Colloids and Surfaces

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Lecture-36
Soil Pollutants

Welcome friends to this NPTL online certification course of environmental soil chemistry. And today we are going to start our module 8 or week 8 lectures. And in this week we will be talking about different soil pollutants and how they impact you know, soil physical, chemical and biological properties.

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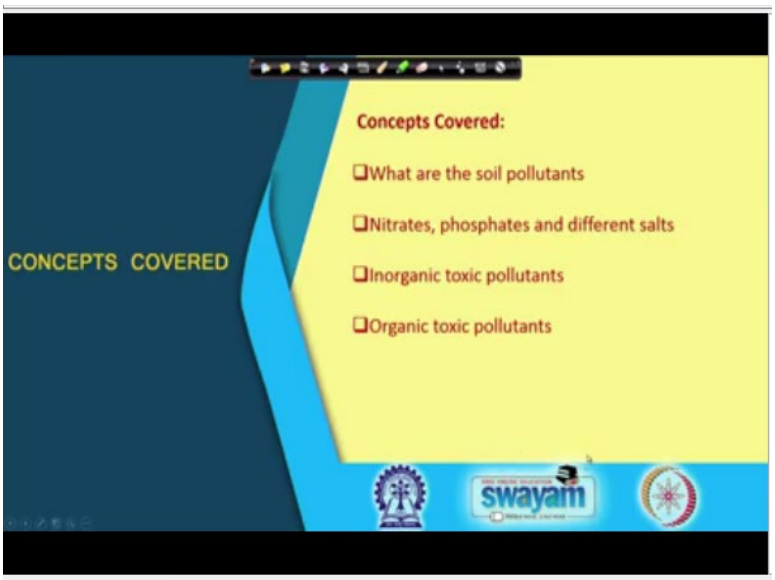

So, these are the concepts we are going to cover that, what are the soil pollutants, and then, you know, we will be talking about nitrates, phosphates and different salts. And also we will be talking about in details about the difference inorganic toxic pollutants as well as organic toxic pollutants for the soil. So, these concepts we are going to cover in this week.

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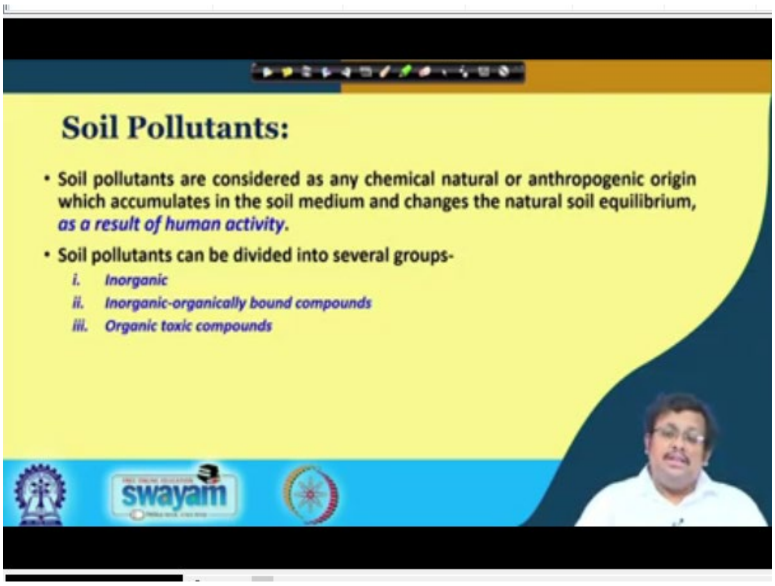

So, if we start with the definition of soil pollutants, what is soil pollutant, what are the soil pollutants. Now, soil pollutants are considered as any chemical natural or anthropogenic origin, which accumulates in the soil medium and changes the natural soil equilibrium as a result of human activity. Now, this is very important, most of the cases these are due to the anthropogenic activities.

And when they accumulate into the soil, they produce disruption of the natural soil equilibria which are present in the natural soil condition. So, this is basically the definition of the soil pollutants. Now, soil pollutants can be divided into several groups, mainly 3, first of all in organic soil pollutants, then inorganic organically bound compounds and third, organic toxic compounds. So, we are going to discuss all of them in details in this week or in this module.

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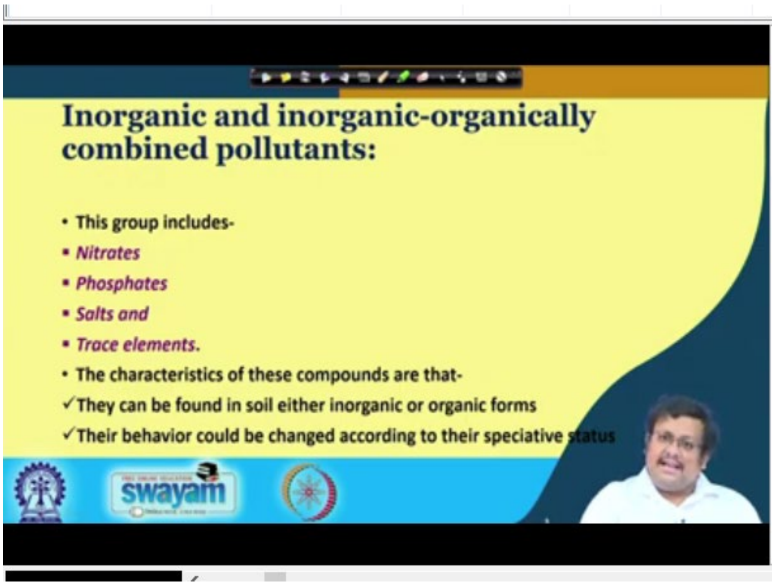

So, let us talk about the inorganic or inorganic organically combined pollutants. So these 2 group basically includes nitrates, phosphates, salts, and trace elements. And the characteristics of these compounds are that they can be found in soil, either inorganic or in organic form, and their behavior could be changed according to the speciated status. So depending on their species, their behavior will change drastically. We will see that in details.

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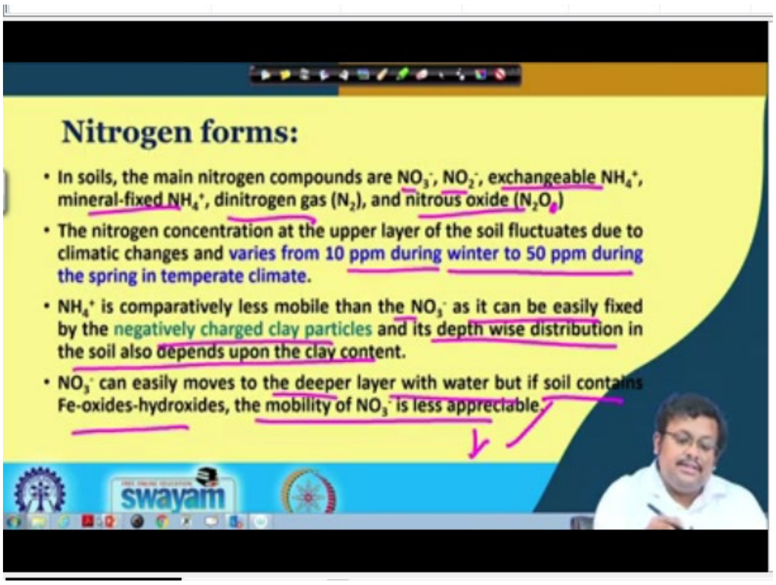

Now, let us start with the most important one you know, that is nitrogen. What are the nitrogen, we are going to discuss what are the important nitrogen forms which are environmental pollutant and how the nitrogen can cause environmental pollution with other nutrients or other elements present in the soil. Now, remember in soil**,** the main nitrogen compounds are nitrate and nitrite.

Exchangeable ammonium, mineral fixed ammonium, dinitrogen, nitrogen gas and nitrous oxides is basically N_2O it is not sorry, it is should be read as N_2O okay. Now, the nitrogen concentration at the upper layer of the soil fluctuates due to climatic changes and varies from 10 ppm during the winter to 50 ppm during the spring in temperate climate. Again, the nitrogen concentration at the upper layer of the soil fluctuates.

And the climatic condition depending on the climatic changes, it varies from 10 ppm in the winter to 50 ppm during the spring in temperate climates, part of it is due to the you know, activity of different microorganisms, which take part in nitrogen conversion. Now, also ammonium is comparatively less mobile than that of nitrate, this nitrate is highly mobile, it is very we do most of the nitrate which we apply to the soil get leach down because they are highly mobile into the soil.

Now, this ammonium is comparatively less mobile than nitrate, as it can be easily fixed by the negatively charged clay particles. Clay particles are negative, so they can easily fix the ammonium and which are positively charged and is depth wise distribution in this soil also depends upon the clay content. So, when there is more clay, obviously, there will be more you know fixation of ammonium.

So, depending on the distribution of the clay there you know the concentration of ammonium changes with the depth and also nitrate can easily move to the deeper layer with water but if soil contains iron oxides or hydroxides the mobility of nitrate is less you know appreciable. So, basically these nitrate can move to the deeper layer as I have already told you, it is very easy to get leached down I mean, the nitrate is highly susceptible to get leached from the soil.

And in the soil contains iron oxides and hydroxides the mobility of nitrite is less appreciable, because they get basically attached to the iron oxides and hydroxides because of an initial reaction you know that.

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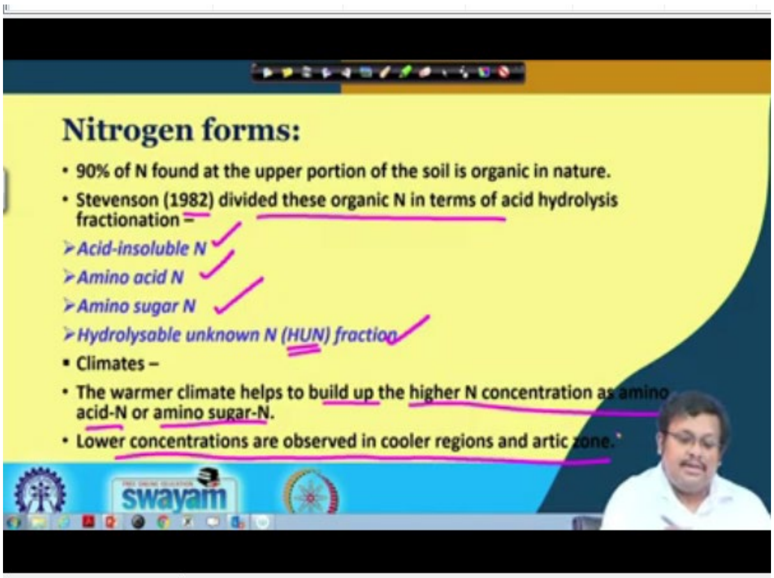

So, 90% of the nitrogen at the upper portion of the soil is in organic in nature. Now, Stevenson in 1982 divided the organic nitrogen in terms of acid hydrolysis fractions, what are those fraction, first of all acid insoluble nitrogen, then amino acid nitrogen, amino sugar nitrogen and hydrolyzable unknown nitrogen and you know fraction we know that we basically denote that by HUN hydrolyzable unknown nitrogen.

Now climates how that climate is impact the nitrogen formation, the warmer climate helps to build up the higher nitrogen concentration as amino acid nitrogen or amino sugar nitrogen and lower concentration are observed in cooler region and artic region. So, lower concentration of nitrogen you can see in cooler region artic region. However, in warmer climate it helps to build up higher nitrogen concentration and the amino acids and amino sugar perhaps due to the activity of different microorganisms. So, these are different nitrogen forms.

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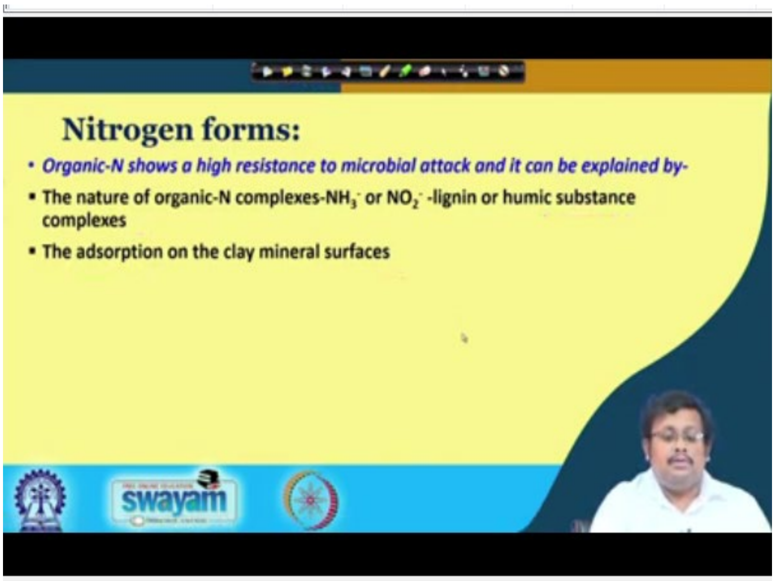

Now, organic nitrogen shows a highly resistance to microbial attack and it can be explained by the nature of organic nitrogen complexes like you know ammonia or nitrate you know basically legally lignin or humic substance complexes and then adsorption of the clay mineral complexes okay.

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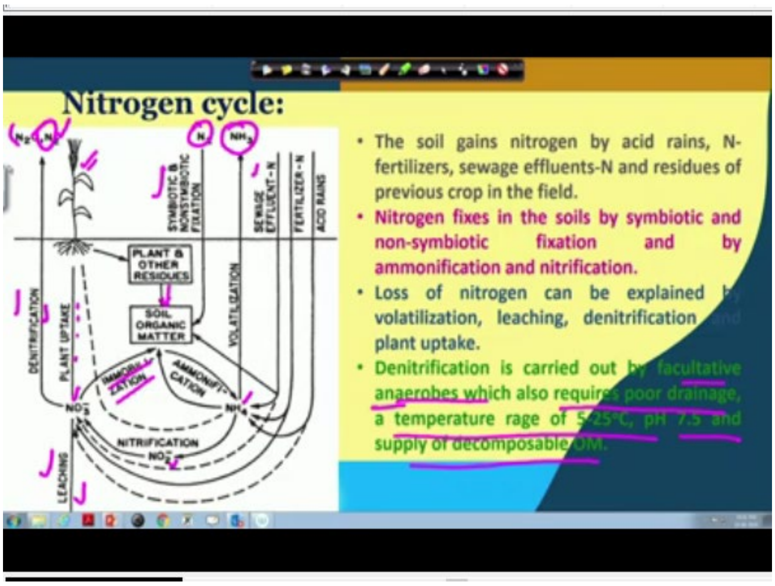

So, let us talk about the nitrogen cycle. These nitrogen cycle shows different processes which basically occur in the soil as come you know from the point of view of nitrogen conversion. So, you know let us start with the plant okay. So, this is the plant. Now when the plant dies, the plant and other deciduous come into the soil and these basically plant residues convert to the soil organic matter okay.

Now, this soil organic matter from the soil organic matter the organic form of nitrogen get converted due to the process of ammonification to ammonium ion and these ammonium get you know through the process of nitrification first convert to the nitrite and then to nitrate and these nitrate also when uptake by different you know they can convert into the soil organic matter through the process of immobilization or these nitrates get uptake in by the plant okay.

Now, these nitrate can also go to the atmosphere as nitrous oxide gas or dinitrogen gas through the process of denitrification alright and also these nitrate lost from the soil through the process of leaching. So, these nitrate either get lost by denitrification process or leaching or by plant uptake okay. So, we can see this is the major process apart from that also these ammonium produce volatilization loss and produce the ammonia which releases into the atmosphere.

This you know also when we apply different sewage effluent nitrogen that can be converted into the ammonia and also they can convert it to the soil organic matters and also when it applies fertilizer nitrogen that also go to the either ammonium pool or in the nitrate pool.

Similarly, when the acid rain happens this acid rain also can go to the ammonium pool or sometimes it go to the nitrate pool.

So, you can see also the atmospheric nitrogen get fixed into the soil organic matter through symbiotic and non symbiotic nitrogen fixation. So, this is basically different dynamics of nitrogen which are occurring into the soil. So, the soil gains nitrogen by you know acid rains, nitrogen fertilizers, sewage effluent nitrogen and residues of previous crop into the field.

Now, nitrogen fixes in the soil by symbiotic as well as non synthetic fixation and by modification and nitrification. What are the losses of nitrogen, the losses of nitrogen can be explained in terms of volatilization, leaching, denitrification, plant uptake, we have seen all these. Now, denitrification is carried out by facultative anaerobes which also require poor drainage, a temperature range of 5 to 25 degrees centigrade pH 7.5.

And supply of decomposable organic matter, now in the presence of decomposable organic matter, this decomposing of the organic method used up all the oxygen. So, these you know anaerobic microorganisms basically, you know facultative microbial anaerobes can they are basically anaerobes can also they are basically a aerobes, but they can survive in the anaerobic condition also.

So, this facultative anaerobes basically uses these nitrate as the electron acceptor in anaerobic condition ultimately converting this nitrate to the atmospheric nitrogen, which releases into the atmosphere through the process of denitrification.

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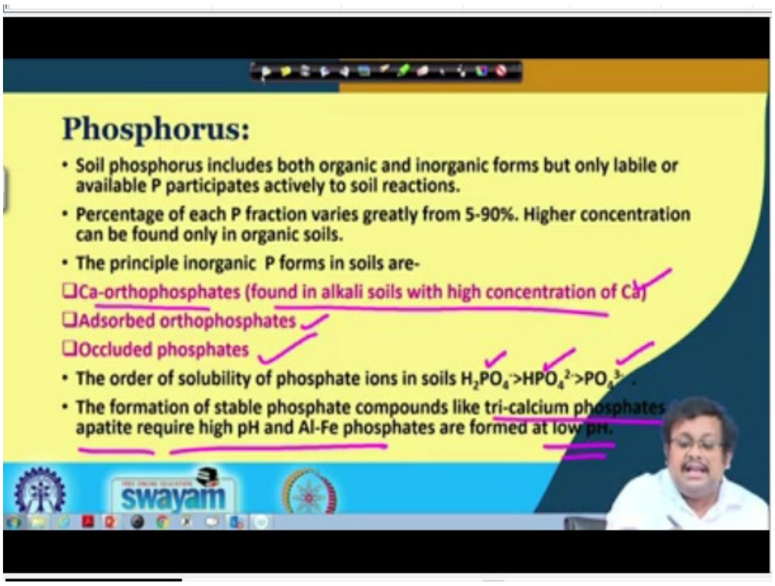

So, we have covered the nitrogen in brief. Now, let us talk about the phosphorus. Now soil phosphorus basically includes both organic and inorganic forms, but only labile or available phosphorus participates actively in the soil reactions. So, labile means which are movable which are basically available. So, percentage of each phosphorus fraction varies greatly from 5 to 90% and higher concentration can be found only in organic soil.

Because organic matter has such function do gives which can mobilize the fixed phosphorus. So, this is how in the organic soil the percentage of phosphorus fraction you know is generally very high. Now, the principle inorganic you will phosphorus sponsor calcium orthophosphate which are found in alkaline soils with high present a concentration of calcium.

These are basically calcium orthophosphate and also you can see adsorbed orthophosphate as well as occluded phosphate. Now, the order of the solubility of the phosphate generally can follow primary orthophosphate iron, which is highly soluble followed by secondary orthophosphate and then followed by PO_4^{3-}, now the formation of stable phosphate compound like tri calcium phosphate and appetite require high pH and.

So, this in case of high pH condition that means, when there is a high calcium concentration, the formation of this tri-calcium phosphate or apatite is there. And in case of low pH condition, where we can see the more concentration of iron aluminium, you will see the iron phosphate as well as aluminium phosphate present in the soil. So, in case of alkaline soil again the predominance of you know you will see the dominance of calcium phosphate or apatite in case of acidic soil, you see the dominance of different aluminium phosphate as well as iron phosphate.

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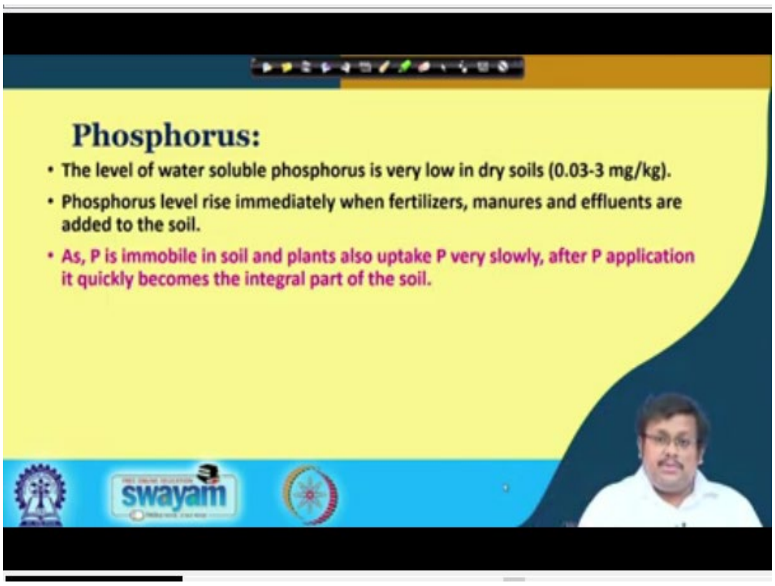

So, the level of water soluble phosphorus is very low in dry soil which is 0.03 to 3 mg per kg or ppm. So, that is why when we apply the fertilizers the phosphorus level rise immediately. However, the most of them are getting fixed because they are not soluble in the water. Now, since phosphorus is immobilized in soil because they are not soluble in water and plants also uptake phosphorus very slowly after phosphorus application it quickly becomes integral part of the soil.

So, in other words it get fixed into the soil. In the acidic condition it gets fixed by either iron phosphate aluminium phosphate or in the alkaline condition get fixed by you know, tri-calcium phosphate or you know or apatite.

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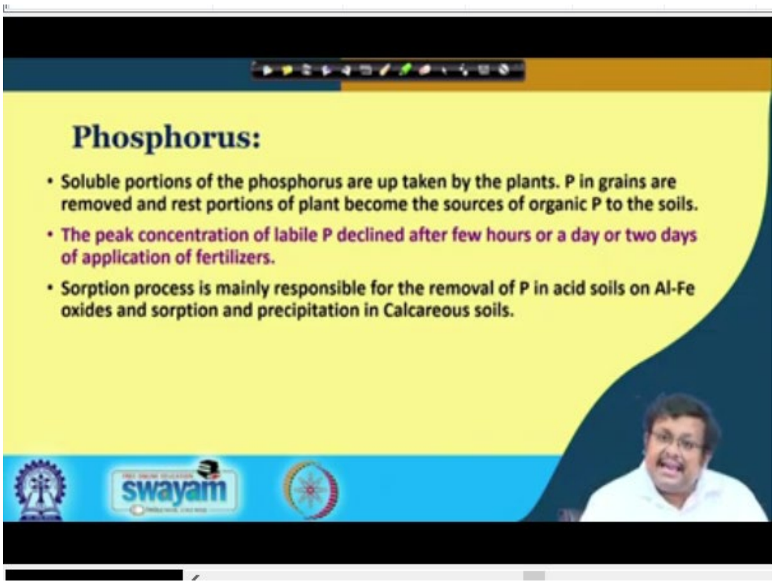

Now soluble portions of phosphorus are taken up by the plants. phosphorus grains are removed and rest portion of the plant became sources of organic phosphorus to the soil. So, we apply this plant residue into the further soil during the further cultivation that becomes the source of organic phosphorus. Now, the peak concentration of labile P declined after few hours or a few days or 2 days of application of fertilizer just for the due to the phosphorus fixation process.

Now, sorption. So, that is why we already you know the in case of fertilizer phosphorus application is always recommended to apply phosphorus in split doses not in you know in one go. Because if you apply all the phosphorus in one go maximum of that fertilizer you know will get fixed and as a result plant cannot get that phosphorus. So, you will see that you know sorption process is mainly responsible for the removal of phosphorus in acid soils on aluminium iron oxides and sorption of precipitation in calcium calcareous soil.

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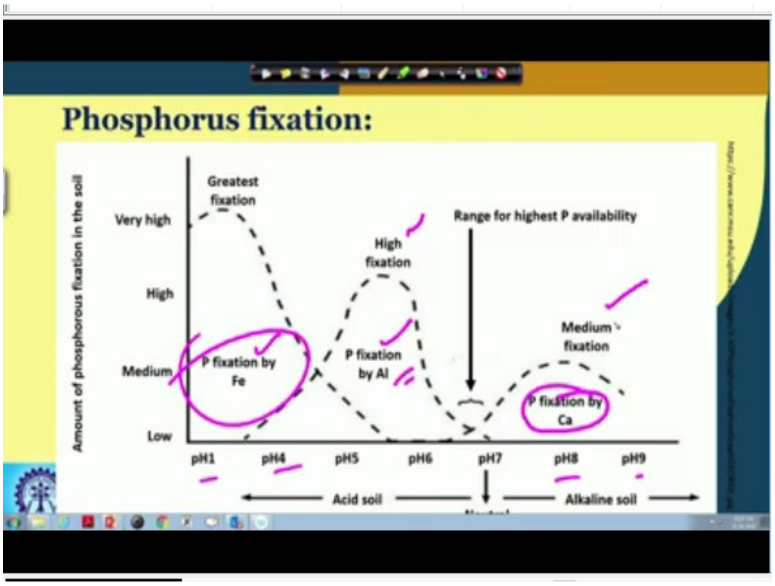

So, if you see the phosphorus you know amount of phosphorus fixation in the soil at different pH level, this graph gives us a very good illustration, it shows a very good illustration. So, obviously, you know clearly there is a line. So, obviously in case of alkaline condition when the pH is greater than 7 or you know 8 or 9 you will see there is a medium fixation level and phosphorus will refills by calcium.

However, when the pH is in the acidic range, you will see to you know fixation hills. So, first of all is showing the high fixation and this is basically showing phosphorus fixation by aluminium, you remember that we have talked that in the acidic soil, there is a high concentration of aluminium and that's why aluminium is considered as an acidic cation.

And as a result of this acidic cation presence there is a high fog you know high fixation and in case of lower pH like pH 1 to around pH 4 to 4.5 you see the greatest fixation is by iron. So, you can see these graph basically gives us the evidence that in the acidic condition, the phosphorus will be present as iron phosphate or aluminium phosphate and in the alkaline condition, it will be present as calcium phosphate.

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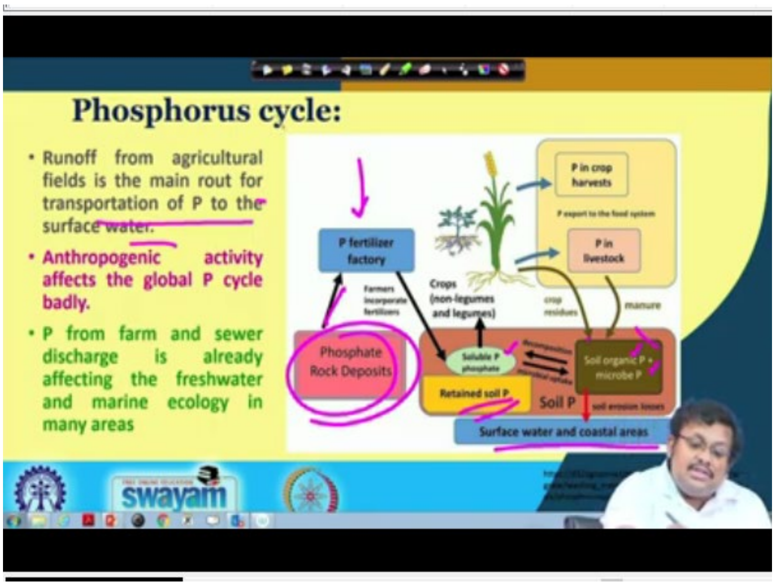

Now, let us talk about the phosphorus cycle. Now in the soil, the phosphorus cycle starts with the crop. So, when the crop beget decomposed after it is dead, so, it basically improves the soil organic phosphorus and microbial phosphorous and these soil organic pool get decomposed to produce the soluble phosphate which further plant can take.

And from this soluble phosphorus pool microbial uptake can occur to convert them into the soil organic or microbial pools also and from the soil organic and microbial pool there can be soil erosion losses, which can further goes to the surface water and coastal areas creating eutrophication, what is eutrophication. We will see and these phosphorus in the solution get retained as soil phosphorus or get fixed.

Now, when we apply phosphorus fertilizer, these fertilizers increase the soluble phosphorus concentration in the soil solution from there, there is some retention also a fixation of phosphorus and you know phosphate rock deposit can be converted to you know phosphorus fertilizer okay. So, further the phosphorus in crop harvests phosphorus in livestock can ultimately go to in the form of crop residues and manure can go to soil organic and microbial P.

So, this is the total phosphorus cycle you can see runoff from agricultural fields is the major cause for transportation of phosphorus in the soil, as I have told you, the phosphorous get fixed into the soil. And as a result of the runoff of the soil particle phosphorus also move away with the soil particle getting in the fixed form and then they reach from one area to another area.

Now anthropogenic activity affects the global phosphorus cycle and phosphorus form from form and sewer discharge is already affecting the freshwater and marine ecology in many areas. We will see that in details. Now, this is a very important term eutrophication.

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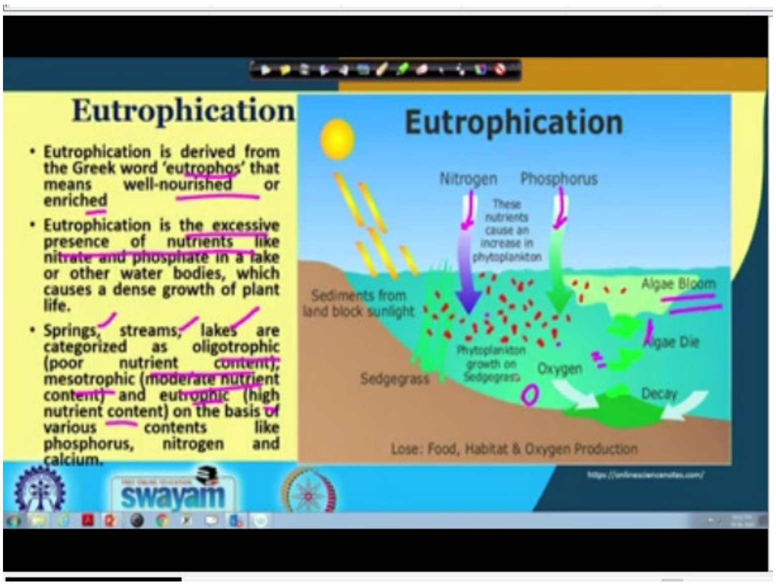

So, we have discussed about the nitrogen and phosphorus, let us see how these 2 nutrients get you know disturbs the equilibrium you know natural equilibrium or ecological balance and then create the problem of eutrophication. So, eutrophication is derived from the greek word called eutrophos that means, well nourished or enriched. So, eutrophication is basically the excessive presence of nutrients like nitrate and phosphate in a lake or other water bodies, which causes the dense growth of plant life.

So, generally you can see these type of eutrophication in springs, streams, lakes or you know in this screen streams or lakes they are categorized as oligotrophic or poor nutrient content or mesotrophic that is moderate nutrient content and eutrophic that is high nutrient content on the basis of various contents like phosphorus, nitrogen and calcium. So, when the high concentration of phosphorus, nitrogen, calcium are there we call it you know eutrophic.

When it is medium then it is called the mesotrophic, when it is low that is called you know, oligotrophic environment. So, here you can see one thing that when the nitrogen and phosphorus due to nitrogen is highly mobile you have already know that as these phosphorus can move away through surface runoff through soil particles in the fixed form. When the deeds the water body, they basically these nutrients are basically used by phytoplankton, okay.

And these phytoplankton wave boom in their population, okay, we call it algal bloom, okay. And as a result of this algal bloom, whatever dissolved oxygen, which is present in the water getting depleted, ultimately killing the aquatic organisms. So, basically, due to the presence of nitrogen and phosphorus and, you know, they basically cause an increase in the phytoplankton because they utilize these nutrients and as a result, there is a algal bloom.

And when these algae basically die, they decay, removing all the oxygen, dissolved oxygen, which are present in the water and ultimately depleting the dissolved water and creating the and basically, you know, ultimately leading towards the death of the other aquatic organisms.

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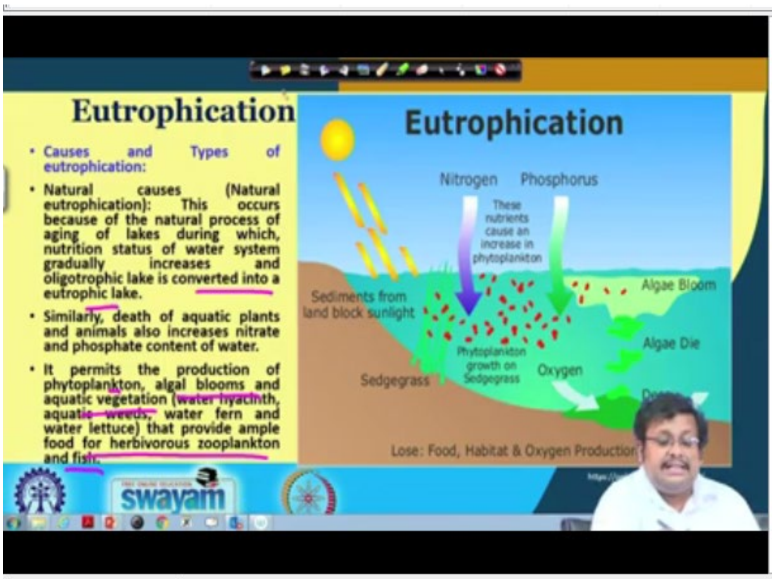

So, what are the causes and types of eutrophication, there are 2 types of causes for eutrophication, one is called the natural cause. So, let us first discuss this first. So, natural cause of eutrophication, natural cause of eutrophication, these occurs because of the natural process of aging of lakes, during which the nutrition status of the water system gradually increases and oligotrophic lake is converted to eutrophic lakes.

So, basically due to the aging process of the lake, the nutrition status of the lake increases to converting it from the poor oligotrophic to highly nutrient content that is eutrophic lakes. Similarly, death of aquatic plants and elements also increases the nitrate and phosphate content of the water and it permits the production of phytoplankton, algal bloom and basically equity you know, it permits the production of phytoplankton, algal bloom.

And equity vegetation like water hyacinth, the aquatic weeds, water fern and water lettuce that provides the ample food for herbivores and you know zooplankton and fish. So basically, these phytoplankton, algal blooms water fern and all these things provide ample food for herbivorous, you know, zooplankton and fish, so their production is increased.

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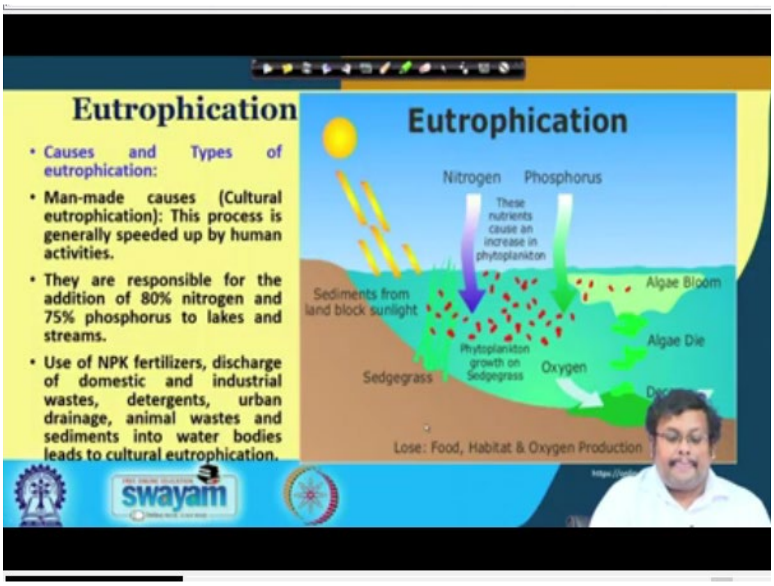

Now, the second cause for eutrophication is manmade causes. So, manmade causes also known as the cultural eutrophication. And these processes generally speed up by anthropogenic activities, and they are basically responsible for the addition of 80% nitrogen and 75% of phosphorus to lakes and streams, and use of also NPK fertilizers, discharge of domestic and industrial wastes and also detergents, urban drainage, animal waste and sediments.

All these are responsible because when they enter into the water bodies they ultimately leads to the cultural eutrophication.

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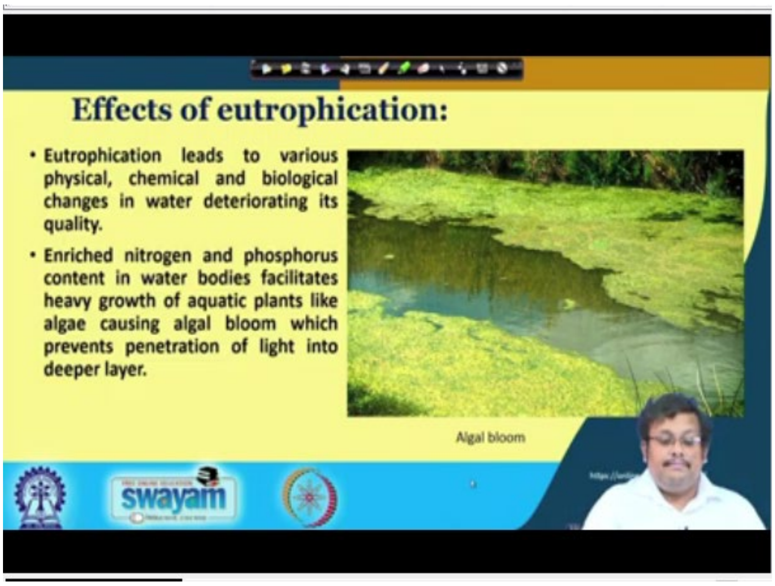

Now, what are the effects of eutrophication. Well eutrophication leads to various physical, chemical and biological changes of water you know deteriorating its quality. We have already talked about that is the you know enrich nitrogen phosphorus content you know in the water bodies facilities the heavy growth of aquatic plants like algae causing this algal bloom as you can see in this picture, okay, which prevents penetration of light into the deeper layer. So, when there is an algal bloom the sunlight cannot penetrate deeper into the water layer.

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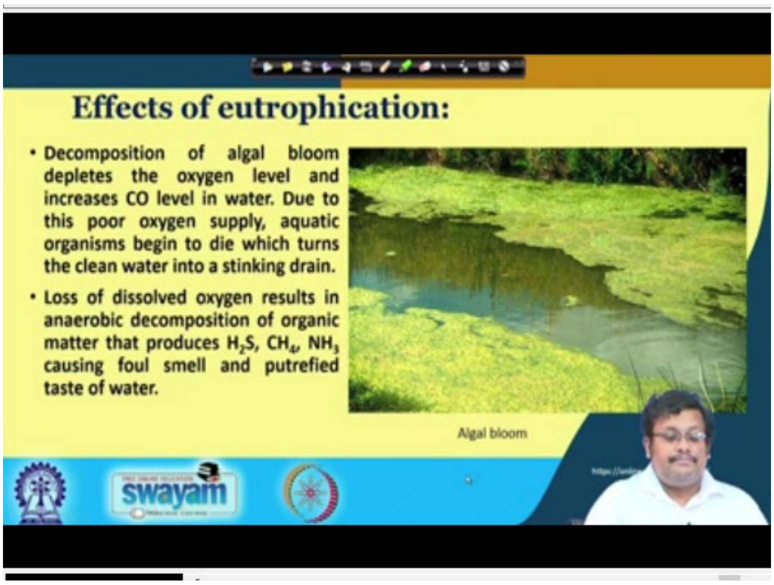

And decomposition of algal bloom depletes the oxygen level and increase the carbon monoxide level in water, because decomposition of algal bloom because, when these algae die, the decomposition of those dead bodies of algae basically will adequate consumption of oxygen and these oxygen is basically present in the dissolve in the water. So, the reduction of dissolved oxygen you know happens when there is a decomposition of algal bloom.

And you know, creating the poor oxygen supply of aquatic organisms and aquatic organisms begin to die which turns the clean water into the stinking drain and also loss of dissolved oxygen results in anaerobic decomposition of organic matter that produces hydrogen sulphide, then methane, ammonium causing foul smell and putrefied taste of water. So, these are the effects of eutrophication.

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And also algae diatoms and rooted weeds show dominance by interfering hydroelectric power, clogging of the water filter during the treatment process, you know also retarding the water flow and affecting the quality of water and water works and also it can produce fatal world you know water borne diseases such as polio, dysentery, diarrhea, typhoid and virus, hepatitis spread as many pathogenic microorganisms, viruses, protozoa bacteria can grow in the sewage products under anaerobic condition. So, these is basically eutrophication and its ill effects.

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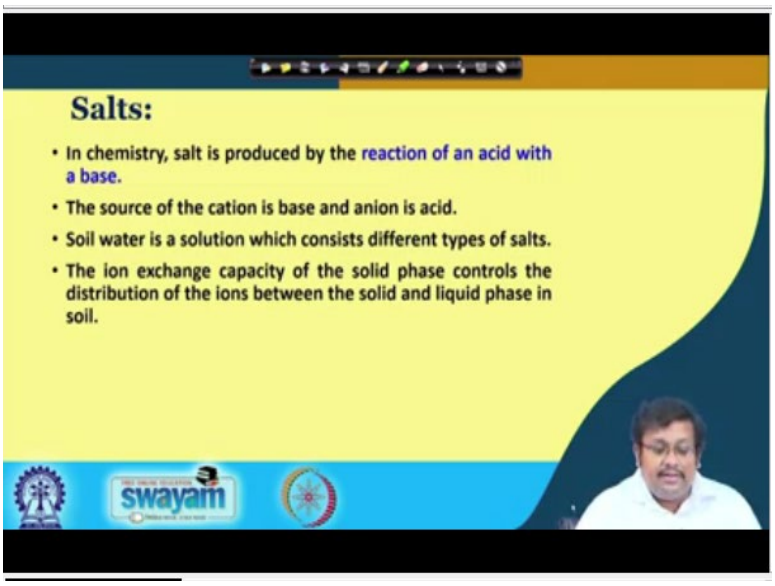

Now, let us talk about the salts, in chemistry, salt is produced by the reaction of an acid and base you know that at the source of the cation is based and anion is basically acid. So, the soil water is the solution, which consists different types of salts like you know, either sodium salt, calcium salt, or salts of other cations you know from magnesium salts are also presents. So, the ion action capacity of the solid phase controls the distribution of the ions between the solid and liquid phase in the soil.

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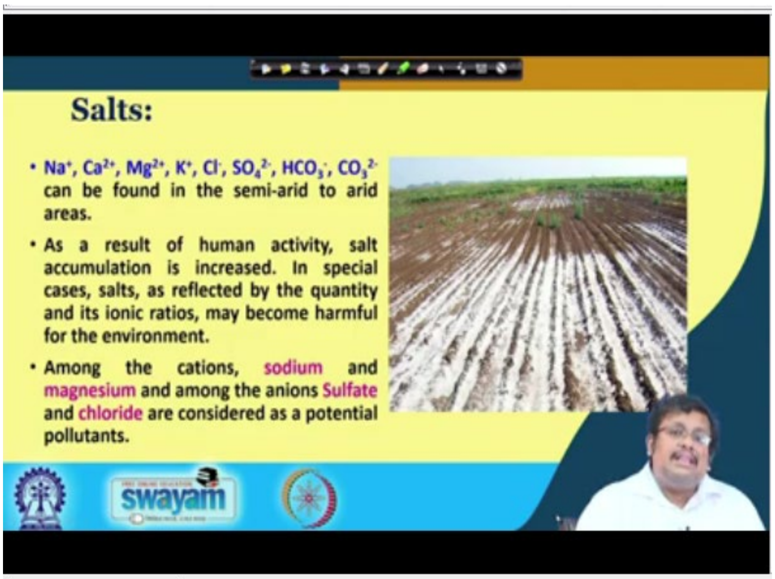

What are the important cations and anions in the salts, sodium, calcium, magnesium, potassium, these are the you know important cations and also chloride sulphate, carbonate bicarbonate, these are the important anions and they can be found in semi-arid to arid areas, why in semi-arid to arid because in the semi arid to arid areas there is high evaporative demand.

And as a result of higher operative demand, the water get easily move to the surface of the soil and ultimately then get you know, the water gets evaporated leaving the salt crust over the soil as you can see here, this is an example of the saline soil and this creates pollution. Now as a result of human activity salt accumulation is also increased. In special cases salts is reflected by the quantity of its iron rations may become harmful for the environment.

Salts also create several toxicity and also when the salt is present in the soil solution x you know plant cannot absorb or plan cannot extract the water through its roots. So, among the cations sodium and magnesium and among the anions sulphate and chlorides are considered as the potential pollutants as far as the salts are concerned.

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Now, if you see the classification of the salt, salts basically consists of anions and cations and what are the major anions sulfate, chloride, in case of cations are sodium and magnesium. So, these are major pollutants which are arising from different salts in the soil. So, let us talk about another important element that is called sulfur.

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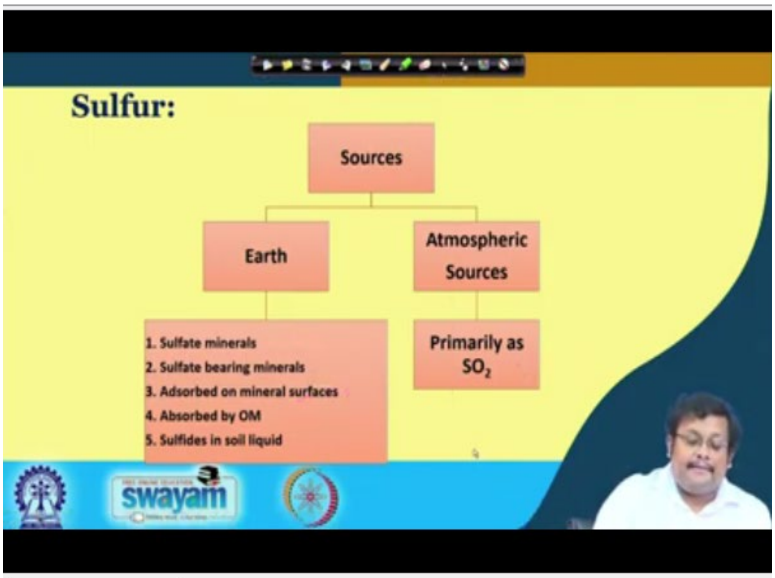

So, sources of sulfur are 2 types one is earth, another is atmospheric sources. Now, the earth sources of sulfur or sulphate minerals sulphate bearing minerals, adsorbed or mineral surface and then absorbed by organic matter and sulfides in soil liquid. However, in case of atmospheric sources the major source is sulfur dioxide.

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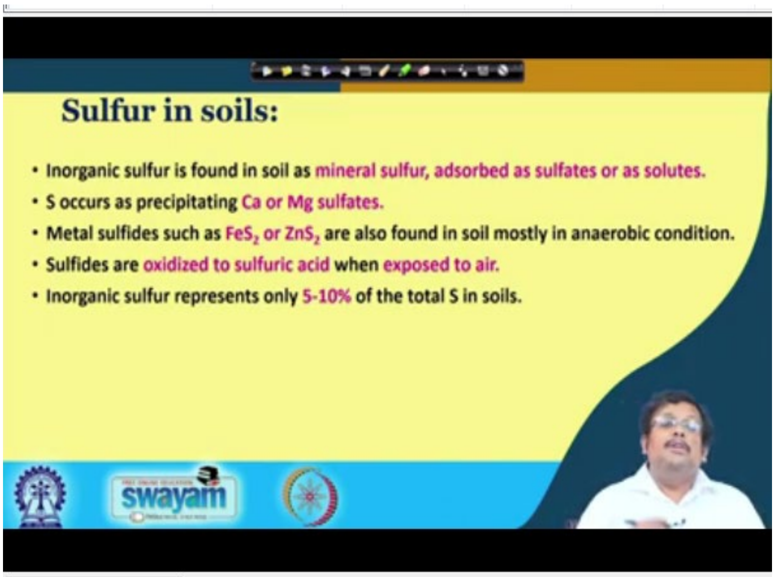

So, how you can see sulfur in soils. Now, inorganic sulfur is found in soil as mineral sulfur adsorbed as sulfates or as solutes. Now, sulfur occurs as precipitating calcium or magnesium sulfates, metal sulfides such as iron sulfide, zinc sulfide are also found in mostly anaerobic condition in case of submerged soils. Sulfides are oxidized to sulfuric acid when exposed to air.

We have seen this thing in some soils of Kerala of India and inorganic sulfur represents the 5 to 10% of the total sulfur in soils.

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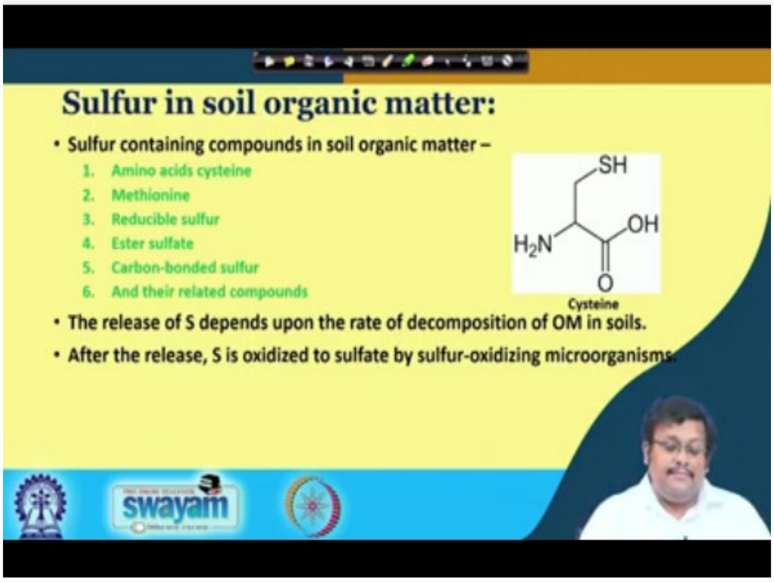

Now, sulfur containing compounds in soil organic matter at several types major list types, one is amino acid cysteine as you can see the structure of the cysteine here, then methionine, then reducible sulfur you know ester sulfate, then carbon bonded sulfur and then you know wood related compounds of the carbon bonded sulfur. So, the release of sulfur depends upon the rate of decomposition of organic matter in soils.

And after the release sulfur is oxidized to sulfate by sulfur oxidizing microorganisms. So, let you know guys we have talked about some of the important elements and how they can influence the soil pollution. We have talked about some important inorganic elements and let us wrap up our lecture here. In the next lecture we will see some other important inorganic and organic pollutants of soil. Thank you very much.