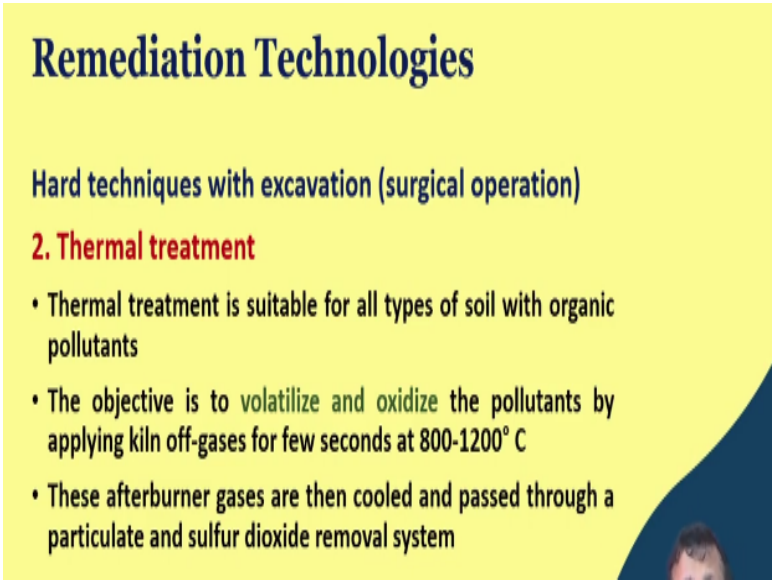

Another technique is called the thermal treatment. Now, in the first module, when we discussed the first module, I have discussed a couple of them briefly. So, the thermal treatment is suitable for all types of soil with organic pollutants. Now, the objective is to

volatilize and oxidize the pollutants by applying the Kiln off- gases for a few seconds at 800 to 1200 degrees centigrade.

Now, these afterburner gases are then cooled and passed through a particulate and sulfur dioxide removal system. So, this is how this thermal treatment is being done. Basically, it is generally applied to the soil mixed with the organic pollutants. It basically volatilize and oxidize the pollutants by applying the gases with few seconds at high temperature 800 to 1200 degrees centigrade.

And these gases are then cooled and passed through a particulate and sulfur dioxide removal system to basically clean. So, this is an example of thermal treatment.

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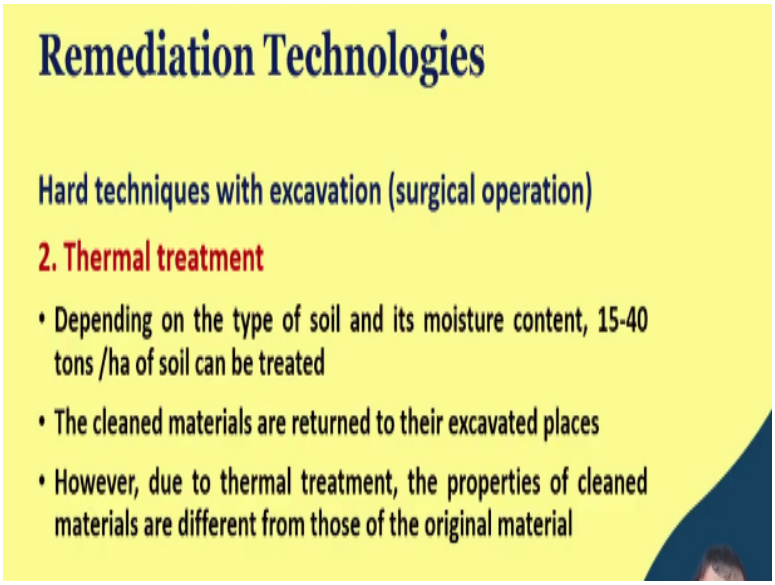

Depending on the type of the soil and the moisture content 15 to 40 tons per hectare of the soil can be treated by thermal treatment. Now, the clean materials are returned to their excavated places from where they have been excavated. However, due to thermal treatment, the properties of the clean materials are different from those of the original material because we are applying the high temperature from 800 to 1200 degrees centigrade.

And obviously their chemical nature has to be changed. So, this is one of the downsides of this thermal treatment.

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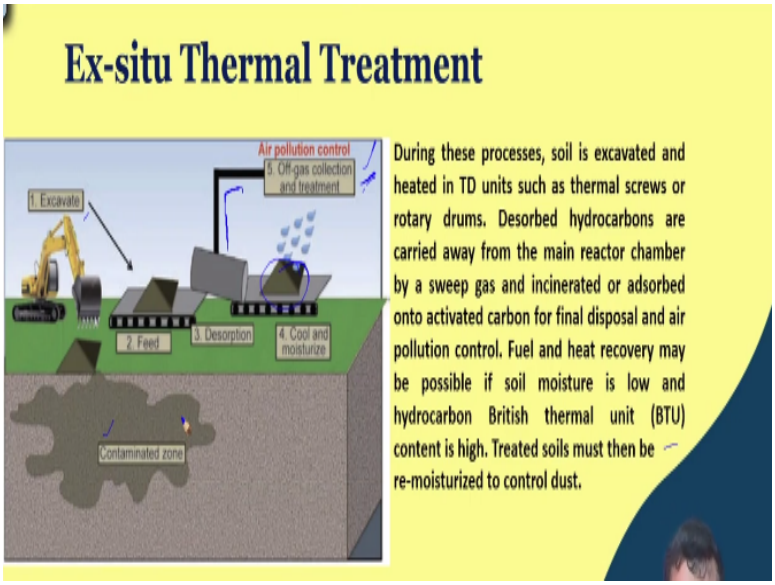

Now, the thermal treatments are again 2 types, one is ex-situ thermal treatment, another is in-situ treatment. Now, the ex-situ thermal treatment has been shown here in this picture. So, this ex-situ thermal treatment during this process the soil is excavated and heated in thermal desorption unit. This TD is the thermal desorption unit such as thermal screws or rotary drums.

So, basically the soil is as you can see here, these are contaminated soil and from this contaminated soil, the soil is excavated and then feed into this thermal desorption unit such as thermal screws and rotary drums you can see here and these desorbed hydrocarbons are carried away from the main reactor chamber by a sweep gas and incinerated and adsorbed onto the activated carbon for final disposal air pollution.

So, you can see the desorbed hydrocarbons basically is carried away from the main reactor chamber by sweep gas and incinerated or adsorbed onto the activated carbon for final disposal and air pollution control. So, these air treatments are being done in this air pollution control unit. So, this is called the off-gas collection and treatment unit also okay.

So, fuel and heat recovery may be possible if soil moisture is low and hydrocarbon British thermal unit, we generally call it a BTU, content is generally high and treated soil must then be re-moisturized to control the dust. So, you can see here first we excavate the soil and then we fed into this TD unit. In the TD unit, the dissolved hydrocarbons in the gaseous form is basically collected in this air pollution control.

And then they further treated by the activated carbon for final disposal into the air pollution control and then the treated soil is basically cooled and moisturized to control the dust. So, this is how this ex-situ thermal treatment has basically been done.

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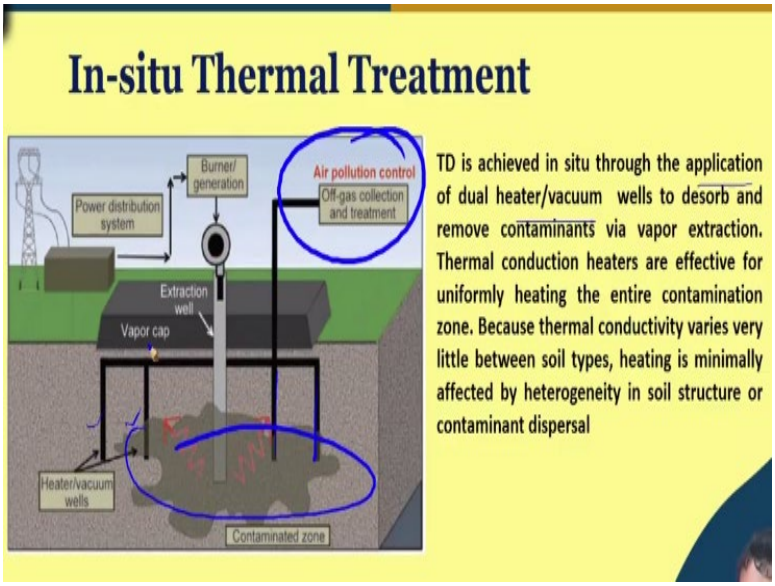

Now, the next thing is in-situ thermal treatment. Now this thermal desorption in the in-situ thermal treatment is basically done by the application of dual heater or vacuum. So, application of dual heater or vacuum wells to dissolve and remove the contaminants by vapor extraction. So, you can see here this is an extraction well and this is the vapor cap and these are the heater and vacuum wells okay.

So, basically this is a contaminated soil, so there is a contaminated zone. So, thermal conduction heaters are effective uniformly, so basically they are the thermal conduction heaters. So, this thermal conduction heaters basically uniformly heat the entire contamination zone. So, this is the contaminant zone, these are the thermal conduction heaters, they basically uniformly heat this zone. And as a result the organic contaminants converts into the vapor.

And they are basically extracted to these extraction wells. So, remember that because thermal conductivity varies very little between the soil types heating is minimally affected by heterogeneity of soil structure or contaminant dispersal. So, this is an example of in-situ thermal treatment. You can see now once this contaminant vapors are collected, they are further being treated in the air pollution control unit just like as the ex-situ of thermal treatment okay.

So, this is how this in-situ thermal treatment is basically done. Generally insert the heaters, conduction heaters, heat the soil and as a result the contaminant convert into the vapor. This vapor is being extracted by these wells, the extraction wells. These extractions well vapor basically goes to the air pollution control unit where they are further being treated before being released into the atmosphere. So, this is the in-situ thermal treatment example okay.

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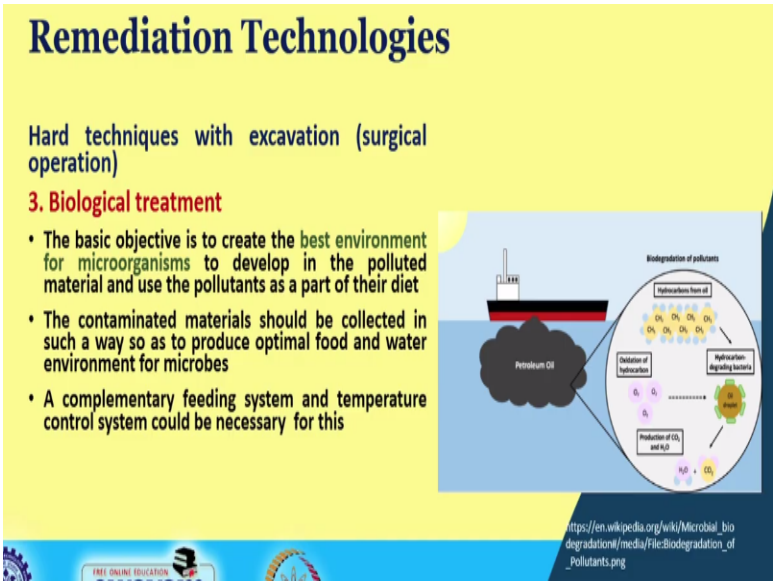

So, remediation technologies also you know hard technologies. Example of hard technologies is biological treatment or bioremediation. The basic objective is to create the best environment for microorganisms to develop in the polluted materials and use the pollutant as a part of their diet. Now, the contaminated material should be collected in such a way as to produce optimal food and water environment for the microbes.

A complimentary feeding system and temperature control system could be necessary for this. So, you can see here the petroleum is spilled, in this picture you can see that the petroleum spill occurred from this oil tanker in the ocean and as a result of that the hydrocarbon from the well is basically acted upon by this hydrocarbon degrading bacteria which basically converts this oil droplet into water and carbon dioxide by adding the oxygen.

So, these large chain hydrocarbons are basically converted ultimately to the water and carbon dioxide by these hydrocarbon degrading bacteria by involving the molecular oxygen. So, this is how these biological treatments helps for this remediation of different organic contaminants.

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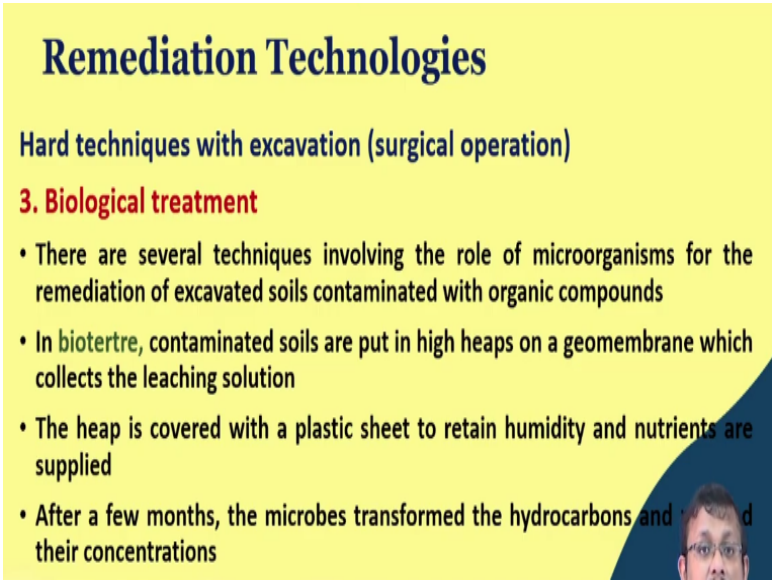

Now, there are several techniques involving the role of microorganism for the remediation of excavated soil contaminated with organic compounds. In biotertre, the contaminated soils are put in high heaps on the geomembrane which collects the leaching solution and the heap is covered with the plastic sheet to retain the humidity and nutrients which are basically supplied.

Now, after a few months, the microbes transformed the hydrocarbons and reduced their concentration. So, this is how the biological treatments are also done for the contaminated soils.

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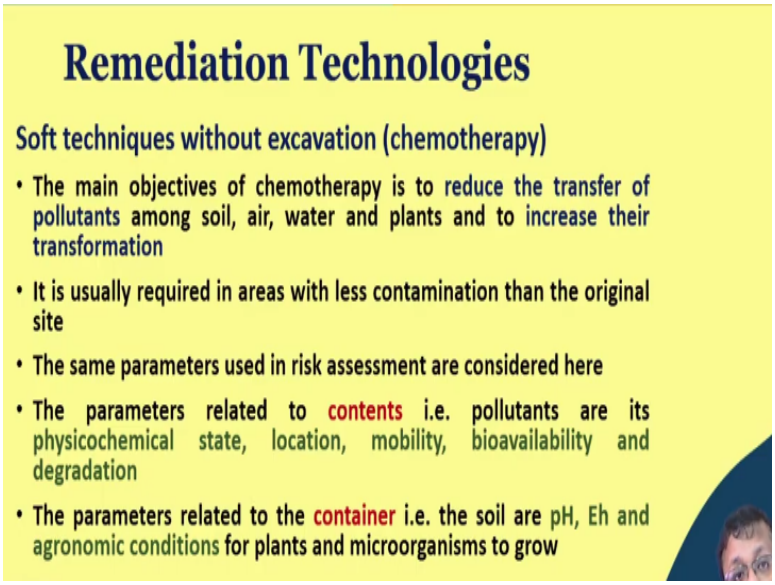

Now, soft techniques. We have covered the hard technical, let us consider the soft techniques. So, the soft techniques are basically done without excavation and also they are known as chemotherapy. Now, the main objective of chemotherapy is to reduce the transfer of pollutants among the soil, air, water and plants and to increase their transformation. So, it is usually required in areas with less contaminant than that of original site.

The same parameters used in risk assessment are considered here, just like we have seen previously, and the parameter related to contents, for example pollutants are its physicochemical state, location, mobility, bioavailability and degradation all these are considered for their remediation and the parameters related to the container that is the soil are the pH, Eh and agronomic condition for plants and microorganisms to grow.

So, all these are being considered for developing a suitable soft remediation technique or chemotherapy technique.

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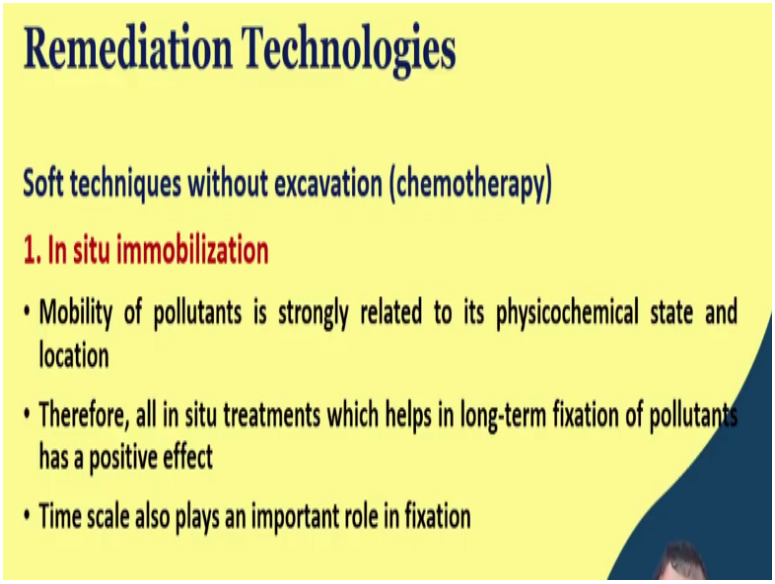

We have completed the hard techniques, let us consider the soft techniques. The soft techniques are basically done without the excavation process. So, they are also known as the chemotherapy. So, the first soft of technique without excavation or the first chemotherapy technique is basically the in-situ immobilization. Now, remember that mobility of pollutant is strongly related to its physicochemical state and location.

Therefore all in-situ treatments which helps in long term fixation of the pollutants has a positive effect. Now, timescale also plays an important role in the fixation of the pollutants.

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Now, remember that fixation of heavy metals by microbes, plants and soil organic matter you know that all these can fix the heavy metals. So, their fixation occurs in a short time scale. This is because the microbes basically die or the soil organic matter transform or oxidize thereby releasing the pollutants back into the soil.

Now, on the other hand if the heavy metals are incorporated in the mineral structure, the long-term fixation is generally expected. So, the techniques which give the long-term fixation of the heavy metals must be used for this chemotherapy process or in-situ mobilization process.

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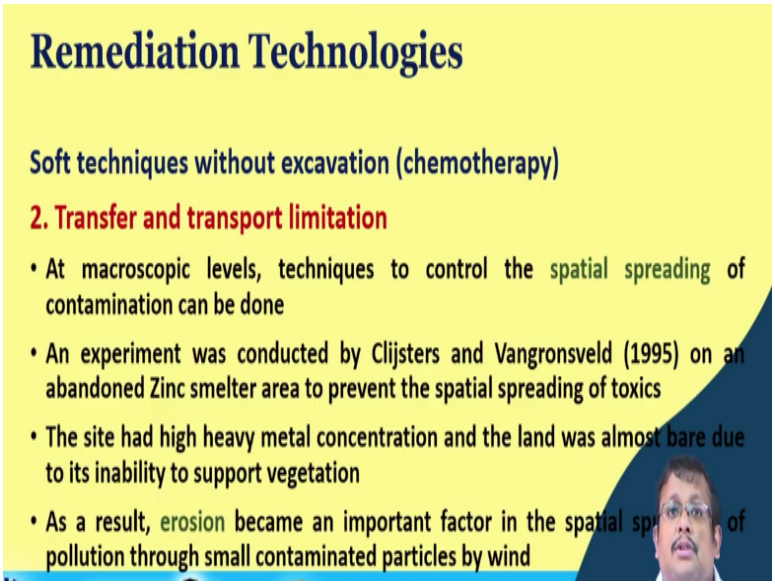

The second technique is the transfer and transport limitations. So, at macroscopic levels, techniques to control the spatial spreading of contaminants can be done. So, an experiment was conducted by Clijsters and this other scientist called Vangronsveld in 1995 on an abandoned zinc smelter area to prevent the spatial spreading of the toxics. So the site had high heavy metal concentration and the land was almost bare due to its inability to support the vegetation.

So, there was no vegetation due to high heavy metal content. So, as a result erosion become an important factor in the spatial spread of the pollution through small contaminated particles by wind. So, this is an important consideration for soft techniques without excavation or chemotherapy techniques. So, this is called the transfer and transport limitation.

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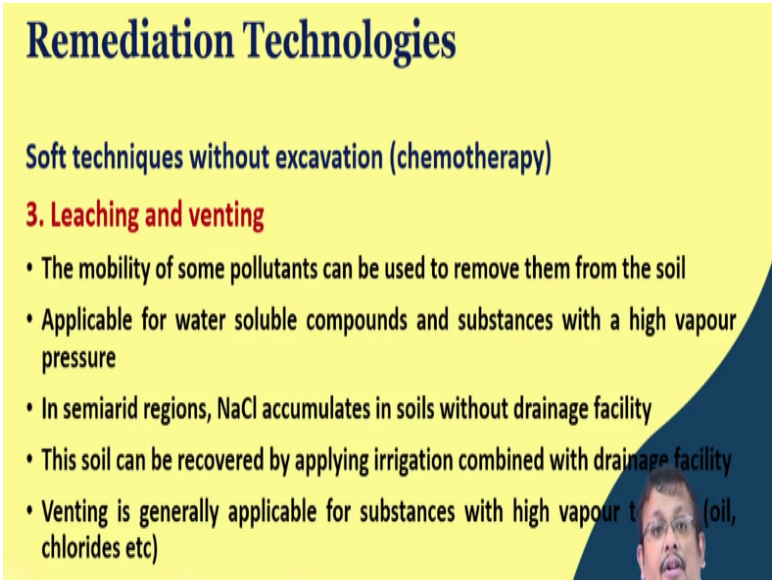

The third one important aspect is leaching and venting. Now, the mobility of some pollutants can be used to remove them from the soil and this is basically applicable, this leaching is basically applicable for water soluble compounds and substances with high vapor pressure. Now, in semiarid regions sodium chloride accumulates in the soil without drainage facility. Now, this soil can be recovered by applying irrigation combined with the drainage facility.

So, leaching is the only treatment which can remediate this sodium chloride concentration in the soil. The second technique venting is generally applicable for substance with high vapor pressure. For example, oil, chloride, etc. So, these have high vapor pressures, so venting is generally done for these types of substances.

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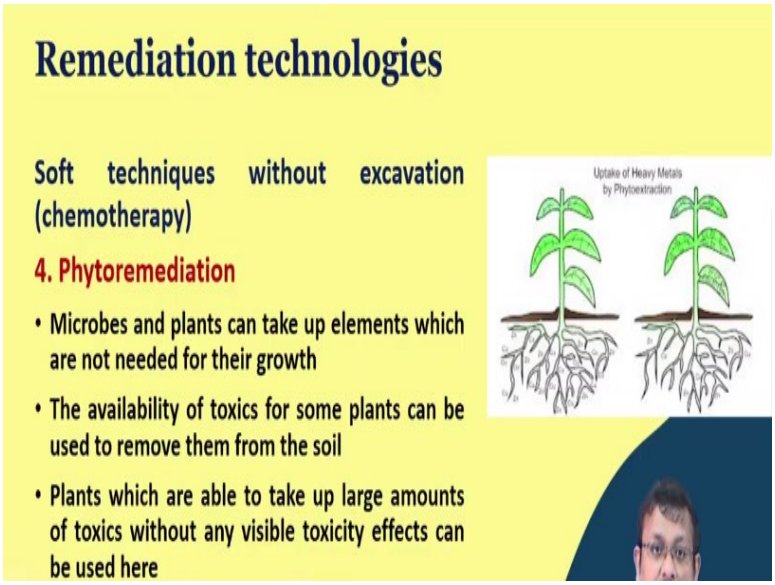

Another important soft technique is phytoremediation, you know about the phytoremediation. Microbes and plants can take up the elements which are not needed for their growth and the availability of the toxics for some plants can be used to remove them from the soil and plants which are able to take up large amounts of toxics without any visible toxicity effects can be used here. So, this is an example of phytoremediation when the plants are extracting the heavy metals from the soil.

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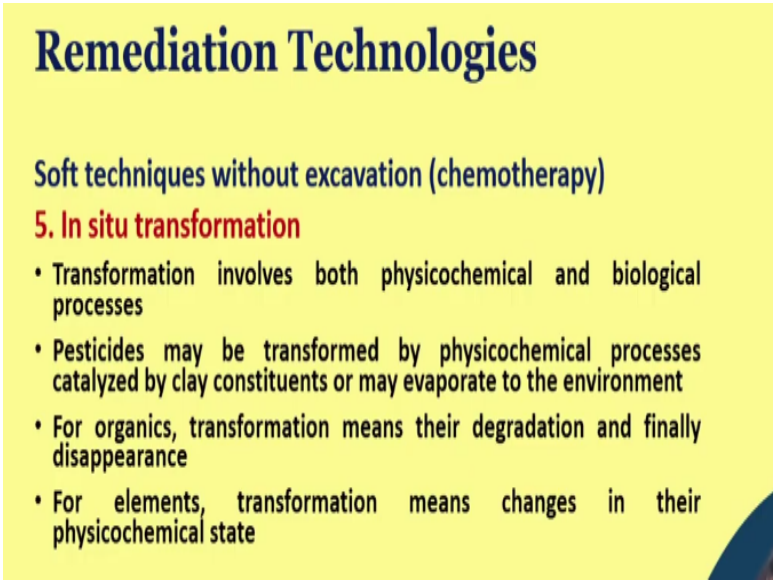

The fifth one is in-situ transformation. Now, transformation involves both physicochemical and biological process. Pesticides may be transformed by physicochemical process catalyzed by clay constituents or may evaporate to the environment. For organic transformation means their degradation and finally disappearance. So for element, transformation means changes in their physicochemical state. So, their toxicity can be reduced.

So, these are all 5 chemotherapy or soft techniques without excavation, which are different from these hard techniques. So, remediation measure for any pollution can be designed by the help of these remediation techniques and there are different types of techniques you have learned, thermal techniques and then biological techniques. And depending on the condition and depending on the cost of the technique also, you can select the best technique for further remediation measures.

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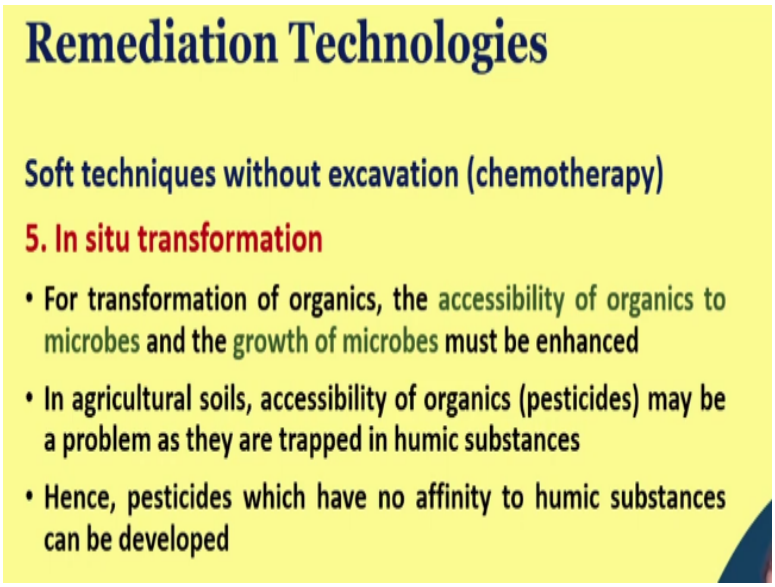

So, for transformation of the organics, the accessibility of organics to microbes and the growth of microbes must be enhanced remember that, so their activity can be enhanced. In agricultural soil, accessibility of the organics or pesticides may be a problem as they are trapped into the humic substances and pesticides which have no affinity for the humic substances can be developed.

So that entrapment by the soil organic matter can be reduced and they are more exposed to the bacteria which can degrade these pesticides. So, this is one of the remediation measures.

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So, by this, we are wrapping up to the module 11. I hope that you have gathered some new knowledge in this week and these are the references for this module. First of all Soil Pollution Process and Dynamics by Yaron, Calvet and Prost and these are the other Vidonish et al in 2016 that Pyrolytic treatment and fertility enhancement of soil contaminated with heavy hydrocarbons.

So, this is another very good paper you can consult for getting more comprehensive knowledge of soil remediation. So, if you have any further questions, please email me, I will be more than happy to answer your queries. And let us meet in our last module to discuss different analytical techniques for soil, environmental, soil pollution control. Thank you very much.