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Environmental Soil Chemistry

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Lecture-04

Evolution of Soil Chemistry (Contd.)

Welcome friends to this new lecture of environmental soil chemistry, we are still in week 1, and this is our fourth lecture of week 1, and today we are going to discuss about different types of solid wastes that we will be seeing the, you know, definition of solid waste and then, different methods of remediation of environmental pollutants. So, in our last couple of lectures we talked about different agents of environmental pollution.

We talked about different nutrients based environmental pollution specifically eutrophication, we talked about point source, nonpoint source pollution, we talked about fertilizers, we talked about, pesticides, and we also talked about trace elements which are very important in, you know, agent of environmental pollution. We talked about acid rain and how it impacts the terrestrial as well as the aquatic environment in brief. And right now, we are going to discuss about different types of solid waste and how they impact the, the terrestrial as well as aquatic environment.

So, what is the definition of solid waste? So the solid waste definition according to the resource conservation and recovery act, RCRA of 1976 that solid waste is a, any garbage, refuse sludge from waste treatment plants, water supply treatment plants, or air pollution control facilities and other discarded materials, including solid, liquid, semi-solid or contaminated gases, gaseous materials resulting from industrial, commercial, mining and agricultural activities.

And from community service activities but does not include solid or dissolved materials in domestic sewage or irrigation return flow. So, this solid waste definition is very comprehensive one and this picture shows the definition of solid waste and as you can see, as far as the, as far as the definition, you know, it, it consists of any garbage, refuse sludge from waste treatment plants.

And water supply treatment plants or air pollution control facilities, so whatever by, you know, whatever waste generated in this waste treatment plants, water supply treatment plants as well as air pollution control facilities and other. So, these basically comes under the solid waste and also some discarded materials including these solid, liquid, semi-solid or contaminated gaseous material results from different types of industrial activity, commercial activities.

And also mining and different types of agricultural activities and also different types of community activities. So, these are all important factors, waste treatment plants and different types of industrial, community and agricultural activities. So, these are the major sources of the solid waste. However, it does not include any solid or dissolved materials in domestic sewage, as well as irrigation flow. So, these are not included in the definition of solid waste.

So, if we go ahead and see the definition of hazardous wastes. What is hazardous waste? Hazardous waste is defined as a solid waste, or combination of solid waste, which because of its quantity, concentration or physical, chemical or infectious characteristics may cause significantly contribute to an increase in serious irreversible or incapacitating reversible illness or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed, or otherwise managed.

So, basically this is a part of the solid waste, which is basically creating different types of environmental hazards. Maybe in terms of human health hazard, or maybe the environmental bad impact. So, so the hazardous waste is a, is basically is a fraction of the total solid waste which are creating different types of diseases, or significant negative environmental impact. So, if we go ahead.

What are the different types of hazardous waste materials? So, question always comes, okay, we have seen there are different types of solid waste. So, what are the different hazardous waste? Obviously, these are different hazardous waste materials like mine wastes. One of the major mining waste is, you know, this acid drainage and this acid drainage also produces different types of, you know, hazardous impact on the environment.

Then acid mine drainage obviously, it is incorporated here, wastes from metal smelting and refining industries. The smelting and metal, you know, smelting and refining industry produces different types of hazardous waste which also reaches to the environment and ultimately creates the environmental pollution. Pulp and proper paper industry wastes and petroleum refinery wastes, waste from paint and allied industries, pesticide applications, inorganic fertilizer, municipal solid waste, so, all these are very important hazardous waste.

Municipal solid waste at the source of a large number of infectious disease, and also huge amount of trace element contamination. Specifically, when those, you know, municipal solid waste are used for agricultural purposes, inorganic fertilizer is an important source of environmental pollution.

Because that creates the concentration, higher concentration of certain deleterious compounds in the soil. Pesticides application, we have already discussed in our last couple of lectures, pesticides have got several, you know, deleterious impact so when it, you know, when it is applied into the environment it creates some problems, waste from paints and allied industries are also very important environmental, environmental pollutants.

So, if we go ahead and see in details that we have talked about different sources of environmental pollution, different agents of environmental pollution. Now, what is the way of decontaminating the soil, because we are more concerned in this course about the soil, we call it soil decontamination. So, soil decontamination is the process in which we generally remove or eradicate different sources of pollution from the soil, using different types of physical, chemical and biological process.

Now soil decontamination, if we are concerned about soil decontamination, the techniques which we employ in soil decontamination are basically of two types, one is this in-situ technique, another is non-in-situ technique or ex-situ techniques. So, to optimize the cleaner for the soil most of the times or more than one that techniques are used. So, it is not that the in-situ technique will produce the best result sometime we have seen that proper combination of this in-situ technique as well as this non in-situ technique or ex-situ technique produces the best remediation practice.

So, the complexity, what is the reason behind that? The reason behind is the complexity of the soil and the presence of multiple contaminants. You know, basically, you know, responsible of negating any specific in-situ or ex-situ techniques. So, that is why it is, it is, it is necessary that judicious combination of both in-situ technique as well as ex-situ technique for proper soil decontamination.

So, let us first consider the in-situ techniques, we will be, we will be discussing these 5 in-situ techniques, you know, volatilization, biodegradation, phytoremediation, leaching and vitrification. So, remember that, the in-situ techniques are used at the site of the contamination. So, soil excavation is not needed and it maximize the, minimizes the exposure pathways. Obviously, the in-situ techniques, you know, are basically applied at the place of contamination.

So, we are not excavating the soil. So, all these techniques are applied at the site of contamination. So, let us see what are these important, so, let us start with the volatilization. The volatilization process is described in this, in this picture. Obviously let us, what is volatilization? So, in-situ volatilization causes mechanical drawing or air venting through the soil. So, we can basically in, you know, incorporate the air into the soil or draw the air from the soil. And during this process, we can remove some of the important contaminants.

So, the other name of this, you know in-situ volatilization is, air sparging or in-situ air stripping. So again, air sparging or in-situ air stripping, and this technique is mainly useful for removing the volatile organic compounds such as petroleum, hydrocarbons. So, how it basically operates, is basically operates, a draft fan is injected or induced, which causes an airflow through the soil and via slotted or screened pipe. So, that air can flow, but entrainment of soil particles is restricted.

And, you know, some treatment like activated carbon is used to recover the, volatilized contaminated and the technique is limited to volatile organic carbon material. So, as you can see in this picture. This is a contaminated soil, so air sparging is basically done through this air sparging well. And, as a result of this air sparging, whatever volatile organic compound or is there is basically volatilizes.

And goes to the upper part of the soil, and from this upper part of the soil, we have, they have installed this vapor extraction wells, which basically draw the air. So, through this process, whatever deposition of volatile organic contaminants are there in this lower parts or lower parts of this contaminated soil will be converted to, you know, more volatile compound. And this volatile compound through the gas or through the air will be further extracted and through this vapor extraction well.

So, this is how this volatilization, or air sparging basically operates. Okay, and some time we also use activated carbon, which is basically used to recover the volatilized contaminant, and ultimately decontaminated, decontaminates the land.

Now another very important aspect of soil decontamination is bioremediation. Now bioremediation is not a single technique, bioremediation is basically a combination of multiple process, multiple techniques. So, bioremediation basically operates, or mediates through the action of different microorganisms. So, this is, you know, so, you know, the presence of, you know, different microorganisms or macroorganisms are important in bioremediation.

There are several types of bioremediation, several aspects of bioremediation, we are seeing here. First of all, natural attenuation, then aerobic or anaerobic, anaerobic biodegradation, we will discuss biodegradation, and then biopiles, land treatment, bioscrubbers, methanotrophic process, in-situ methanotrophic process, the plant root uptake or phytoremediation, we will also discuss in details the phytoremediation process.

Then then solid phase bioremediation, bio wall for plume decontamination in-situ, then biodegradation, composting, bioreactors, dehalogenation, binding of metals, fungi inoculation process, slurry phase remediation, bioventing and bioremediation of metals, basically changing of the valence. So, these are different aspects of bioremediation. We will discuss some of them specifically biodegradation and phytoremediation. And in the due course of, you know, in this course we will see this processes, we will discuss these processes in detail.

So, let us go ahead and see what is biodegradation. Now, in-situ biodegradation involves the enhancement of naturally occurring microorganisms by stimulating their numbers and activity. So, in situ microorganisms and their activity, their numbers have been boosted by this in-situ biodegradation technique, and the microorganisms then assist in degrading the soil contaminants because these microorganisms are known for degrading the substances, organic substances or some time the inorganic substances.

So, a number of soil environmental, chemical and management factors affect the biodegradation of soil pollutants including, you know, moisture contained, then pH, temperature, the microbial community present and the availability of the nutrients and the optimum soil pH for bioremediation is 7, whereas the temperature, optimal temperature is 293 to 313 Kelvin, one specific community of microorganisms can degrade only a specific form of pollutants. So there is specificity for degrading the, some of the chemical, you know, some of the, some of the environmental pollutant is well established. So, we will discuss a couple of them.

For example, this is a bacterial bioremediation of arsenic. So, bacterial bioremediation arsenic basically occurs through, you know, incorporation of, you know, these are some bacterias. So, this research had been produced in India in the year 2011, where the researchers have identified several strains of bacterias, and they have seen that these strains of bacteria can ingest huge amount of arsenic compound specifically different forms of arsenic in their body.

And as a result of that, they can decontaminate the soil. So, these bacterias are, you know, the specific strains of bacteria are known to ingest this arsenic, from the environment and thereby, they basically fixed, they basically fix this arsenic in their body. And this is basically the scanning electron micrograph, and this is the transmission electron micrograph shows the internal deposition of arsenic within this microbial body.

And this shows the EDX analysis showing the presence of arsenic here. So, this basically shows, I mean, there are thousands and thousands of research are going on for bioremediation of heavy metals, and this bioremediation of heavy metals are, you know, is very important for decontaminating the soil.

Now another important aspect of bioremediation is phytoremediation where we use plant. The name phytoremediation comes from the plant based remediation, phyto means plant. So the use of plants to decontaminate soil and water is known as phytoremediation, remember that this phytoremediation can be quite effective, and there are hundreds of plant species that can detoxify different types of pollutants.

The research on phytoremediation is going on in several places. For example, recently, you know, a brake fern the scientific name is Pteris vittata was found to be an arsenic hyperaccumulator and very effective in remediation of soil contaminated with chromated copper arsenate. So, this Pteris vittata has been found to accumulate the arsenic from the, from the soil which is contaminated by arsenic.

And hyperaccumulates means high concentration of the accumulates in their body, and basically they extracted 1442 to 7526 ppm of arsenic in from the contaminated soil. So, almost all the arsenic present in the plant was basically inorganic and there was indicators, indications that arsenate, arsenate, which is arsenic V was converted to arsenide during the translocation from roots to fronds. So, that shows how this phytoremediation occurs. Phytoremediation is an important, and environmental friendly and sustainable way of decontaminating the land without use of any chemical.

There are some other examples of phytoremediation also, you know, sunflower can absorb uranium, it has been found in several studies, and also certain ferns have the high affinity for arsenic, as we have already seen brake fern. Alpine herbs, they can absorb zinc and then mustards can absorb lead and clovers take up oil and poplar tree destroys the dry cleaning solvents. So, these are some examples of phytoremediation. And that is why, you know, phytoremediation is recommended practice to clean the contaminated soil in several instances.

This shows different types of, different processes of phytoremediation obviously, and remember that these different processes of phytoremediation occurs at different plant parts. So, you can see here, you know, phytodegradation, which is basically use of plants to destroy the organic pollutant. So, sometimes the plant destroy the organic pollutant that is phytodegradation.

Phytovolatilization which is basically conversion of metals or metalloids to less toxic and volatilized form, volatile form. So, this is called the phytovolatilization. Similarly, you know, phytostabilization is another important process of phytoremediation where it immobilizes metals, and ultimately reduce the toxicity and phytostimulation is the degradation of organic pollutants by plant root exudates.

And also, basically it degrades the organic pollutants as well as different types of metals and phytofiltration. So, these are different processes of phytoremediation, which are important. And each of these processes can be studied more details for, for a better understanding of this phytoremediation process.

Another important way of decontamination is leaching. So, this method basically, this method of leaching basically involves leaching the in-place soil with water often with a surfactant to remove the contaminants, the leachate is then collected and then, we know, downstream of the site using a collection system for treatment and or disposal so once we collect the leachate, it will, it will contain a huge amount of pollutants.

And these pollutants will be either further treated or can be further disposed off. So, the use of this method has been limited since large quantities of water, you know, is basically required and, you know, and the effectiveness basically depends on the permeability, porosity, homogeneity, texture and mineralogy of the soil. So, these are some of the, you know, these are some of the plus points as well as negative points for leaching. But regardless, regardless of these, leaching is one of the effective methods for, for decontamination of the soil.

Another important aspect of decontamination, soil decontamination is vitrification. Now, in in-situ vitrification, the contaminants are either solidified with an electric current. So, basically this results in their immobilization. So, again, this in-situ vitrification, the contaminants are basically solidified via electric current and ultimately it produces the immobilize. So, vitrification may immobilize pollutants for long as well as 10,000 years.

Since a large amount of electricity is necessary, the technique is very, very costly. As you can see here, this shows, this picture shows the different process of, different process of this vitrification. As you can see, there are some melting zone, vitrified zone, electrodes are there which are drawing the power from this power supply system, and ultimately, you know, this is a contaminated zone.

And this so, the vitrification again produces the, you know, it converts this contaminants in this contaminated zone into solid form, and ultimately contain their movement within the soil. So, this is another effective method, however, only downside is, its huge cost involvement and, you know, large energy requirement in terms of electricity.

Other ways of decontaminating the land is isolation of or containments of the contaminants. So, with this method contaminants are held in place by installing subsurface physical barriers such as clay liners and slurry walls to minimize the lateral migrations. So, you know, these liners or slurry walls cannot be, you know, are non-penetrable. So, these contaminants cannot move further. So, they are contained in a specific zone.

And that, that is how we maintain or we control its movement. So, scientists or engineers have also added surfactants to clay minerals, we call them organo-clays and these organo-clays enhance the retention of different types of organic pollutants. And then, we also use organic clays in liners and to minimize the mobility of the pollutants and in wastewater treatment. So organo-clays are very important component of this isolation or your containment process, which produces, you know, which minimizes the mobility of the pollutants in wastewater treatment.

So, so, an other way of doing the remediation of the contaminated soil is passive remediation. And with this method natural process, you know, with this passive remediation different types of natural processes, such as volatilization, aeration, biodegradation and photolysis are allowed to occur. And this process may cause decontamination, and this passive remediation is a simple and inexpensive and requires only monitoring of the site.

However, the factors that affect this type of remediation includes biodegradation, adsorption, volatilization, leaching, photolysis, soil permeability, groundwater depth infiltration and the nature of the contaminant. So friends, we have discussed some of the important points today which, you know, this, you know, we, we talked about the different types of remediation techniques. We talked about bioremediation. We talked about in-situ remediation, we talked about ex-situ remediation and then passive remediation.

We talked about phytoremediation, what are the different processes which are involved in the phytoremediation. Hopefully you have got some new information in this lecture, and we will start from here in our next lecture to complete all the 5 lectures of our week 1, which is basically, you know, giving you an overview of the, of the extent of environmental pollution and how it is related to environmental soil chemistry. Thank you very much. Let us see in our next lecture.