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Environmental Soil Chemistry

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Lecture-05

Evolution of Soil Chemistry (Contd.)

Welcome friends to this fifth lecture of week 1 of this course environmental soil chemistry. And in this lecture, we will talk about some passive remediation techniques for land and soil. And so far we have discussed about different aspects of environmental soil chemistry. We talked about different types of agents of soil contamination starting from different nutrients, which we apply through different fertilizers.

Apart from that, we also discussed about different types of pesticides, different trace elements, acid deposition due to different types of anthropogenic actions and we discussed different types of solid wastes and how the water of our surrounding are getting polluted from different point and non-point sources of pollutions. So, we discuss all of these, we have discussed about different types of land management techniques both in-situ techniques as well as ex-situ techniques.

So, in the in-situ technique we talked about vitrification, we talked about bioremediation, which is one of the most important methods of land reclamation. And while talking about the bioremediation, we talked about phytoremediation also, and phytoremediation basically, you know, that it is a

plant mediated decontamination process. And so today, we will start from different passive remediation technique.

Now, the passive remediation in case of passive remediation different natural processes such as volatilization, aeration, biodegradation and photolysis are allowed to occur as you can see in these slides, these are the important process in passive remediation. However, we, we, we allow this process to be, to be operated under passive remediation techniques like volatilization, then aeration, biodegradation and photolysis.

And these processes may cause decontamination. Now, passive remediation is simple and inexpensive and requires only monitoring of the site. They say there are several factors which affect the type of remediation include basically bio bioremediation, then adsorption, then volatilization, leaching, photolysis, soil permeability, groundwater depth, infiltration and nature of contaminants. So, all these factors are very important, which affect the remediation by, you know, which basically impacts the passive remediation.

So, so, let us move ahead and see what are the different types of non in-situ methods sometimes we call them ex-situ methods also. So, non in-situ methods involve removal of the contaminated soils usually by excavation and then the soil is treated on site or transported to another location and then treated. So, basically, it is basically excavation followed by different types of treatment of the soil.

So, with this method there are obviously concerns about the exposure of the contaminants in the moving or hauling process. However, in some areas, this technique is still followed. There are several types of non in-situ techniques. For example, land treatment is there as you can see here, land treatment is there, then thermal treatments sometime we call it incineration, then asphalt

incorporation, solidification, chemical extraction, excavation. All these are non situ, in-situ methods. So, let us, let us see them one by one.

First of all let us see the land treatment. Now, the land treatment is a technique when the contaminated soil is excavated and sprayed over the land so that, the natural process such as biodegradation or photodegradation can occur to decontaminate the soil. So, basically, here the soil is excavated and then it is kept over the surface. So, that it can produce the required area for carrying out the bioremediation practice, bioremediation process as well as decontamination, other decontamination process.

Remember, the land area which is basically used for this land treatment is basically prepared by grading to remove rocks and other debris and the area is surrounded to lessen the runoff. Because if there is a runoff, then there will be chance of movement of contaminant from this untreated soil or contaminated soil to other areas where contamination is not present. So, this is about the land treatment.

Let us move ahead and see what are the other aspects of land treatment. Now, the soil pH, in case of land treatment is basically adjusted to 7 to immobilize heavy metals and to enhance the activity and effectiveness of the soil microbes. You know that the soil contains millions and millions of different types of microorganisms starting from bacteria. Then protozoa, then nematodes, then fungi, then algae, different types of other macro fauna.

So, the, the soil basically the microbes, which are present in millions and millions per gram of soil, they are very active in degradation of different types of contaminants, especially the organic contaminants and some inorganic contaminants also. So, to activate these microbial flora and fauna, it is necessary to produce the conducive environment and the conducive environment for most of the bacterial, you know, species is near neutral pH.

So, that is why, we generally try to keep or maintain the soil pH near about 7 to maintain their activity. So that, they will be able to degrade the organic as well as some of the inorganic contaminants. Sometimes, we also add nutrients for microbial stimulation. Because when you apply the nutrients, that will help in microbial growth and then stimulates the microbial growth for further degradation process.

So, the contaminated soil is then spread on the site and mixed with other soil to enhance the contact between the contaminant and the microbes and to promote aerobic conditions. So, the aerobic condition is needed for most of the microbes which are aerobic in nature and by the stimulation process, their activity is enhanced and ultimately these enhanced microbial activity degrades the organic as well as inorganic contaminants.

Another method which is important is called the excavation. So, with this method, the contaminated soil is basically removed and disposed elsewhere. Specifically, most of the time these contaminated soils is disposed in the landfill area and will talk about the landfill very soon. So, landfill basically usually contains the liners such as clay that diminishes the mobility of the contaminants.

We have already talked about the organo-clays. So, when we are putting the lining, in the help of, with the help of clay that contains those contaminants within that area or the landfill sometimes should be located on the sites where the soil permeability is low. Remember that landfill requires large land areas and often pose hazardous to the human because of its contaminated pollutants and then different odors and all these things.

So, excavation and disposal costs are generally very high. And there are also liability problems, safety concerns, odor productions and potential runoff and

groundwater contamination problems. So, as you can see here, this picture basically shows the excavation process. So, if, if this is a contaminated zone, this excavator basically excavating this contaminated soil and then it is being feed to and then pyrolyze and cool, moisturize and re-green.

So this is one of the way of treating and, excavating and treating the soil. Most of the time the excavated soil get deposited in the landfill region. So, those who do not know about what is the landfill, basically the landfill is an area where all the municipal solid waste and other contaminants are disposed. And then, this is specifically, this area is specifically used for that purpose. Now, the next treatment is basically known as a thermal treatment. Sometime we call it incineration. Remember that with the thermal treatment, the excavated soil is exposed to high heats using a thermal incinerator and the high temperature breaks down all the pollutants.

And, and basically released different types of volatiles and then collected and move through an afterburner and combusted or recovered with different types of solvents. So, this is how the thermal treatment basically works. And so, this is basically a landfill area, a landfill is a basically carefully designed structure which is built into, or on top of the ground in which trash is basically separated from the area around it. So, this area is supposed to contain huge amount of different types of contaminants both organic as well as inorganic in nature.

So, we have talked about excavation, we have talked about thermal treatment or incineration. Sometime both excavation and incineration, operated simultaneously for treating the soil. Remember that excavation and incineration is successfully used, simultaneously used method for cleaning up the toxic waste. This method involves digging up and removing the poisoned soil from the aquifers and then burning it at a high temperature.

So, that only nontoxic materials are released into the air, the toxic metal burned into the incinerator, while the soil remains behind and then the clean soil can be placed back into the ground. So, this is the total process and this picture basically shows this process as you can see, this is a polluted aquifer which contains polluted soil materials. So, this soil, contaminated soil can be excavated from this polluted aquifer.

And then it will be feed through this portable incinerator and due to this heat treatment, most of the toxic materials burns into the incinerator. So, incinerator burns the toxic material out of the soil and the clean soil you can see then is dumped back into the excavated aquifer. So, this is basically a combination of two processes, one is excavation another is incineration.

So, let us move ahead and see what are the different types of pros and cons of this joint excavation and incineration process. Well, the plus point of these, you know, combined excavation and incineration processes. This method ensures that most of all the pollutants are removed from the ground there is a first important point. The second important point of any water that flows through the ground in the future will be cleaner.

So, this is another important aspect of this combined treatment and if the polluted area is small and not too deep, then the area can be cleaned up in a short period of time because of this incineration process. So, this, this combined excavation and incineration process basically has these three advantages. However, it also comes with different types of disadvantages. What are those first of all, buildings, streets, lakes, etc may have dug up and then destroyed in order to find the pollution because we had to dug the soil from this polluted aquifer.

Secondly, because of the digging and need for large equipment, there will be a lot of noise and dust in the neighborhood or the area and some of the dust could

contain the toxic materials which are, which are hazardous for human health. Third is, accidents may happen to the workers because sometimes in these areas, cave ins occurs and as a result some accident occurs. So, some toxic ashes may remain after the burning.

And these must be transported to a safe storage site and stored waste may leak over time, if not properly, you know, cared for and potential air problem from the incineration process is another threat for this combined excavation and incineration and possibility of toxic material leaking from the incinerator or during transport to the incinerator is another big problem.

Building a large incinerator or buying a small portable incinerators or, you know, it is a big upfront cost and however, you know, once you have it, other toxic materials can be burned. So, these are the some of the disadvantages or downside of this combined excavation and incineration processes. So, we have finished this excavation and incineration.

And the next method of ex-situ decontamination is asphalt incorporation. Now, with this method contaminated soils are put into the hot asphalt mixes and these mixtures are used in basically in paving as you can see in this picture and the asphalt and the soil are heated while they are mixed and this causes different volatilization or decomposition of some of the contaminants.

And the remaining pollutants are then immobilized in the asphalt. So, in this process again, this asphalt is basically mixed with the contaminated soils and then they are used for paving the ground or paving the road. And then this basically causes volatility, you know, this basically, while, while mixing the soil with the hot asphalt in here, you know, then it causes volatilization or decomposition of the some of the components.

And the remaining pollutants are then immobilized in the asphalt, which is a beneficial effect of this asphalt incorporation. So, this is a very important method for ground treatment, soil treatment in urban areas. And, another process of a non in-situ soil treatment or ex-situ soil treatment is solidification and stabilization. So, this technique basically involves the addition of an additive to excavate, or contaminated, excavated or the contaminated soil, so, that the contaminants are encapsulated. Again, this technique basically involves the addition of an additive. So that, the contaminants are encapsulated, they are bind together.

So, the mixture is then landfilled, thus the contaminants are not free to move alone. However, they are not basically destroyed. They are basically contained in the landfill region after, you know, encapsulated with the help of these additives, however, they are not destroyed. However, this method has been employed to minimize the inorganic pollutant contamination in some places.

The next method for ex-situ soil treatment is chemical extraction. Now, in this treatment the excavated soil is basically mixed with the solvent, surfactant or solvent/surfactant mixture to remove the contaminants and the solvent or surfactant and released contaminants are then separated from the soil and the soil is then washed or aerated to remove the solvent, surfactant and the latter is then filtered for the particles and treated to remove the contaminants.

And this technique is expensive and not very often used. So, basically it is, is solvent or surfactant, surfactant based extractors, extraction of contaminants from the contaminated soils and however this method is very much costly. So, you will not see it very often except for a couple of cases.

So, so, this table basically summarize different types of in-situ and non in-situ or ex-situ methods of soil treatment.

If you can see here again, we have discussed all this but let us see again here you can see in the in-situ methods we have discussed volatilization, biodegradation, phytoremediation, leaching, vitrification and in the passive, we have talked about isolation or contaminants containment and in case of non in-situ, we talked about land treatment, thermal treatment, asphalt incorporation, solidification. Sometime, you know, groundwater extraction and treatment is also there and chemical extraction is also there.

So, if we, you know, if we if we summarize we can see that the advantage of this land is, land treatment is basically natural degradation process and thermal treatment basically is very helpful because it, it ensures complete destruction of the contaminants.

In case of asphalt incorporation is basically using up the existing facilities or use of existing facilities. So, it is helpful. In case of solidification, it basically helps by immobilizing the compounds. In case of groundwater extraction treatment, to basically product recovery and groundwater restoration it helps in and finally, in case of chemical extraction or excavation it basically removal the soil from the site.

So, there are also some limitations, as you can see, in case of land treatment, some residuals is already, already there. So, you cannot completely remove the contaminated soil in case of land treatment. In case of thermal treatment, usually basically it requires a special features and also temperature generation is very, you know, depends on different types of other electrical, you know, energies like electric supply which is costly.

Asphalt incorporation also has some limitation. For example, there is incomplete removal of heavier compounds. In case of solidification, it is not commonly practiced for soils and also in case of chemical extraction, it is not commonly practiced. However, in case of excavation it, it has a problem of

long term liability. So, relative cost if you see the relative cost obviously, land treatment is basically, you know, it has a moderate cost involvement.

In case of thermal treatment, it has very high cost involvement, in case asphalt incorporation, it has moderate, in case solidification, it has moderate again, in case of groundwater extraction treatment as again moderate and then chemical extraction excavation, it has high, you know, cost involvement. In case of passive decontamination process, the limitation is the compounds are not destroyed, because it is only the containment process.

And only the advantages, it physically prevents or impedes the migration and in the relative cost if you decide that if we discuss the relative costs, it is basically low to moderate. So, this basically summarize different types of, you know, advantages, limitations and relative costs of different in-situ and ex-situ processes. In case of in-situ processes obviously, we have discussed but let us discuss again.

So, in case of volatilization, you can see it can remove some compounds, which is resistant to bioremediation. However, the volatile organic compounds only, you cannot you cannot remove the nonvolatile compounds. So, it is the relative cost is very low. In case of bioremediation, it is effective on some nonvolatile components also, but it recurs long timeframe and it has got moderate cost involvement.

In case of phytoremediation, it is effective with a large number of inorganic and organic chemicals. However, it has the limitation that plants are often specific for particular contaminant. So, you have to use a group of plant if you want to remediate a group of contaminants and the relative cost is low to minimum. In case of leaching it could be applicable to a wide variety of the compounds.

However, the limitation is it is not commonly practiced because it has also had some moderate relative cost. Vitrification, vitrification is a developing technology and cost involvement is very high. So, these are some advantages and limitations of different types of in-situ techniques and I hope that this slide basically summarize the major take, you know, take home message from these different in situ and non in-situ techniques which we have discussed for last two lectures.

So, so, then we have completed these different land treatments and land decontamination process and there is another important term which is very popular nowadays called molecular environmental soil chemistry. We have talked about the soil chemistry. Now, let us talk about the molecular environmental soil chemistry. The use of small scale techniques in environmental research has resulted in new multidisciplinary field of study that environmental soil chemists are actively involved in.

And this is called the molecular environmental science, it is a multidisciplinary approach for addressing the environmental problems. And molecular environmental science can be defined as the study of chemical and physical forms and distribution of contaminants in soils, sediments, waste materials, natural waters and the atmosphere at the molecular level. So, this is what we call the molecular environmental soil chemistry.

Remember that, there are different types of applications in molecular environmental soil chemistry, of which this, you know, you know, include speciation of the contaminants, which is essential for understanding the release of mechanism, spatial resolution and then chemical transformation, toxicity, bioavailability and ultimate impact on human health. These are all important applications for this molecular environmental soil chemistry.

And for microbial transformation example, bioremediation, phytoremediation and then development of predictive models, effective remediation and waste management strategies, and also these assessments. So, all these, so you can see here, the molecular environmental soil chemistry basically addresses the environmental contamination in a holistic way and it is a multidisciplinary.

And so, it is basically again, it is a multidisciplinary approach for addressing a specific environmental problem related to soil. So, if you see the illustration of various spatial scales that environmental scientists are interested in, you can see they are interested from the atomic level to the molecular level to the microscopic, macroscopic to the field and landscape levels. So, this is a, you know, it is basically comparison of differ or relative spatial extent of different levels of this molecular environmental soil chemistry.

So, at last we could, I just want to focus on this slide which basically shows what are the contemporary research areas in the environmental soil chemistry domain. So, if you see, there are a number of, you know, domains in the, advanced domains of research areas nowadays in the environmental soil chemistry, when we are taking the soil, from the soil from different horizons and also from different sediments and water.

They all can be used for analyzing or characterizing a number of different types of components, which are basically metal oxides, among the metal oxides, iron oxides, aluminium oxides and manganese oxide are very important, also biopolymers is very important and is a component, you know, and then virus, inorganic contaminant, layer silicate structures, which we will discuss in the next week.

So, layer silicate structure, their natural organic matter, bacteria, organic contaminants all these are very important and all these play an important role while we are talking about environmental soil chemistry and research is in

advanced countries, in western countries, basically going on for these metal oxides and all these individual components. Remember that all these individual components can coexist.

And there are several processes which are responsible for the sorption, transformation, bacterial adhesion and biomineralization/ dissolution. All these processes are active in the soil, which basically governs the dynamics of these individual components. So, these are some advanced research areas in the, in the environmental soil chemistry domain and as the course progress, we will discuss other areas which are having advanced application of environmental soil chemistry.

So, friends, let us wrap up week 1, this is a basically in this week we have an overview of different aspects of environmental soil chemistry. We started with the definition of soil chemistry and environment and how it is, how it is diff, how, how the normal soil chemistry differs from environmental soil chemistry, we talked about different agents of contaminants, different agents of contamination.

And how contamination basically occurs in water as well as in soil and how to prevent that contamination or take management decisions for remediating those contaminated soil we have discussed different types of in-situ passive and non in-situ or ex-situ techniques we have discussed. We have discussed their different types of advantages and disadvantages and relative cost involvement.

I hope that this first week lectures have given you enough insights on which direction we are going in coming weeks of this course, and I hope that you have gathered some important information from this overview lectures of week 1, and from next week, we will start discussing in details about the chemical

composition of soil and their different implications. Thank you and let us meet in the next week lectures.