Transcriber's Name: Prabhavathi

Environmental Soil Chemistry

Prof. Somsubhra Chakraborty

Agricultural and Food Engineering Department

Indian Institute of Technology-Kharagpur

Lecture-02

Evolution of Soil Chemistry (Contd.)

Welcome friends to this new lecture of environmental soil chemistry. And this is the second lecture of week 1 and in the first lecture of environmental soil chemistry, we tried to give you some overview of this course and we discussed what is soil chemistry and what is the difference between soil chemistry and environmental soil chemistry. Remember this environmental soil chemistry basically deals with different types of environmental issues which are related to both soil and water.

And in our first lecture we discuss the definition as well as we briefly discussed the evolution of this branch of soil chemistry, that is environmental soil chemistry, how this branch was affected by enactment of different types of laws, which specially initiated in the United States and what was different implication of those laws. Then we talked about what are the different kinds of pollutants which are mainly responsible for soil and water pollution.

We started with some nutrients specifically nitrogen and phosphorus and because they basically create eutrophication of lake and water, water bodies, and then we talked about, you know, the different sources of water pollution, we talked about point source of pollution, we talked about nonpoint source of

pollution and what are the different non-point, non-points pollution sources, what are the different types of point source pollution sources.

So, we discuss all of these, we discuss the different interaction between different point source and nonpoint source pollution sources. And then we talked about the fertilizer consumptions, especially the changings in, you know, changes in fertilizer consumption in developed countries as well as in India. And in today's lecture we will be discussing about other environmental pollutants which are responsible for soil and water pollution due to their indiscriminate uses.

And mainly we will cover different pesticides, overview will give you some, an overview of the pesticides which are responsible for environmental contamination. And then we will talk about trace elements which are also very important source of environmental pollution, and then we will talk about some methods which we generally employ for remediation of soil and water contamination. So, let us start with these pesticides.

If you see here, you know, the pesticide is very important groups of chemicals and this pesticide can be classified into, you know, 5, you know, 4 to 5 different subclasses. For example, you know, we can, you know, herbicides which are basically used for controlling the weeds. Secondly, insecticides which are basically use for controlling the insects, then fungicides which are required for controlling the fungi and fungal infection.

And then nematicides which are required for controlling the nematodes and rodenticides, which are responsible for controlling the rodents. So, all these are important classes of pesticides and based on their specific, you know, target groups they have been classified into different names. So, remember that the pesticides were first used in agricultural production, in the second half of the 19th century.

And especially some examples included, you know, lead, arsenic, copper and zinc salts and naturally produced plant compounds such as nicotine. So, all these elements like leads, arsenic, copper and zinc salts, all they have, you know, intake insecticidal properties, and this nicotine which we now it is no, you know, this is present in tobacco, this is also this nicotine also has high, you know, insecticidal properties.

So, in the second half of 19th century when people started using different types of pesticides, they actually used these different types of salts as well as nicotine. Now in the 1930s and 1940s, you know, 2, 4-D which is the short form of 2, 4-dichlorophenoxyacetic acid and which is, which is basically herbicide and another insecticides called DDT, which is the short form of dichlorodiphenyltrichloroethane as you can see in this slide the both of them, you know, I have presented the structure of both these chemicals.

So, this 2,4-D is an herbicide and this DDT is basically an insecticides are basically introduced in 1930s and 1940s which are highly effective for controlling these, different types of weeds as well as different types of insects. Now, the benefits of this pesticide have played an increasing crop production at a reasonable costs are obviously unquestioned. So, there is no question that while introducing these new pesticides in 1930s and 1940s, they, you know, hugely contributed for controlling the pest and, you know, weeds to increase the, to increase the agricultural production.

However, as time goes on, I mean, as the time went, you know, the indiscriminate uses of these herbicides and pesticides have contaminated the soil and water and created a huge impact on the environment. So, that is why, you know, most of the countries DDT is now banned, because of its high environmental residual impact.

So, you know, the total pesticide if you if you if you see, the total pesticide use in United States has stayed a constant about 409 million kgs per year after increasing significantly through the mid-70s due to greater herbicide use. And so, you know, the use of herbicides have continuously increase after 1970s. Initially, there was mainly insecticides however, from 1970 there has been a continuous increase in herbicide application both in the US and other countries as well as in India, which we will see later.

And as a result that there is, you know, the, you know, application of insecticides was kind of stayed constant in the United States. Remember that agriculture accounts for 70 to 80% of the pesticide use and about 60% of the agriculture use of pesticides involves herbicides applications, because weed is a very important issue nowadays for agricultural production. In this regard, we want to, you know, we want to discuss one important law.

You know, proposed by this USGS, 1999 USGS, so, that is called water quality assessment that is NW, NAWQA program which basically takes into account the problem of pesticide based pollution of soil and water. So, it is one of the most recent and comprehensive assessment of water quality in the United States and that has been conducted by the USGS.

So, if you see the pesticide consumption in USA, this plot gives you some indication of how the use of different pesticides and herbicides changes over the time. So, you can see from 1964 to 1996, there has been a continuous increase in application of herbicides in agriculture, as well as, you know, there has been a continuous increase in total pesticide use in agriculture and also cumulatively the total use of pesticides also continuously increase up to 1980s.

And then suddenly, then, you know, it decreased a little bit and then, you know, reaches a plateau around 1992 and in 1990s. However, the total

organochlorine insecticides especially the DDT and other organochlorine insecticides, which are highly, you know, important environmental pollutant, their use have been continuously diminished because of increased environmental concerns.

So, as you can see these, the application of total organochlorine insecticide used in agriculture was continuously decreased, because of their, you know, environmental impact, where the, while the use of pesticides especially the herbicides have continuously increased and then reaches a plateau.

So, if you see the relative level of contamination in streams and shallow groundwater from different sources, you know, in different areas like urban areas, agricultural areas and undeveloped areas, you will see that nitrogen produces medium level of contamination in urban areas whereas, it produces medium to high level of contamination in the agricultural areas because of nitrogenous fertilizers use.

And in case of undeveloped areas obviously, there is no significant effect of nitrogen contamination, in case of phosphorus the similar, you know, phosphorus in both urban and agricultural areas we get, you know, medium to high level of contamination whereas, in undeveloped areas that is again low level of contamination. In case of herbicides obviously, agricultural areas due to huge application of herbicides, the, you know, produces low to high amount of, you know, contamination in agricultural areas.

However, since the application of herbicide is limited in urban areas, the hazard from the herbicide application is being somewhat medium in case of urban areas. However, we did not have any data for its application and hazards in undeveloped areas, you know, currently used insecticides if you think about the currently used insecticides obviously, it produces medium to high level of contamination in urban areas.

Whereas, it produces low to medium level of contamination in the agricultural areas whereas, there is no data available for undeveloped areas. And in case of historically used insecticides, obviously, in urban areas it produces medium to high level of contamination, because these DDTs and all these things were basically used for controlling other insects which are present in urban areas. And agricultural areas also produce low to high contamination.

However, in case of undeveloped areas produced low amount of impact, so, if you can see in a nutshell, in the streams of these urban areas and agricultural areas, it produces, you know, medium to high level of contamination from all of these sources starting from first nitrogen, phosphorus, then herbicides, currently used insecticides as well as historically used insecticides.

So, both these urban areas and agricultural areas were known to be impacted by the use of different types of herbicides, insecticides as well as sources of eutrophication. However, if we considered the shallow groundwater in urban areas and agricultural areas, nitrogen creates medium problem in case of urban areas. However, it produces high contamination in agricultural areas because of use of nitrogenous fertilizer, indiscriminate use of nitrogenous fertilizer.

In case of phosphorus, we did not see any, you know, contaminant any any any, you know, any substantial contamination. In case of herbicides where it in urban condition, it produces medium level of contamination in case of shallow groundwater. However, in case of the agricultural areas, you know, they produces medium to high level of contamination.

Currently used insecticides is produces low to medium in both these conditions. However, in case of historically used insecticides, it produces low

to high in both these conditions. So, if we can see, if we can consider the shallow groundwater apart, you know, nitrogen produces stark differences between the urban areas and agricultural areas, because of, you know, shallow water nitrogen contamination due to indiscriminate use of nitrogenous fertilizers.

However, in case of insecticides and, you know, in case of insecticides, both urban areas as well as agricultural areas, shallow water shallow groundwater produces almost similar level of contamination. So, if we can, if you see, if you want to see the levels of nitrates in shallow groundwater in different parts of US, this, you know, map gives a better indication.

So, you can see in several parts of US, you know, the nitrogen, you know, nitrate in shallow groundwater exceeded the background concentration for example, these, these red dots specifically surrounded and these, you know, yellow dots surrounded by these, surrounded by these bold outline basically indicates, you know, the median values in these areas exceeded the local background concentration which is considered as a reference value.

And so, this trend is, these trends can be seen in these eastern parts of United States as well as some western parts of the United States and so, the southern parts of the United States is not highly showing these nitrate contamination. So, but however, some medium level of contamination is all, you know, is present in the mid United States. So, basically that shows the distribution of pollution of nitrate in shallow groundwater and, and in which areas the concentration increases beyond their background concentration.

So, if we also see the frequently detected pesticides in water of agricultural and urban areas, some important trends are there. So, we can see here for example, let us consider this agricultural land and then urban land and then major rivers and aquifers. And if we consider these, so obviously frequent

frequency detection of different types of pesticide, if we consider you will see that Atrazine is highly, you know, highly detected.

The frequency of Atrazine detection is high in case of both major rivers and aquifers as well as in urban land and agricultural lands followed by these metolachlor and other pesticides. And in case of, and also, we can see, you know, simazine and then prometon. All these things are also highly prevalent in both major rivers as well as in urban land and agricultural lands. So obviously, in case, if we consider the agricultural lands, the application, the occurrence of these atrazine is high which is an important pesticide.

And in case of urban land also we can see the high occurrence of atrazine and then simazine and prometon and in case of major rivers obviously, again the Atrazine. So, that, that says the, you know, that says that Atrazine is one of the most important pesticides which has shown, you know, increase level of their occurrence in different areas, be it in agricultural land, it may be in urban land or it may be in the rivers and other, you know, aquifers.

So, if you see the pesticide consumption trend in India, obviously from the, you know, this plot shows the data from 2000 to 2001 to 2016, 17. So, you can see there has been some, you know, some increase in pesticide consumption from 2000 to 2016. So, almost in 2014, 15 and 16, 17 the consumption was almost the same. So, but there has been a continuous, there has been an increase from pesticide consumption from 2000 to 2016, 17 obviously.

So, also the consumption per hectare also increased and reached a plateau in 2014 and so, that gives you an, you know, that gives an indication of how these, you know, pesticides consumption, increase in case of Indian farms. However, so, if you see the pesticide consumption in India in different states, different states. So, one important, you know, some important trends you can

see here, first of all, if you consider the latest, you know, data of 2015, 16, you will see that the total consumption is highest in Maharashtra followed by obviously Uttar Pradesh and then followed by Punjab and other states.

So, the the the the consumption of pesticide, one of the reason of high consumption of pesticide in Maharashtra is the cotton cultivation and cotton requires a huge amount of pesticide application. So, that is probably one of the major reason for high pesticide consumption in Maharashtra and followed by Uttar Pradesh and Punjab. So, so this basically leads gives you an indication of how different states are using, you know, huge amount of pesticide for agricultural sector.

So, if we go ahead and see the, you know, pesticide, you know, another pesticide consumption trend, that means how the, you know, share of different classes of pesticides has change along the, you know, across the time so from 2003 to 2004 and then 2016, 17, one trend is very apparent. First of all, as I have already told you, that the consumption of insecticide has continuously decreased and the consumption of fungicides and herbicides and rodenticides showed increase increments.

So, there has been a continuous trend of decreased use of insecticides. However, the other classes of insecticides, other classes of pesticides like, you know, fungicides, herbicides and rodenticides due to increased awareness of their specific use, their use have been continuously increased.

So, if you see the pesticide trade scenario in India, obviously, you know, for India export huge quantity of fungicides about 174,000 tons and, you know, followed by herbicides and then also it is, you know, it exports huge amount of insecticides. However, it also imports different types of pesticides like, you know, 16,000 tons of herbicides, 8000 tons of fungicides and 18,000 tons of different insecticides.

As far as the plant growth regulator is concerned, you know, India export very little amount, only 2000 tons of, 2000 tons of plant growth regulator. However, they import 11,000 tons of plant growth regulators for their use. So, if you see the countries in which, you know, India mainly export the different types of pesticides and also the countries from which they import this pesticide you see some, see some trends here.

For example, as far as the export is concerned, the major destination for export for Indian insecticides, fungicides and herbicides are Brazil and also USA. However in case of France, they have only exported the different types of fungicides. In case of importing different types of pesticide, China is the major source of import of different insecticides, fungicides as well as herbicides and also India import, India importing insecticides from Germany.

And also fungicides from Germany. However, from Japan and Israel, they import different types of herbicides. So, that shows the, also, you know, different types of bilateral trades as far as the insecticides, different types of classes of pesticides are concerned from India.

So, that gives an overview of pesticides, different types of classes of pesticides, their consumption view, their consumption trends, and, you know, consumption trends both in the United States as well as the India and due to their increased use in agricultural sector as well as in other parts of our urban environment, they are one of the major source, one of the major sources of environmental pollutant.

And that is why pesticides have got, you know, increased importance nowadays, whenever environmental soil chemistry is discussed. So, so, another important aspect of environmental pollution is acid deposition. And remember, this acid rain is another name of this acid deposition. So, acid rain

refers to this deposition of acidic components in either wet or dry forms, either it could be in particulate forms or in terms of rain.

So, it is basically defined by a pH of the liquid which is generally less than 7 in case of acidic and more than 7 is basically basic. We know that. So, natural acid range which can be caused by, you know, different types of volcanic emissions and different types of biological process. And remember that in case of rain, which is basically, we consider as a clean rain, which is a natural, you know, it produces a natural acidity of 5.2 on the pH scale.

Because this acidity is produced because of the presence of carbonic acid. And now you can ask me how this carbonic acid is formed. So, basically when the water reacts with the carbon dioxide which is present in the atmosphere, they produces to form this carbonic acid which is a, which is a mild acidic, which is a mild acid and as a result that, this clean rain has a acidity of 5.2.

So, this is how this carbonic acid is basically formed as you can see, which is, water when it reacts with the carbon dioxide produces H_2CO_3 or carbonic acid. And this carbonic acid further reacts with water to produce these carbonate ions as well as these hydronium ions.

Now, acid deposition, or acid rain basically results from the burning of fossil fuels such as coal, which generate different types of sulfur dioxide as well as nitrogen oxides and from exhaust of motor vehicles, which is a major source of nitrogen oxide. So, all these burning of fossil fuels and exhaust from these automobiles produces these type, these gases specifically sulfur dioxide and nitrogen oxides, which basically reacts with the water vapor which is present in the atmosphere to produce different types of nitric as well as sulfuric acids, that are often carried for long distance by wind.

And then fall to the earth via precipitation such as rain, snow, sleet, mist and fog. So, as you can see here, burning of coal, which is another major source of these sulfur dioxides and, you know, these gases, these gases basically reacts with the water vapor to produces, to basically produce the acid rain.

So, this picture gives you a more, you know, comprehensive idea of this acid deposition as you can see from here, obviously, burning of the fossil fuels produces these nitrogen, you know, nitrogen oxides, however, then you know, burning of fossil fuels also produces the sulfur dioxide and NO x which ultimately goes to the atmosphere and mixes with the water vapor to produce the sulfuric acid and nitric acid which can either produce dry deposition in, you know, in the form of particulates or gases or it can produce the wet deposition in the form of rain, snow and sleet. So, this is the total process of the, this is the total process of acid rain.

Now, what human has to play in this whole process of acid rain? Well, human effects are very important while, you know, while considering these acid rain because human emissions of sulfur oxides, sulfur dioxide and nitrogen oxides contribute to the acidification of the rain because whatever the sulfur dioxide and nitrogen oxides generate into the atmosphere due to different types of burning of fossil fuels, these are all anthropogenic process.

Now, emission began during the, you know, industrial revolutions remaining unchecked until the 1970s. So, during the industrial era, during the industrial era, basically different countries, both developed and developing countries produces huge amount of these industrial emissions, which remain unchecked until 1970s. So the biggest contributor, remember the biggest contributor is the burning of the coal.

And annually, remember, 70 Tera grams of sulfur emissions comes from burning fossil fuels. Whereas compared to the only 8 Tera grams from

volcanoes and 2.8 Tera grams from wildfires, wildfires. So that shows the overall impact of anthropogenic effects in producing the acid rain and that's why, it is very important to control these different sources of producing acid rains for safeguarding our environment.

So, friends, so far we have talked about different classes, subclasses of pesticides as well as, you know, their specific uses and their consumption trends in developing countries as well as in India and how their application have been changed across the years for last 30 to 40 years. And you know, what is the acid rain and how different human, you know, human or anthropogenic activities affects these, you know, the production of these acid rains.

So, I hope that you have gained some important information through this lecture and let us continue from here in the next lecture. Thank you very much.