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Module No # 07 Lecture No # 37 Soil Pollutants (Contd.,)

Welcome friends to this second lecture of week 8 and in this module 8 we are talking about different soil pollutants. In the first lecture we have talked about some important soil pollutants, inorganic soil pollutants we have talked about nitrogen different forms of nitrogen. And also we discuss the nitrogen cycle we also discussed the phosphorous and major phosphorous forms. And how they get fixed in depending on different pH and what are their forms which are present at different pH level.

And then we are talked about the eutrophication's which is nutrient enrichment based pollution process and what are the causes of eutrophication. And then we have talked about you know what are the ill effects and effects of eutrophication's. And then we have talked about the salts what are the different types of salts which are present. And we started with the sulfur among different elements we will start with the sulfur

So in the last lecture we have talked about the different sulfur containing compounds which are present in the soil organic matter and then we will start from here. And in this lecture we will be talking about some more you know elements which are important soil pollutant. So let us start with the sulfur containing compounds in the soil organic matter.

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We know that they are mainly amino acids cysteine and then Methionine you know reducible sulfur, Ester sulfate, carbon-bonded sulfur and also different related compounds to carbonbonded sulfur. So you can see this is the structure of the cysteine and the release of sulfur depends on the rate of decomposition of organic matter in the soils. So the organic matter decompositions rate controls the release of sulfur from this organic-bonded form and the release of you know after this release of after this release this sulfur is oxidized to sulfate by sulfur oxidizing microorganisms

They are both sulfur oxidizing microorganisms and sulfur reducing microorganisms so sulfur oxidizing microorganisms basically oxidizing the sulfur to produce the sulfate okay and this sulfate is more available to the plant.

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Atmospheric sources of sulfur:

- S is primarily found as SO₂ in the atmosphere. The quantity of SO₂ in the air is mostly high in the urban areas where different power stations and industries are situated.
- These gases are dissolved with rain water and cause acidification.
- The acid rains again increase the acidity of the soil.
- But, this problem is considered as a local problem.



Now what is the atmospheric sources of sulfur? Sulfur is primarily found in sulfur di oxide in the atmosphere and the quantity of the sulfur di oxide in the air is mostly highly in the urban areas where different power stations and industries are situated. So, basically this sulfur di oxide in the atmosphere basically generated through industry as well as automobile emission. Now these gases are dissolve in rain water and causes the acidification as you can see in this picture this sulfur di oxide along with the nitrous oxide due to the industrial process.

They goes to the soil they goes to the atmosphere and then they react that the water vapor which is present in the atmosphere. And ultimately you know returns back to the earth in the form of either nitric acid or sulfuric acid. So the acid rains again increase the acidity of the soil however luckily this acidic rain problem is a local problem it is not a very privacy problem.

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Other sources of sulfur:

- Irrigation with saline water
- Rise in the drainage water sulfate level
- Use of CaSO₄ for soil reclamation

Now other sources what are the other sources of sulfur? You know other sources of sulfur it is irrigation when we irrigate with the saline water that could be a source of sulfur. Then rise in the drainage water you know water sulfate level so that could be one of the sources of sulfur. And also use of calcium sulfate for soil reclamation could be one of the sources of sulfur how you apply a gypsum to reduce the soil you know each. So that gypsum application can also increase the sulfur in the soil.

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Now let us see the sulfur cycle so this sulfur cycle shows that how sulfur converts into the soil environment. So let us start with the crop so the crop basically takes the sulfate which is present in the solution and then sulfate is so sulfate is up taken by the plant. And this plant when you know after the death these plants reside is basically enrich the organic sulfur these organic sulfur helps in the mineralization to the sulfate form and this sulfate is further goes towards the organic sulfate through the mobilization process.

And also this sulfate get adsorbed you know getting the you know you convert it the adsorb form or mineral sulfur and from their also there is some dissolution of this mineral sulfur to the sulfate form okay. And also due to the weathering of different minerals due to the weathering of different weathering process there is permission of the sulfate. Atmospheric deposition I have talked about the acetic rain in the previous slide so that atmospheric deposition can contributes some sulfate okay.

So when we apply the mineral fertilizer it can produce either elemental sulfur or it can produce the sulfate okay. Now this elevators sulfur are when they goes oxidation through different process they produce the sulfate. And also this oxidation you know occurs to different sulfur oxidizing bacteria. And from this sulfur due to the reduction due to the anaerobic condition it produce bacterial reduction occurs and ultimately produce the reduce sulfur H_2S and HS^- .

So basically reduce sulfur fractions are produced and further from this reduced sulfur H_2S when bacterial oxidation occurs they produce sulfate okay. From this reduce sulfur that is H_2S then it can convert to you know it can volatize it goes to you know it can go to the volatilize or it can produce the mineral formation. Now these volatilize form of sulfur or H_2S gas can produce the atmospheric sulfur and this atmospheric sulfur further is adsorbed by as a sulfur di oxide gas by the plant.

So this is how sulfur moves to the soil how here this green like elemental atmospheric sulfur, elemental sulfur, reduced sulfur, sulfate adsorb or mineral sulfur or organic sulfur are basically showing the components at this green boxes and this blue boxes like atmospheric deposition, animal manures, plant residues, mineral fertilizers, weathering is basically showing the different inputs of the soil.

So you can see these are basically inputs from the in terms of fertilizers and plant residues, plant manures, atmospheric deposition and weathering and losses are basically denoted by these orange boxes. So basically you can see the plant uptake, crop harvest, volatilization, runoff and erosion and mineral formation these are different losses of sulfur in the soil sulfur cycle.

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So another important element which creates the soil pollution is called chloride. Now chloride can be easily found in the soil water but it becomes a pollutant when added to the soil system under uncontrolled management. As you can see due to the application of saline irrigation water there is a salt deposition on the surface. And most of the cases is sodium chloride which is a common salt.

Now the origin of this chloride in the soil is basically dissolution of chloride pistols and the deposition of the chloride and their irrigation with saline water as you can see here. And finally the rise of; you know chlorotic ground water due to the poor drainage. So when there is a poor drainage high operative demand previously there will be movement of this chlorotic ground water to the surface; and then further evaporate you know these water getting evaporated living the salt over the salt surface producing the surface you know salinity.

Now chlorine is negatively charged and can be easily adsorbed by positively charged soil surfaces or oxides hydroxides.

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Magnesium:

- · Mg is the forth most abundant mineral in the living organisms.
- It is present as an exchangeable cations (0.5-14 kg⁻¹cmol) in the soil exchange complex with Mg saturation exchange capacity 10-20%.
- Exchangeable Mg is usually 20-60% of total magnesium.
- It remains as a solute in liquid phase. Soils in arid regions have higher solute concentration in soil solutions due to lack of leaching.
- · The total Mg content increases with increasing clay content in soils.
- Soil contains 0.015%-1.02% total Mg.

Now let us talk about magnesium is the forth most abundant mineral in the living organisms. And it is present in the exchangeable cations from 0.5 to 14kg centimole in the soil exchange you know complex with magnesium saturation exchange capacity from 10 to 20%. And exchangeable magnesium usually 20 to 60% of total magnesium so it remains as a solute in liquid phase and soils in arid regions have higher solute concentration in soil due to the lack of region

So magnesium just like calcium can be found in higher quantity higher concentration in the arid and semiarid region where the evaporate demand is quite high. And the total magnesium contains increases with increase in clay content in soil because soil contains soil clay materials which have the brucite or trioctahedral. Remember this trioctahedral they are basically occupied by magnesium ions. Now soil contains 0.015 to 1.02% total magnesium.

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Now magnesium minerals can be classified into 3 major fraction one is soil clays that is smectite Vermiculite illite etc., then solution magnesium minerals like Dolomite, magnesium sulfate etc., And then different anthropogenic sources like irrigation water.

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So how magnesium fixation occurs now fixation of magnesium depends on soil pH and magnesium remains exchangeable below pH of 6. And magnesium becomes non-exchangeable above pH 6.5 so it remains in the soil solution if other cations you know occupy the exchange sites specifically calcium. So there is a always competition between calcium magnesium to occupy in the oxygen site. So if the oxygen site is occupied by calcium then magnesium will not occupy the oxygen side and remain in the salt solution.

So you can see the magnesium cycle here you can see here you know magnesium in the salt solution and this magnesium is you know susceptible to leaching and also this magnesium gets converted to organic matter. And then from, this, organic matter due to you know mineralization process. The magnesium can further comes to the soil solution when the crop residues we apply the crop residues into the soil then it can also move in convert into the organic matter which can further produce the magnesium into the soil solution.

Also this magnesium can be present in the form of exchangeable magnesium when we apply the mineral and inorganic fertilizer that also applies that also increases the magnesium concentration in the soil okay. And also magnesium get lost due to the harvest of the crop which uptake the magnesium. Now in the soil also you can see erosion occurs due to the run of process. And also from the primary minerals you know primary minerals converted to the secondary minerals.

And from the secondary minerals they can form in the non-exchangeable magnesium and this magnesium you know primary minerals can contribute directly to the magnesium soil solution. And also from magnesium soil solution secondary minerals are basically in equilibrium to each other. And similar thing occurs between the magnesium in soil solution and non-exchangeable magnesium.

So this is how magnesium basically rotates in the soil so it is basically showing the dynamics of magnesium in the soil. So again when the exchange complex is occupied by calcium magnesium comes into the soil solution

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Sodium:

- The important sodium mineral in soil is NaCl.
- Highly soluble and quickly removed from the soil after heavy rainfall and irrigation with good drainage condition.
- But, if its accumulation is greater than leaching (>15% of Na⁺ in exchange complex), Na⁺ can replace other cations like Ca²⁺ and Mg²⁺ from the soil exchange sites and deteriorate the soil's hydro-physical properties.
- · It completely destroys the soil structure.
- The accumulation of Na⁺ taken place when soils are irrigated with saline water
- High Na⁺ concentration in the soil water can be toxic for many agricultural crops.

Let us talk about the sodium the importance is sodium mineral in soil is basically in the form of sodium chloride you know. It is highly soluble and quickly remove from the soil after heavy rainfall and irrigation with good drainage water. So since it is highly mobile when we apply irrigation good quality irrigation water it is easily remove from the soil and also due to the heavy rainfall it is also can leach away or it can move away with the flowing water.

But if they accumulation is greater than leaching that is greater than leaching that is greater than 15% in sodium in the exchange complex then you know sodium can replace other cations like calcium and magnesium. Now remember in case of calcium magnesium they decrease the zeta potential. When they decrease the zeta potential they increase you know the chances of flocculation. When they increase the chances of population there is a more chance of getting more irrigated soil.

However, when we apply sodium or when the exchangeable sodium percentage goes beyond 15% that basically, replaced the calcium magnesium from the exchange site. As a result of that there is an considerable increase in the zeta potential when the zeta potential increase obviously the soil will be dispersed. So when the soil will be dispersed that will be causing a major disruption in the hydro-physical process.

Because the clog the pores will be clogged and as a result of that there will be no aggregate formation no pores will be clogged. And as a result the surface crusting and all the other non-

favorable condition as far as the soil hydro physical properties are concerned will be there. So this sodium is a it is detrimental for the soil physical properties it completely destroy the soil structure as just I have told you how it destroy the soil structure it increases the zeta potential when it increases the zeta potential there is a you know there is no aggregate formation.

The flocculation will be there will be no flocculation no aggregate formation soil will be dispersed and as a result there will be destruction of the soil structure. The accumulation of sodium takes place when the soils are irrigated with saline water and high sodium concentration in the soil water can be toxic for many the agricultural crops.

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Now sodium carbonate formation in this soil what is the 2 different process. What is the physiochemical process and there is biological process? And the physiochemical process, leaching with highly sodic water then again leaching with water with low salinity. So, sodium carbonate happens in that way and also weathering of igneous rocks and also evaporation and then precipitation of carbonates.

Like calcium carbonates, magnesium carbonate when they convert to sodium carbonate that is one of the way of you know of sodium carbonate formation. And biologically sodium carbonate can be formed in soil as a resultant of reduction process.

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Now if we see the sodium carbonate forms which are associated with alkali soil so there are 3 many types. One is the sodium bicarbonate that is called Nahcolite and then sodium carbonate $10NH_2$ that is soda and then Trona which is sodium carbonate sodium bicarbonate and $2H_{20}$. So if you see the sodium cycle in the soil this is the sodium cycle in the soil, so basically in the soil solution sodium is present and the soil accumulation occurs due to the evaporation when from the soil solution water gets evaporated when the evaporation occurs and vice versa okay.

So this sodium in the soil solution get easily removed by leaching in the ground and goes ultimately to the ground water and also where there is a high evaporative demand. Then the ground water can show capillary movement and ultimately this sodium moves to the soil solution also oil industry brines can produce considerable amount of sodium in the soil solution and ground water. And also from soil bearing rocks also they produce the huge amount of sodium into the ground water okay.

At this sodium you know occupies the certain percentage of this CEC or cation exchange capacity since it is positively charged. And also it can be immobilized to organic matter and further comes back to the soil solution through the mineralization process. These plants, animals and sodium you know these plants and animals basically animal basically plants and both animals and plants basically contribute to the formation of organic matter.

And also when we apply sodium fertilizer then that sodium also goes to the organic matter so this is how the sodium moves in the plant, animal and the soil. Also you can see from the soil solution when there is some atmospheric sodium into the precipitation process they basically reach to the soil solution. And these atmospheric precipitation also produces the surface water saline surface water this saline surface water it can also evaporate to produce you know evaporate to the atmosphere.

Now the parent material can be weathered to produce the secondary soil minerals we know that and from this secondary soil minerals also sodium can come to the soil solution. Also it produces loses to the parent material so this is the sodium cycle and it basically shows and one more thing that capillary movement and CPH can occurs from surface occurs from surface water to the ground water and vice versa

So this is basically sodium cycle in the soil and this is how when the sodium consideration increases in the exchange complex it creates the unfavorable condition for the soil.

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Potentially toxic trace elements:

- Adriano (1986) defined "trace elements" as those elements that occur in natural and perturbed systems in small amounts and that, when present in sufficient concentrations, are toxic to living organisms.
- It is admitted that the inputs from the anthropogenic sources exceed the contribution from the natural sources.
- Human activity is primarily responsible for increasing the chances of trace metals contamination in soils.

Now potentially toxic trace elements what are the potentially toxic trace element Adriano in 1986 defined trace elements as those elements that occur in the natural and perturb system in small amounts and that when present in sufficient concentration are toxic to living organisms. Now it is admitted that the inputs from the anthropogenic sources exceed the contribution from the natural sources.

Although this trace elements can be a, originate from the natural sources the anthropogenic are the sources from the major contribution of this stress element and ultimately creating them toxic. Now human activities primary responsible for increasing the chances of trace you know metal concentration in the soils.

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7. Sewage and sludges

Now what are the anthropogenic sources? When you talk about the potentially toxic trace elements like arsenic then blade then cadmium, chromium these are all potential toxic elements. So; how this potentially toxic trace elements occur in the soil due to different anthropogenic processes, so this anthropogenic processes or application of fertilizers specific phosphate fertilizers.

And this fertilizer contains different kind of these trace elements when you apply the fertilizer into the soil these trace elements also comes into the soil. Second is application of different chemical used for soil reclamation. So we applied different types of chemical into the soil reclamation and when they apply these chemicals for soil reclamation and also creates the high concentration of toxic elements.

Different organic biocides pesticide is one of the major source of this toxic trace element pesticide contains this toxic trace elements, and when you apply the pesticides into the soil they remain into the soil they persistence in the nature so remain in the soil, and simultaneously these organic or these toxic trace elements also remain in the soil. Mining residues is one of the major you know one if the major contributor of this trace elements.

Automobile emission products huge amount of these toxic elements are emitted due to the automobile emission and ultimately deposited in this soil surface. Municipal soils and this sewage and sludges so these are all examples of you know different anthropogenic, and you know remember that these are all anthropogenic sources because for all these the human activities are involved human activities are responsible. So these are the anthropogenic activities and they basically create this toxic trace elements okay.

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General trace metal cycle

So this general metal cycle if you see the general metal cycle obviously due to the you know industrial process. You can see the heavy metals is moving this yellow shade is basically showing the heavy metals which are coming from different industrial process different. You know agricultural process fertilizer corrosion you can see and ultimately reaching different water body and also from mining industrial also okay.

So and also sediment is coming from different urban lands and different agriculture lands due to the runoff and ultimately reaching into the water body okay. So when it reaches into the water body there is biological transformation occurs in the heavy metals alright. And also these sediments gets settled in you know they basically get settle or further goes to the suspension. And these elements ultimately store in the stream bed as you can see here. Sometime these elements which are getting stored in the street bed will volatilized, so this is how these trace metals basically move you know in this soil water continent okay.

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So what are the different effects of the trace elements on plant and animals so this shows different list you know this shows the list of different trace elements and they are essential beneficial nature of the for plants and animals potential toxicity to the plants and animals and their several features. So for example let us talk about the elements silver. So, silver as no essential or beneficial they are not beneficial to the plants and animals.

However, they are toxic to animals so because they you know they basically interacts with copper and selenium. So if we talk about for example arsenic is not toxic to the plant however it is toxic to the animal and it shows the potential you know I am sorry it is essential it is not essential to the plant but it is essential to the animals. And also it produces potential toxicity for both plants and animals.

So it basically phytotoxic before animal toxic may be also carcinogenic it is long term accumulation of arsenic in our body shows different you know different types of cancers. Let us talk about cadmium is not useful for both plant and animal however they are showing the potential toxicity you know they are they show you know potential they are potentially toxic in nature as you can see here. So for both plants and animals they are narrow margin and they can

enrich in the food chain they are carcinogenic and producing itai-itai disease okay. So let us see another important toxic element like chromium.

Chromium is toxic to the plant okay similarly laid is very much toxic to the both plant and animals. And basically, aerial dispersion and primarily surface deposited cumulative poison okay so we can see the comments. So similarly mercury it is a highly toxic from the animals okay it enrich in the foods and aquatic accumulation and it produces the minamata disease. So you can see that trace elements produce huge amount of potential pollution for both plants and animals, and that is why they are very important to you know their discussion is very much important when you are talking about soil pollutants.

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Different trace elements:

- According to Adriano (1986), the potentially toxic micro-nutrients are Zn, Mn, Cu, Fe, Mo and B.
- · Others are As, Cr and Cd
- The radioactive trace elements are dangerous for the environment.
- · Radioactive elements generally reach the soil accidentally following an unsafe disposal
- Their behaviors are also similar to other non-radioactive elements.

Now different trace elements according to Adriano in 1986 the potentially toxic micro-nutrients as far as the micro-nutrients are concerned the potentially tonic toxic plant micronutrients are Zinc, Manganese, Copper, Iron, Molybdenum and Boron. And others are you know arsenic then chromium and cadmium. So the radioactive trace elements are dangerous for the environment okay.

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Effect of trace elements on plant and animals:

| Element | Essential or beneficial to | | Potential toxicity to | | Comments |
|---------|-------------------------------|----------|--|----------|---|
| | Plants | Animals | Plants | Animals | |
| Ag | No | No | | Yes | Interacts with Cu and Se |
| As | No | Yes | Yes | Yes | Phytotoxic before animal toxicity; may be carcinogenic |
| B | Yes | No | Yes | | Narrow margin, especially in plants |
| Ba | No | Possible | | | Insoluble; relatively nontoxic |
| Be | No | No | Yes | Yes | Speciation important; carcinogenic |
| Bi | No | No | Yes | Yes | Relatively nontoxic |
| Cd | No | No | Yes | Yes | Narrow margin; enriched in food chain; carcinogenic; itai-itai disease |
| Co | Yes | Yes | Yes | Yes | Relatively nontoxic; high enrichment factor; carcinogenic |
| Cr | No | Yes | Yes | | Speciation important; Cr4+ very toxic; otherwise relatively nontoxic; carcino- genic |
| Cu | Yes | Yes | Yes | | Easily complexed in soils; narrow margin for plants |
| F | No | Yes | Yes | | Accumulative toxicity for plants and animals |
| Hg | No | No | | Yes | Enriched in food chain; aquatic accumulation; minamata disease |
| Mn | Yes | Yes | <ph 5<="" td=""><td></td><td>Wide margin; toxic in acid soils; among the least toxic</td></ph> | | Wide margin; toxic in acid soils; among the least toxic |
| Mo | Yes | Yes | 1000 | 5-20 ppm | High enrichment in plants; narrow margin for animals |
| Ni | No | Yes | Yes | Yes | Very mobile in plants; relatively nontoxic; carcinogenic |
| Pb | No | No | Yes | Yes | Aerial dispersion and primarily surface deposited; cumulative poison |
| Sb | No | No | | Yes | Insoluble; relatively nontoxic |
| Sc | Yes | Yes | Yes | 4 ppm | Narrow margin for animals; interacts with other trace metals |
| Sn | No · | Yes | | Yes | Relatively nontoxic; very low uptake by plants |
| Ti | No | Possible | | | Insoluble; relatively nontoxic; possibly carcinogenic |
| TI | No | No | | Yes | Very mobile in plants |
| V | Yes | Yes | Yes | Yes | Narrow margin and highly toxic in animals; high enrichment factor; carcinogenia |
| W | No | No | | | Very mobile in plants; very rare and insoluble |
| Zn | Yes | Yes | | | Wide margin; easily complexed in soils; may be lacking in some diets; relative/ nontoxic |

We have seen some radioactive trace elements you can see here there is some radioactive trace elements like radioactive trace elements you know we can see here lead is a radioactive trace elements okay. So this is very potential toxic to the animal body so this radioactive trace elements dangerous for the element. Radioactive elements generally reach the soil accidently following an unsafe disposal and their behavior are also similar to other non- radioactive elements.

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So let us start with the arsenic now arsenic basically comes from group 5A of periodic table it has a atomic weight of 74.992. It has a common oxidation states are either 0, 3 and 5 however these arsenic 3 oxidation state is more toxic than arsenic 5 forms basically formed as bound

covalently with most metals and stable organic compounds and sources are soil materials. So it is naturally occurring one of the.

So this arsenic is basically still occurring however from the anthropogenic sources landfill waste, airborne emissions, also creates the arsenic okay.

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As in soil environment:

- In uncontaminated soils, the total As in general does not exceed 20 ppm and stays as insoluble compounds with AI, Fe, and Ca.
- The water-soluble fraction can reach about 6% of the total As in soils as sodium arsenite (As³⁺) (NaAsO₂).
- The reduced form of arsenite (III) is four to ten times more soluble in water than the oxidized state (V- arsenate).
- In a strongly reducing soil environment, elemental As and arsine gas (As³⁻) carexist.
- In an aerobic environment, arsenate (V) is stable.
- Arsenite (III) can be the predominant form under moderately reducing conditions created by flooding.

Arsenic environment in contaminated soil the total arsenic in general does not exceed 20 ppm and stays as insoluble compounds with aluminum, Iron and calcium and the water soluble fraction can reach about 6% of the total arsenic in soil as sodium arsenate As^{3+} so sodium arsenate. And the reduce form of arsenate that is arsenic 3 is 4 to 10 times more soluble in water than oxidized state that is arsenate.

In a strongly reducing soil environment element Arsenic and arsine gas can exist so arsine gas is a gas of arsenic in an aerobic environment obviously arsenate stable and Arsenate can be predominant form under moderately reduced conditions created by flooding. And this arsenate again I am telling this arsenate is more toxic than arsenate. So friends we have talked about some important trace elements we have talked about some important trace elements. We started discussing them with the arsenic and let us wrap up our lecture here.

And let us continue these and let us discuss the other important trace elements in details in our coming lecture. And also we will be seeing other important organic pollutants for soil and their

different ill effects or pollution ill effects in different soil physiochemical and biological properties thank you very much.

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