Transcriber's Name: Prabhavathi

Environmental Soil Chemistry

Prof. Somsubhra Chakraborty

Agricultural and Food Engineering Department

Indian Institute of Technology-Kharagpur

Lecture-01

Evolution of Soil Chemistry

Welcome friends to this first week of lecture of, first week of lectures for this NPTEL course of environmental soil chemistry. I, myself, Dr. Somsubhra Chakraborty and let us start the lecture 1. Basically in this week, we will be basically covering these topics, or concepts. First of all, we will be talking about what is soil chemistry, and environmental soil chemistry.

And then, we will be talking about a brief about the evolution of soil chemistry. And then, we will be talking about modern environmental movements, contaminants in water and soils, and then we will be talking about soil contamination. And also, we will be covering the molecular and environmental, you know, soil chemistry.

So, the question first come that what is soil chemistry and environmental soil chemistry and what is the difference. So, soil chemistry is a branch of soil science that deals with the different types of chemical composition, chemical properties and chemical reaction of soils. You already know that, the soil is basically composed of different types of components. There are certain components which are solid, some components are liquid and some are gaseous.

Soil is basically composed of fractions, which are sand, silt and clay, organic matter, soil air and moisture and soil chemistry basically deals with the soil chemical properties. Remember, so, basically that means the soil is a heterogeneous mixture of air, water, inorganic and organic solids and also soil contains millions and millions of microorganisms and soil chemistry has traditionally focused on the che mical reaction in soil that affects plant growth and plant nutrition.

There is a specific terminology for this, we call it edaphology when the soil chemistry basically concerns, you know, about the plant nutrition. Now, environmental soil chemistry is the study of chemical reactions between soil and environmentally important plant nutrients. Also radio nucleotides, radionuclides, metals, metalloids and organic chemicals.

So, what is environmental soil chemistry? Environmental soil chemistry is fundamental in predicting the fate of contaminants in the surface and subsurface environments. We are not only concerned about the surface of the soil, but also we are considering the movement of different types of contaminants and its interaction in the soil in the subsurface zone. Now, it is necessary for understanding of environmental soil chemistry.

That, you should comprehend the array of chemical reaction that contaminants may undergo in the soil environment, which may include equilibrium and kinetic processes such as dissolutions, precipitations, polymerization, adsorption, desorption and oxidation-reduction. So, these are different types of reaction which are integrally involved in the field of environmental soil chemistry.

Because they impact or control the movement or interaction of different pollutants in the soil water system. These are, these are the processes which

also affects the solubility, mobility, speciation, toxicity and bio availability of the contaminants in soils and in surface waters and groundwaters. So, that is why we need to understand these processes in details before we can discuss about different types of soil contamination processes.

So, what is the evolution of soil chemistry? If you consider the evolution of the soil chemistry, in the early 1850 by J. Thomas Way, who is a scientist in the Royal Society of agriculture in England, he found that soil could also adsorb both cations and anions and that these ions could be exchanged with other ions in the soil system and so, after that, you know, several, you know, discoveries have been made.

And, during early 1930s, Hendricks and co-workers found that clay minerals in soils were crystalline and x-ray studies were conducted to identify different types of clay minerals and to determine their structures. Now, you already know different types of clay minerals which are present in the soil and you know, that they can be divided into crystalline and non-crystalline. And in the crystalline, we have already discussed in our previous NPTEL course, different types of crystalline clay minerals like one is to one type of clay mineral, two is to one type of clay mineral, two is to two type of clay minerals and also amorphous clay minerals like allophane.

So, we have discussed this so, you know, that crystalline clay minerals are the prevalent in organic fashion in the soil and these were first described by Hendricks and co-workers in 1930. And they started the X-ray studies. And studies on soil acidity, ion exchange and retention of ions by soils and soil components such as clay minerals and hydrous oxides were major research themes for many, many decades.

If you consider last 50 years of soil research, you will see that most of the soil chemistry based research were confined indeed in dealing with soil acidity,

ion exchange, retention of ions by soil and different types of soil components and also different types of clay minerals or different types of soil economics.

So, the modern movement or modern evolution in the field of soil chemistry started about 30 years ago, when the emphasis was on reducing the pollution from smokestacks and sewer pipes. Basically, remember that all these modern environmental movement happened in the developed countries like UK, and also in other European countries and also in United States.

In the late 1970s, a second movement that focused on toxic compounds was initiated and several laws have, you know, enacted, which had a profound influence on environmental policy in US. So, there are several laws which were enacted by the US environmental agencies, and these are the clean air act of 1970, the clean water act of 1972, the endangered species act, the superfund law of 1980 and the amended resource conservation and recovery act, that is called RCRA of 1984.

So, these are the laws which were enacted during that period which helped in the modern evolution of soil chemistry from the traditional, you know, fields like soil acidity, then colloid chemistry and other soil exchange, you know, phenomena to the soil contaminant interaction and movements.

So, the third environmental wave, which began in the late 1980s, were basically done by the farmers, businessman's, homeowners and others, when they questioned some of the environmental laws containing regulations that some pollutants cannot be contained in the air, water, soil and levels greater than a few ppb. So, this, you know, movement, the third movement in this evolution of soil chemistry basically initiated by the common people, like businessmen, some farmers.

Because they were concerned about some, you know, some laws and the maximum limits they have imposed for certain elements up to certain ppbs. So, they just questioned, why you need and what is the possible modification for those limits? So, that is how the laws become more and more stringent and also this environmental soil chemistry domain became more and more important in daily life.

So, once we completed the evolution of soil chemistry, let us discuss an overview, let us have, you know, let us have an overview of the contaminants which are present in waters and soils. Now, there are a number of inorganic or organic contaminants that are important in water and soil. They are basically, first of all, you know, they are basically plant nutrients and when we talk about the plant nutrient they are basically nitrates and phosphate.

Because they cause the eutrophication. Also heavy metals like cadmium, chromium and lead, because they can cause different types of, you know, health hazards, when they are mixed with the soil and water, different types of oxyanions like arsenide, arsenate and selenite. Arsenic is a major problem in Indian subcontinent where, you know, you will see the groundwater contamination by arsenic is creating a, you know, hazardous condition both in West Bengal state of India as well as in Bangladesh region.

Different types of organic chemicals, we have already discussed in our introductory lecture about the PCBs, how PCBs, you know, polluting the, you know, the environment in India. So, PCB is a very important organic chemical which is, which is a hazardous chemical. So, so chemicals like, you know, PCB, and PAH. All these are very much important for contaminating both water and soils.

And also, different types of inorganic acids and radionuclides are also important contaminants for water and soil. Remember, the sources of these

contaminants basically are fertilizers, pesticides, acidic depositions, agricultural industrial waste materials, and radioactive fallouts. So, that is why all these inputs are very much important in the context of environmental soil chemistry. And that is why, there are strict rules and regulations imposed for controlling the use of these compounds for soil and water.

So, let us start with the water quality. Now, there are 2 basic types of pollution once we, once we are considering the different, you know, water pollution, there are 2 basic types of pollution, one is called point source pollution and the other is nonpoint source pollution. Now, point source pollution or point pollution, as the name point pollution, is a contamination that can be traced to a particular source such as industrial site, septic tank or wastewater treatment plant.

Now, it follows the definition by United States environmental protection agency or US EPA that, any single identifiable source of pollution from which pollutants are discharged such as pipe, ditch, ship or factory smokestack and this was given by the scientist Hill in 1997. Remember, factories and sewage treatment plants are two common types of point sources. But as far as the water quality is concerned, you can see that the sewage treatment plants are the major source of, you know, point source pollution.

So, as you can see in this picture, the sewage from the different industries are treating or you know, when they are when they are exposed to the water bodies, they are acting as a point source pollution. There is, these are some other pictures of point source pollution as you can see, the large, you know, farms of different animals can also act, you know, can also act as an important point source pollution.

Because the animal waste can be discharged into the nearby water body as a point source pollution. Here, you can also see the factory smokestack which is also, which also acts as a point source pollution. The other source of pollution or water quality is nonpoint source pollution, the other name is nonpoint pollution. Now, the nonpoint pollution results from large areas and not from any single source and includes both natural and human activities.

So, what are the sources of nonpoint source pollution? There are several majors, there are several sources for non-point source pollution. First of all, the major source of nonpoint source pollution is agriculture. Due to the runoff which is generated as a result of rainfall, a huge amount of fertilizer can move from agricultural fields to the nearby water bodies and create, and which creates basically the eutrophication problem.

So, agriculture is considered as a major source of, you know, nonpoint source pollution. Human is another, you know, agent of nonpoint source pollution, forestry, urban constructions and mining activities and atmospheric deposition are also important as a source of nonpoint source pollution. What are the naturally occurring nonpoint source pollutants? The, you know, naturally occurring nonpoint source pollutants are geological erosions, saline seeps and breakdown of minerals and soils.

So, nonpoint source pollution, these, you know, these can be explained by these two pictures as you can see. First picture is basically showing the runoff, the field runoff due to the rainfall and also when these runoffs from the adjacent, you know, fields ultimately reaches to the nearby water bodies, it contaminates the whole water body and this is a very good example of nonpoint source pollution and this type of pollution is prevalent in all countries.

This picture also gives you a snapshot of nonpoint sources, you can see that these are the major nonpoint source pollutants, for example, urban streets, suburban developments, rural homes, crop lands, animal feed lots, these are very important sources, nonpoint sources from which all different types of contaminants, may be it is a fertilizer or organic or inorganic chemicals can go to the nearby water body to contaminate.

However, these are some points sources like wastewater treatment plants and factory. So, this slide basically gives us snapshot of different point sources and nonpoint sources of pollution. Again, here in this picture the point sources are wastewater treatment plants and factory outlets into the water bodies. However, nonpoint sources are suburban developments, urban streets, rural homes, crop lands and animal feed lots from where the different nutrients and contaminants can move in bulk through water or rainfall and ultimately reaches the nearby water body to contaminate.

This shows also another condition where there is a pollution from leaking petroleum tanks. So, you can see here, when the tank is leaked, petroleum tank is leaked, it goes and ultimately contaminates the nearby water wells and other groundwater sources. Now, this slide also shows the nonpoint source pollution where water in many central China's rivers are greenish black of, you know, which is due to the uncontrolled pollutions by thousands of factories.

So, this is also an example of water quality deterioration when the water is getting the pollution from different point sources. Again here, the water is getting greenish black because the water is getting sewage from different industries through different point sources. In India, daily more than 1 million Hindus, bathe, drink or carry out religious ceremonies in the highly polluted Ganges river and as you can see, the water contamination issues in India.

It not only so, you know, different types of point source and nonpoint source pollution, you know, creating a huge amount of pollution in the river Ganga and ultimately which is being used by millions and millions of devotees in India. So, the two plant nutrients of greatest concern in surface and groundwater are nitrogen and phosphorus and their impacts on water quality is also very important. Now remember, the United States environmental protection agency has established a maximum contaminant level, we call it MCL of 10 milligram per liter, nitrate as nitrogen for groundwater, whereas total phosphorous not exceeded 0.05 milligram per liter in a stream where it enters a lake or reservoir.

And total P in stream that do not discharge directly to lake or reservoir not exceeding 0.1 milligram per liter. So, these are different types of maximum contaminant level, which are set up by United States environmental protection agencies. Because, once these nutrients enters into the big water bodies, they create eutrophication problem. What is eutrophication problem? When the nitrogen and phosphorus enter into the nearby water bodies, it increases the fertility levels which produces the algal bloom.

That means, whatever the algal which are present, algae which are present in the water body, they will take up that nutrient and they will multiply, they will create a bloom. And due to the excessive growth of these algae and other problematic aquatic plants, there will be a condition where the dissolved oxygen from the water will be reduced, we call this condition as hypoxia condition. So, in this hypoxia condition, all the organisms, other organisms which are present in the water body will be eliminated.

So, this is the ill effect of eutrophication and this eutrophication is mainly mediated by the excessive nitrogen and phosphatic fertilizers, which we apply into the agricultural fields. So, that is why indiscriminate use of agricultural resources are creating a big problem as far as the environmental soil chemistry and also water chemistry are concerned.

So, remember, excessive nitrogen again in the form of nitrates has been linked to methemoglobinemia or blue baby syndrome. It is a very important disease, which occurs due to the nitrogen pollution in the groundwater aquifers. Also, it results in abortion in human and increase the risk of non-Hodgkin's lymphoma. Phosphorus as phosphate is tenaciously held by soil through both electrostatic and non-electrostatic mechanisms which we will discuss.

And usually does not leach in most soils. On the other hand, nitrate nitrogen is weakly held by soils and readily leached in soils. Now, again, remember that major sources of N and P in the environment are inorganic fertilizers, animal manure, bio solid application, septic system and municipal sewage systems. So, the discharge from these sources or application of some of the sources has to be highly regulated to control the pollution scenario which is due to the nitrogen phosphatic fertilizer.

So, what is the current status of this nitrogen and phosphorus fertilizer consumption, in both US as well as in India? So, let us consider first serious condition. Now inorganic nitrogen and phosphorus fertilizer increased 20 and 4-fold respectively between 1945 and the early 1980s. And after that, they leveled off. In 1993, around 12 million metric tons of nitrogen, and 2 million metric tons of phosphate was used nationwide in US.

And at the same time animal manure accounted for around 7 million metric tons of nitrogen, about 2 million metric tons of phosphorus and additionally about 3 million metric tons of nitrogen per year were derived from atmospheric sources. So, if we can see this plot, it basically shows the changes in nitrogen and fertilizer use over the decades. So, you can see, from 1945 to 1995 there has been a continuous increase in nitrogen fertilizer consumption or sales in million tons per year.

And also, there has been an increase of phosphatic fertilizer sales. However, comparatively, the fertilizer sales in case of nitrogen is way bit higher than that of phosphorus. And this is from a US geological survey circular, which was published in 1999. And you can see, this table has been compiled from a research and it has been found that, you know, they are basically showing the natural concentration of various elements, ions and compounds in groundwater.

So, you can see for different elements starting from calcium to barium and beryllium. And you can see different types of typical values and then extreme values. And also, you can see the elements for up to Zirconium and what are their extreme values. So, that will give us the idea about the safe level of these elements in the groundwater and what is the maximum threshold level we cannot violate. And these should be keep in mind while we are devising different types of management practices.

What is the fertilizer consumption situation in India? If you consider the fertilizer consumption situation in India, United States and China you can see, in all these three countries, there has been a continuous increase in fertilizer consumption in million tons starting from 1960. In India, starting from 1960, there has been a, as a result of green revolution, there has been a continuous increase in fertilizer consumption.

In China, the increase is more steeper and that shows that all these sources of groundwater and soil pollutions, you know, are very important. And also that shows the alarming situation where these developed countries, developing countries like China and India are increasing, continuously increasing the use of these inorganic fertilizers and which can create a very hazardous situation in the near future.

And this slide also shows a snapshot of different types of interactions, which are going through different point sources and nonpoint sources. You can see that runoff can be generated from the nearby areas and also wastewater can be dumped into the nearby water bodies. Runoff can be generated from the agricultural fields, which will ultimately go, which will ultimately contaminate the nearby water bodies' groundwater.

And also, this groundwater will be discharged into the streams. And, you know, ultimately creating the, ultimately creating the pollution, ultimately creating the pollution of the total soil and water system. This slide is self-explanatory. I would request you to go through and see the details. And this is, you know, from the US geological survey report of 1999. So that is how. We completed today the evolution of soil chemistry.

And we also discussed about the point source pollution and different nonpoint source pollution and how they interact in this soil and water system. In the next lecture, we will be discussing the other aspects of soil pollution. And we will be discussing about the pesticides and other sources of soil contamination. Thank you very much. Let us meet in the next lecture.