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Environmental Soil Chemistry

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Lecture-03

Evolution of Soil Chemistry (Contd.)

Welcome friends to this third lecture of week 1 in the NPTEL course of environmental soil chemistry and in our previous lectures we discussed about different aspects of environmental soil chemistry, we discussed about, we know, the difference between soil chemistry and environmental soil chemistry, we discussed about different types of pollutants specifically we talked about different types of nutrients which basically cause eutrophication in the water bodies.

Then we talked about pesticides, the consumption trends of pesticides, in USA, in India what are the different types of pesticides, which are more prevalent or, you know, mainly used in USA as well as India and what are different, you know, their export trends, their import trends specifically in the context of India. And we talked about also different point sources and non-point sources of pollutions.

And their interactions and fertilizer consumption in India as well as in other developed countries. And today, and we also started the acid deposition specifically the acid rain, which is one of the major environmental concern and today we will start from the, where we left in, in our last lecture. So, in our last lecture.

We were talking about the acid deposition and, you know, that the acid rain refers to the deposition of different acidic components in either wet or dry forms. And it is basically defined by the pH of the liquid because less than 7 pH is always acidic whereas, greater than 7 pH is known as basic condition.

Remember that again the natural acid rain can be caused by volcanic emissions as well as the different types of biological processes what happened in case of clean rain, you know, it has a natural acidity of, you know, about 5.2 on the pH scale, because, when the water reacts with the carbon dioxide in the atmosphere, it produces carbonic acid which is one of the, you know, mild acids.

And as, you know, as it is as the pH goes down to 5.2. So, as you can see here in this slide, when the liquid water reacts with the carbon dioxide it produces this carbonic acid, this carbonic acid again, you know, dissociates into carbonate as well as hydronium ions. So, this is how this, you know, clean rain basically behaves.

And, but in case of acid deposition due to different types of automobile emission, as well as burning of fossil fuels, especially coals, you generate different types of gases like sulfur dioxide and different types of nitrogen oxides, which basically reacts with atmospheric, you know, you know, atmospheric with water and other materials to produce different types of caustic acids like nitric acid and sulfuric acids.

And that are often carried for long distance by wind and then fall to the earth via precipitation such as rain, snow, sleet, mist or fog. So, as you can see in this slide, these are the different types of coal, you know, different industries which are producing huge amount of smoke and burn due to the burning of the fossil fuels which is basically creating the acid rain.

Now, this slide also shows, you know, how these different components of acid rain are there, you know, burning of the fossil fuels produces sulfur dioxide as well as nitrogen di oxide, which goes to the atmosphere either deposited by dry deposition but in the forms of particulate or gases or it produces sulfuric acid and nitric acid and, you know, deposit in terms of wet deposition, rain, snow and sleet. So, this is how this total cycle of these acids rain goes and this acid rain is very, very harmful as far as the natural vegetation is concerned I will show you a couple of pictures.

So, what is human effects? So, obviously, the anthropogenic effects are very important because the sulfur dioxide and nitrogen oxides are basically contributed by the burning of the fossil fuels because this coal burning and, you know, is a major contributor for this acid rain producing huge amount of industrial smokes and annually, you know, around 70 tera grams of sulfur emissions comes from fossil fuel burning, which is compared to the 8 tera grams from the volcanoes and 2.8 tera grams from the wildfires.

So, that shows that what is the impact of human anthropogenic in, you know, influences for producing this acid rain which is very important, you know, important consideration, what, you know, very important, important aspect as far as the environmental pollution is concerned.

So, coal power plants obviously, as I have already told you that burning coal is extremely cheap and efficient but dirty, which releases a huge amount of sulfur oxide, sulfur dioxides, which become sulfuric acid when it mixes with the atmospheric water vapor and obviously when they moves, areas down wind of power plants receive heavy acid rains and, you know, smokestacks as you can see builds to counteract the direct deposition of sulfuric acid only spread the problem.

So, you know, this is how this coal power plants produces huge amount of smoke or different types of gases, which ultimately produces this acid rains. So, let us talk about what are the impacts of acid rain. Now, obviously, you know, when there is an acid rain in that area, you know, you cannot see many things can grow because it renders the soil infertile and one of the major cause of this infertility is the low pH and high aluminum concentration which can basically damage or kill fish and aquatic population. So, it basically can damage the growth of the plant.

The roots, it cannot, you know, the the, you know, when there is a low pH and huge amount of aluminium in the soil it hinders the germination from the seeds, as well as, in case of aquatic life it basically kills the fish and other aquatic populations. So, soils can be damaged by hydronium ions H 3 O+, which mobilizes aluminium and encourages leaching of minerals such as magnesium which are essential to plant life, you know that magnesium, calcium, sulphur.

All these are macronutrients which are responsible, which are essential for plant growth. However, due to the production of this acid rain, these, you know, these hydronium ions basically mobilizes the aluminium and as a result of that, these acid rain, these magnesium and to some extent calcium leaches down to the soil becoming unavailable to the plant for the extraction through their roots and as a result of that, they became unavailable to the plant and renders the soil infertile.

Forests suffer from soil damage, however, the most food, you know, most food crops are unharmed because the nutrients lost are replaced by the fertilizers. However, in case of forests, the soils are not replenished, the soil fertility is not replenished because we do not apply fertilizer there. As a result of that, the worst affected areas due to acid rain are the forests.

So, as you can see here, this shows a forest area which is impacted by the acid rain and as you can see the deleterious effect of acid rain which, which, you know, which is clearly visible here. So, this is why we should be very, very careful for industrial, industrial different operations as well as different anthropogenic influences to control the release of these gases because that will impact this forest ecology.

Now, what are the other effects of acid rain? Well, if you see I mean, this acid rain is basically producing rain, which are, which are basically having caustic acids like sulfuric acid as well as nitric acid. And these, you know, these caustic acid basically erode the different monuments which are made of calcium carbonate because calcium is a basic cation. So, the calcium carbonate which is basically limestone and marble gets damaged.

Because it reacts with the acid and ultimately produce the gypsum, which is calcium sulfate 2H 2O. So, it basically increases the, you know, increases the wearing of calcium carbonate and, you know, limestone and marble. Also, it increases the oxidation rate of metals such as copper and bronze as you can see this is a monument which basically would damage due to the acid rain. So, this also shows the negative impact of acid rain in our current civilization.

So, what are the areas of highest concern due to the acid rain? Currently, there are some areas, there are some locations in the world which are worst hit by this acid rain. First of all, eastern United States, then Southern Western Canada, then Eastern Europe and east coast of China. So, these are the, some of the areas which are worstly, you know, impacted by this acid rain, however there are some potential future problem areas which may develop this problem in near future southern India, West Africa, Indonesia and Thailand.

So, we should be very, very careful while, while, you know, considering the, the extension of industrial, industrial we should be considered, we should consider these aspects when we talk about different types of pollution, which are basically causing from different types of industrial expansions.

So, obviously, this table shows the different types of environmental effects, which are related to this acid rain. So, the problems are mentioned as you can see here, there are 1 2 3 4 5 problems. For example, you can see coastal eutrophication, you can see mercury accumulation, you know, decreased visibility, climate change and tropospheric ozone. So, obviously, each of these having some linkage with this acid deposition.

As you can see, the coastal eutrophication is related to the acid deposition because atmospheric deposition, you know, it basically supplies the nitrogen to the coastal waters. So, when there is an atmospheric deposition of this acid rain, it produces nitrogen to the, you know, coastal waters which further causes this coastal eutrophication by producing algal blooms.

Also, when there is a surface water, you know, get acidified due to the acid rain which enhances mercury accumulation in the field also produces this mercury accumulation, which is one of the major environmental problem nowadays. Also, sulfate aerosols are an important component of atmospheric particulates because they decrease the visibility So, also it produces decreased visibility as you can see here, this is another important point, sulfate aerosols increases atmospheric albedo, you know, cooling the earth and offsetting some of the warming potential of the greenhouse gases.

Also tropospheric ozone and nitrous oxide as the greenhouse gas and ultimately it produce a huge impact on climate change. So, this, you know, this, this acid deposition not only impact the, the ecosystem in the, in the, in the, in the terrestrial as well aquatic life it also impacts the climate change,

also emission of nitrogen oxides contributes to the formation of ozone which produces tropospheric ozone.

So, all these you can see are very important environmental impacts and all these are related to the, you know, sulfur dioxide as well as nitrogen oxide, emission and ultimately producing the acid rain. So, let us move ahead and see what are the other environmental pollutants, which are very important. So, first of all the trace elements. So, trace elements are, is an element which present at a very low level, you know, most of the time it is less than 0.1% in natural materials such as in the lithosphere, in the, if the concentrations are high enough they can be toxic to different types of living organisms.

So, there are several toxic metals or trace elements which are present in our terrestrial environment. And if we find, you know, if their concentration increase somehow then you will see an impact on the living organisms. So, different types of the composition of trace elements are there, we can see, we have, you know, the trace elements are there, heavy metals are there, metalloids are there, arsenic is an important metalloid.

Then micronutrients and as well as trace inorganics. So, these are very important when they are highly, you know, in their present in a very high concentration. They can create several types of environmental hazards. So, we will discuss them. So, this table basically shows the trace elements in different types of natural waters. So, let us start with arsenic as you can see here, arsenic is very important mining byproduct, also they are used in pesticides as well as chemical wastes, they are highly toxic and possibly carcinogenic in nature.

We will discuss arsenic in details in the coming slides. But, you know, arsenic is an important metalloid which creates, you know, very important environmental problem. Also beryllium which is produced from the coal and

nuclear power and space industries also can produce different types of acute and chronic toxicity and also produce carcinogenic effects. Boron comes from coal, then different types of detergent formulation and industrial wastes. And also they are highly toxic to sometimes, all the boron is in, you know, is an important micronutrient.

But still, it is toxic to some plants. Cadmium industrials discharge cadmium mainly found in industrial discharge, then mining waste, metal plating and water pipes. And, you know, basically it produces problem by replacing zinc biochemically, causes high blood pressure and kidney damage, it also destroyed testicular tissue and red blood cell, toxic to aquatic biota. So, this is how it creates problems.

So, cadmium is an another important trace element which creates different types of environmental hazards. chromium, chromium can be found in metal plating and then cooling tower water additive for chromate and then normally found as chromium VI in polluted water and obviously, it is an essential trace element because it produces glucose tolerance factor. However, this Cr VI produce, you know, consider as a possible carcinogen.

And then copper, copper is also found in metal plating and industrial and domestic waste mining and natural mineral leaching. It is an important essential trace element. However not very toxic to animal, toxic to plant and algae at moderate levels. Fluorine, specifically in the fluoride ion, they are also generated from natural geologic sources, industrial wastes and water additive.

And basically it prevents tooth decay at above 1 milligram per liter, causes mottled teeth and bone damage, when there is a high concentration. Iodine which is also an industrial waste natural you can find iodine in natural brines and seawater intrusion and also it produces, you know, it prevents goiter, so,

it is very important and iron. Iron are, you know, present in corrugated metal, industrial wastes.

So, obviously, essential nutrient. So, as you can see some of the important trace elements have, you know, beneficial effects, some of the important, some of the trace elements have very deleterious effect or hazardous impact. So, depending on, depending on its effects or significance, we should be careful about their concentration in the, in the terrestrial as well as aquatic environment.

So, let us go ahead and see what are the other important trace elements. Obviously, lead is very important trace element which is basically prevalent in industrial effluent, mining, plumbing, coal and gasoline and it produces acute toxicity, specifically anaemia, kidney disease, nervous system and, you know, wildlife destructions. Manganese mainly found in mining area, mining activities also present in industrial waste, acid mine drainage.

And relatively it is nontoxic to the animal and toxic to plants at higher levels. In terms of mercury, mercury basically coming from industrial waste, also mining activities, pesticides and coal and it produces acute and chronic toxicity. It is highly toxic in nature. Molybdenum found in, again, industrial wastes, natural sources, cooling tower, you know, cooling tower, you know, cooling tower water additive, and possibly toxic to animals.

Selenium, mainly from the natural and geo, different types of geological sources and essential at low level, toxic at higher level, causes alkali disease and blind staggers in cattle. So, this is also some, you know, deleterious effect of selenium, silver also natural geogenic sources, also we can find it in mining and electroplating industries and causes blue gear discoloration on the screen and also mucous membranes in eyes.

So, these are deleterious effect, zinc industrial waste, metal plating you can find and also plumbing, which is an essential element in mainly metalloenzyme, essential for plant and also aids wounds healing. So, as you can see again, some of these trace elements have some beneficial impact and most of them have, you know, deleterious or hazardous impact.

So, heavy metals are those elements having a densities of greater than 5 gram per cc and some of the examples of heavy metals are cadmium, chromium, cobalt, copper, lead, mercury and nickel. So, what are the major sources of the trace elements? Major source of the test elements most of the time one of the major sources of the trace elements is the geologic sources. So, most of these trace elements are geogenic in nature, some of them are, you know, anthropogenic in nature.

So, soil parent material you can see the rocks are one of the major source of these trace elements and commercial fertilizers, liming materials, bio-solids, irrigation water, you know, then coal combustion residues, metal smelting industries and auto emissions, all these are different sources of these trace elements.

So, obviously, this slide or this table shows the concentration of trace elements and drugs as you can see that their concentration of arsenic, barium, beryllium, cadmium, chromium, and then cobalt, copper, fluorine, iron, lead, mercury, molybdenum, nickel, selenium, vanadium, zinc have been mentioned and their concentration in different rocks, specially ultramafic rocks, then basaltic rocks, granitic igneous, shale and clays.

Black shales, deep sea clays, all these are mentioned here. So, that again shows that most of these trace elements are mainly occurring in the nature in different types of rocks or geological materials. So that is why in most of the cases we have found, arsenic is one of the major example arsenic toxicity in

India and Bangladesh most of this, you know, most of the parts of arsenic affected zone of India and Bangladesh are geogenic in nature. We will discuss that later on.

So, if we go ahead, obviously arsenic let us start with the arsenic. Arsenic is metalloid, which is a known human carcinogen it produces carcinogenic impact in the human body. Drinking water contaminated with arsenic has been linked to cancer, diabetes and different types of cardiovascular problems. The sources of arsenic in drinking water, particularly inorganic arsenic is often weathering of minerals of rocks and soil, as I have already told you, that most of the cases, the sources of arsenic in drinking water is the weathering of minerals in rocks and soils.

So, mostly it is geogenic in nature. And remember that the arsenic basically occurs in the environment in two major forms. One is called the As III + another is As V, As III is known as arsenite and As V oxidation number basically known as arsenate, remember that between these arsenite and arsenate, arsenite is comparatively more toxic. So, we should be more careful about if there is a presence of arsenite.

Arsenite is primarily present in, since it is lower number of oxidation number lower oxidation number, so mainly they are prevalent in anoxic environment where there is little or no oxygen while arsenic V or arsenate is found in oxic soil because it is oxidized form and remember, again both arsenic species is primarily occur as oxyanions in the natural environment and strongly complex with metal oxides such as aluminum and iron oxides as inner sphere products.

So again, arsenic is a major, you know, trace element specifically it is a metalloid and it is a known human carcinogen, mainly in the drinking water, it is, its concern is mainly, it is concentration in the drinking, drinking water.

And the concentration of arsenic in drinking water mainly comes from the weathering of rocks. So, basically their concentration in the terrestrial as well as the aquatic environment is basically geogenic in nature.

Some amount is obviously anthropogenic, but mostly it is geogenic, there are 2 types, 2 oxidation states, arsenite and arsenate, arsenite is 3 oxidation state whereas arsenate is 5 oxidation state and arsenite is more toxic than arsenate, arsenite mainly found in anoxic type of environment. However, in case of arsenate is basically found in oxic soil due to the oxidized condition.

Both arsenic species primarily occur as oxyanions in the natural environment and strongly complex with metal oxides again such as iron and aluminum oxides. So, this slide, this is, this slide shows the status of arsenic contamination in, you know, in India as well as some of the health effects as you can see here, this is the India map and the concentration of arsenic, you know, the groundwater arsenic contamination is greater when there is a blue, you know, the the these region basically shows the high concentration of groundwater arsenic and as you can see, this is mainly the indo gangetic plain areas.

So, this indo gangetic plain areas is mainly affected by this groundwater arsenic problem. And this is basically a geogenic problem and as compared to the other parts of India, however, this also shows some health impacts of this arsenic as you can see, due to the consumption of arsenic, lead and groundwater for a longer periods of time, it produces different types of health impacts and ultimately produces cancer.

So, that shows the impact of arsenic pollution. However, you can see here area of endemic states are almost 5 million square kilometers as you can see, and population of these endemic states are 359 million and potential exposed

population is 50 million. So, that shows the impact of arsenic contamination in India.

So, if you move ahead, we will see the status of different states of, as far as arsenic contamination is concerned. So, obviously, you can see the major states which are affected by this groundwater arsenic contamination are Bihar, West Bengal, Assam and some amount in Uttar Pradesh also. So, these are the areas which are worstly affected by this groundwater arsenic pollution.

And this map shows the arsenic contamination status of West Bengal which is one of the worst, you know, worst impacted area of groundwater arsenic contamination and also you can see the groundwater arsenic contamination, you know, these red region basically shows higher groundwater concentration more than 50 microgram per liter. So, it basically, you know, one thing is clear from there that at the lower end of the river Ganga when it reaches to the Bay of Bengal it produces highest amount of arsenic contamination.

And this arsenic contamination is basically geogenic in nature and so, that shows the impact of arsenic contamination in this area and also in nearby Bangladesh region. So, friends, today, we have discussed the impacts of these trace elements. Also we discussed the, you know, impact of acid rain. Hopefully you have got some information, new information and about these different aspects of environmental pollution.

We will start from here in our next lecture, and we will see the other issues related to the environmental soil chemistry. Thank you very much.