Air pollution and Control
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Lecture 40
Global and Regional Environment Issues: Acid Rain

Hello friends, so, far we have discussed about several global issues of environmental nature that is the pollution which causes environmental issues at the scale of global level like ozone hole or global warming, climate change, today we will discuss in that series the acid rain. And acid rain is basically reasonable environmental issue, but it is also can be termed as global environmental issue because of its, like continental nature or in different countries it is spreading. So, we can call it as a global regional environmental issue, which is very important.

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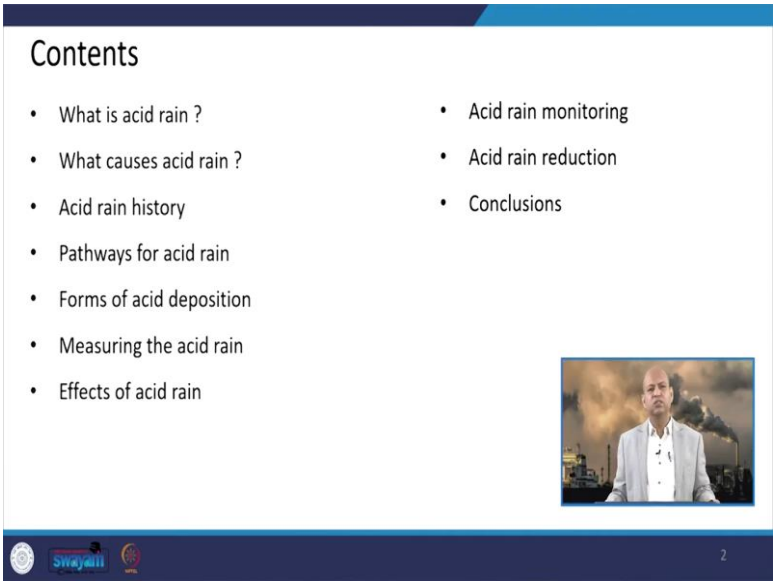

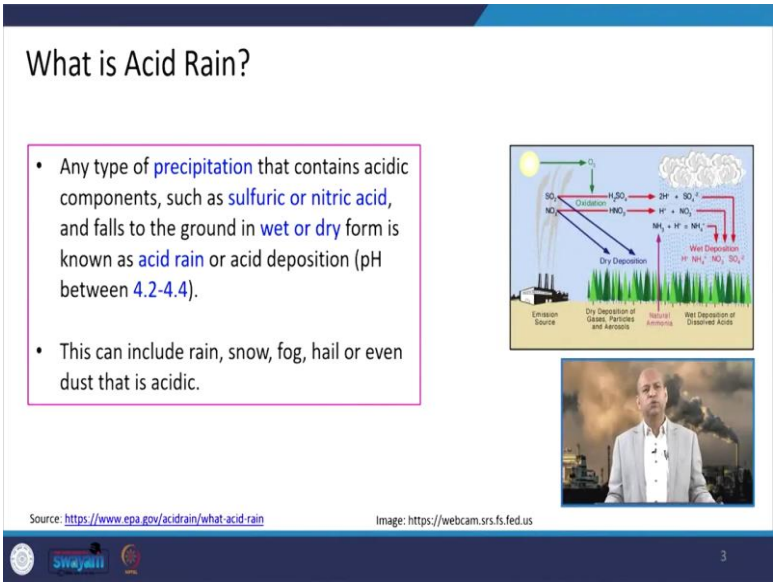

So, today we will discuss about what the acid rain is and what causes the acid rain then a little bit timeline of the acid rain history and pathways which are responsible for the acid rain. Then different forms of the acid rain like wet deposition, dry deposition, how to measure the acid rain and its effects and how do we monitor or different kind of monitoring networks which are responsible for monitoring the acid rain, so, that it can be known about types intensity and in which area it is more and how can we control it and then how to reduce the acid rain basically those kinds of measures we will discuss in our class we will conclude.

So, when we talk about what is the acid rain, so, you can imagine like raining and the pH of the rain, which is normally less than the 7 because of CO_2 present in the atmosphere and that weak as H_2CO_3, but if the pH of the rain is in the range of like 4.2-4.4 means less than the 5 then we can call it as acid rain because that signifies or it indicates that maybe some elements or some compounds or some chemicals like sulfuric acid or nitric acid which is because of presence of sulfur dioxide and NOx and when they react with the moisture of the atmosphere and ultimately create these acids.

So, those assets become part of the droplets. So, in the precipitation it comes down and pH of the rainwater changes. So, then wherever it meets like if it joins the water bodies or it falls on the surfaces, then the pH of the soil is also reduced. And it can come in several forms like not only the rain, but it can come down in the form of snow, in terms of the fog or haze or even dry deposition like particles which are of acidic coating those kinds of things, and they can come down and that is why this acid rain occurs this phenomena of acid rain.

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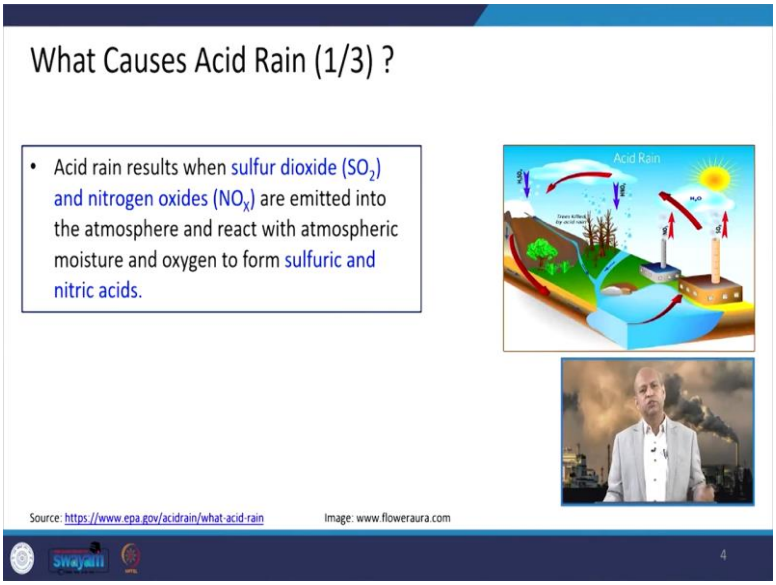

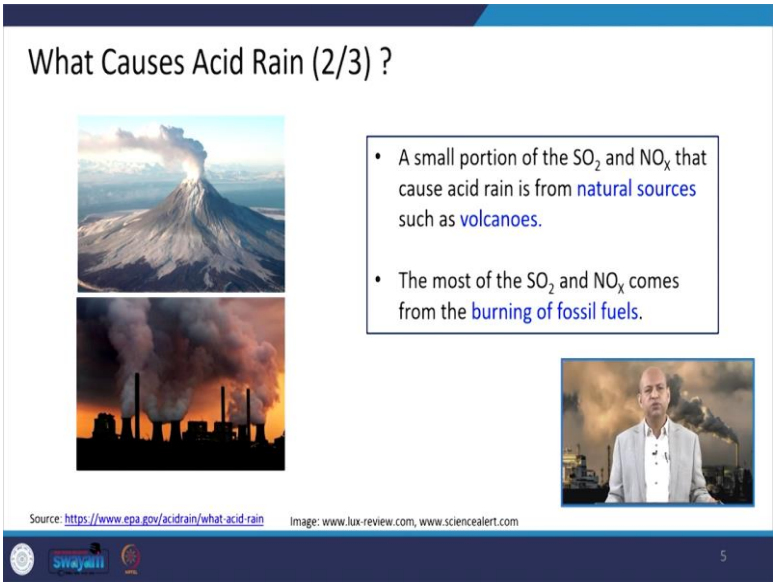

And the causes or the responsible reasons for this is basically those kind of emissions of the air pollutants like oxides of sulfur or oxides of nitrogen which are emitted in the atmosphere because of several anthropogenic activities, where we burn different kinds of fuels like the coal burning power plants, where coal content sulfur then sulfur goes like sulfur dioxide in the air unless we really capture it completely.

So, sometimes those captured instruments are not 100 percent that kind of efficiency and some sulfur oxide is there and several sources maybe they are not only the thermal power plants based on the coal, but several other sources can be there of the sulfur dioxide, the NOx emissions can come from several other sources like automobiles or wherever we are burning the fossil fuels.

So, those kinds of emissions which are responsible for these particular acidic gases, which comes into the air and then they react with the atmosphere, atmospheric moisture and create these sulfuric acid and nitric acid. Well a small portion of SO_2 and NO_x that causes acid rain is from natural sources also. And not only the small but quite large amount, comes out of volcanoes. Then most of the these emissions of sulfur dioxide and NO_x they come from fossil fuel, because of anthropogenic activities, wherever we are burning fuels, we are generating some sort of emissions of like oxides of nitrogen and oxides of sulfur.

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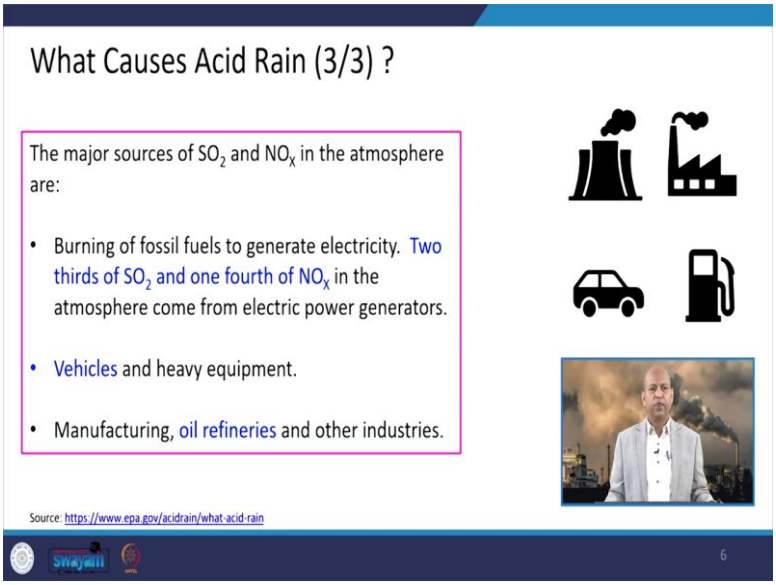

Well, these burning of fossil fuels, which we do in electricity generation. So, they are responsible like two thirds of SO_2 and one fourth of NO_x in the atmosphere it is estimated that they come from electric power generator facilities. Then vehicles and heavy equipment's also burn a lot of fuels and they are also responsible for such gaseous emissions, manufacturing oil refineries and other industries, they are also responsible for emissions of these gaseous components.

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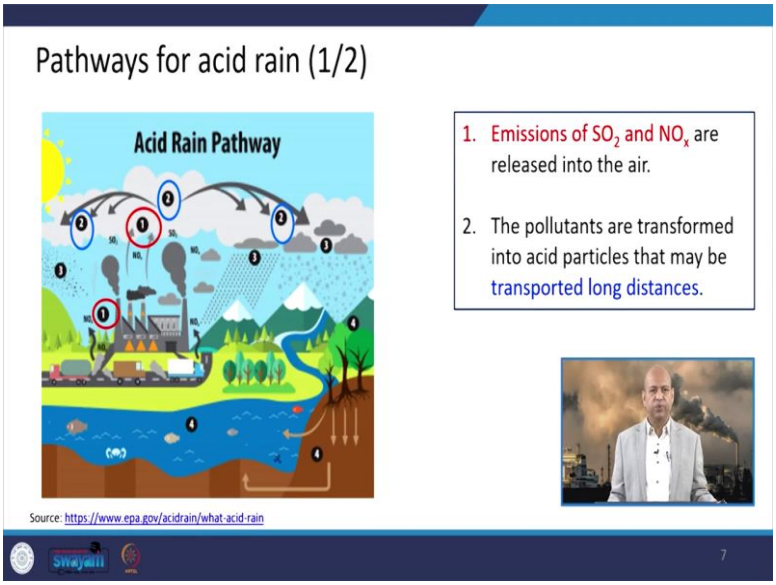

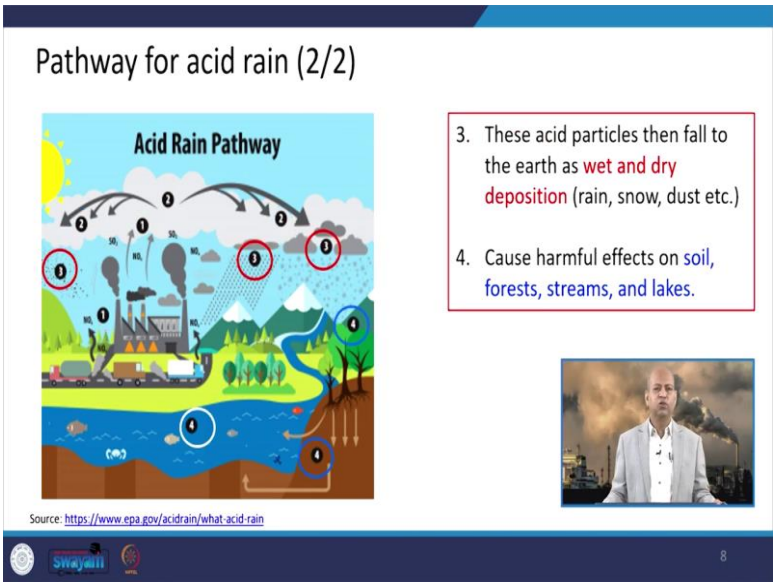

Well, when we talk about pathways for the acid rain basically when these emissions are released into that air like these the emissions of SO_x and NO_x etc, then they get converted into calcium sulfate or magnesium sulfate or nitrate or something. So, the gaseous components can be transformed into particulate nature or solid form. So, these particles can also be responsible for transporting from one place to another or these gases components can react with the moisture in the atmosphere.

So, all these phenomena is basically responsible for this generation of the acid rain and then it gets transported in the downwind direction and particles can get deposited as the dye deposition and other these sulfuric components or nitrate etc, they can get deposited as wet deposition also. So, both wet deposition and dry deposition of acidic components are responsible for the

acid rain and they can cause harmful effects or negative impacts on whatever surface they come in contact to like weather soil, weather forest or streams or lakes, because they change the pH of those particular ecosystems.

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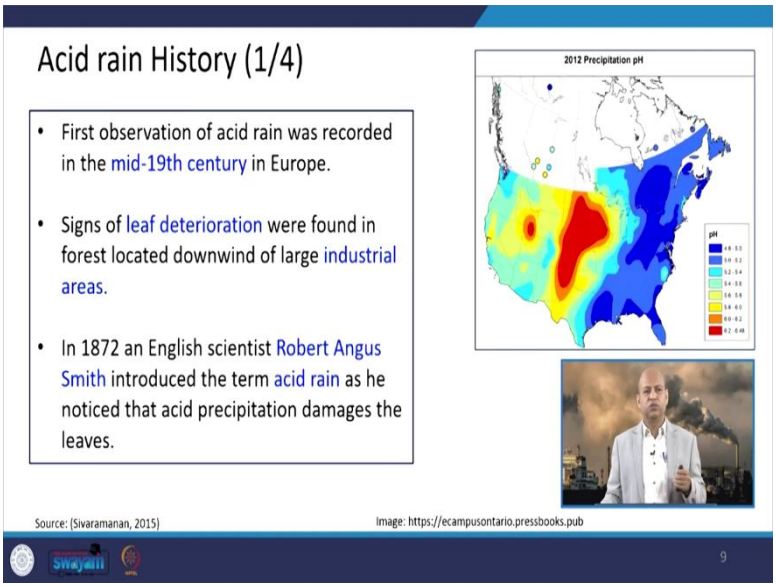

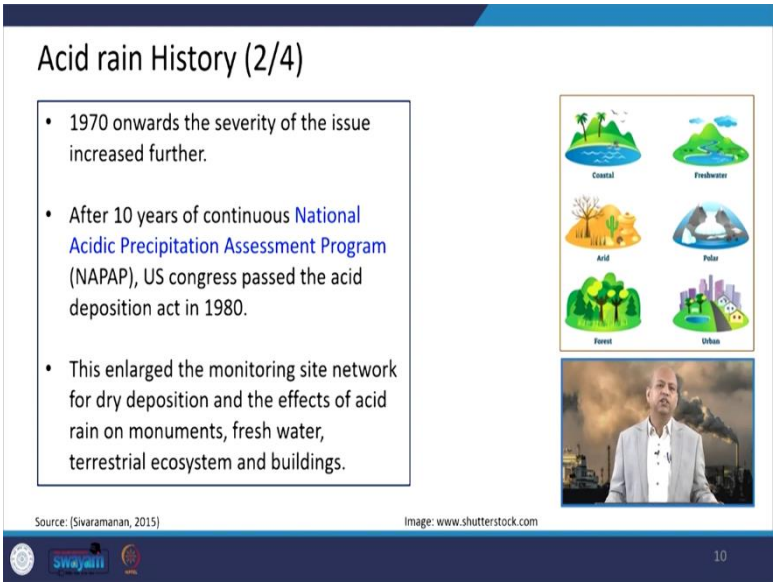

Now, if you talk about the history of acid rain, or the timeline when it was noticed and how it increased, so, a basically, the first observation of acid rain was recorded in the mid nineteenth century in Europe, because in Europe, a lot of these coal burning activities took place and the signs of this acid rain was noticed like deterioration of the leaves, they were noticed in the forest like black forest of Germany was completely devastated because of these acid rain which occurred because of emissions of sulfur and other oxides in England and it was later proved

and then treaty was signed between Germany and Great Britain that those emissions must be curtailed, so, that, these black forest deterioration because of acid rain can we stop.

So, those kind of relationships or historical events are there. In 1872, an English scientist, Robert Angus Smith, the he introduced this term of the acid rain, as he noticed this acid precipitation damages the leaves of the plants and the forest.

In 1970 onwards, the severity of the issue increased further because acid rain increased in several parts. And after 10 years of continuous national acidic precipitation assessment program of the US Congress, when US Congress, notice this as per basis of this program observation, so, the US Congress passed the acid deposition act in 1980.

And further, this was enlarged as a monitoring, site network for dry deposition, and the effects of acid rain on monuments or freshwater bodies, or terrestrial ecosystems and buildings. So, those were also covered, after this act was enacted.

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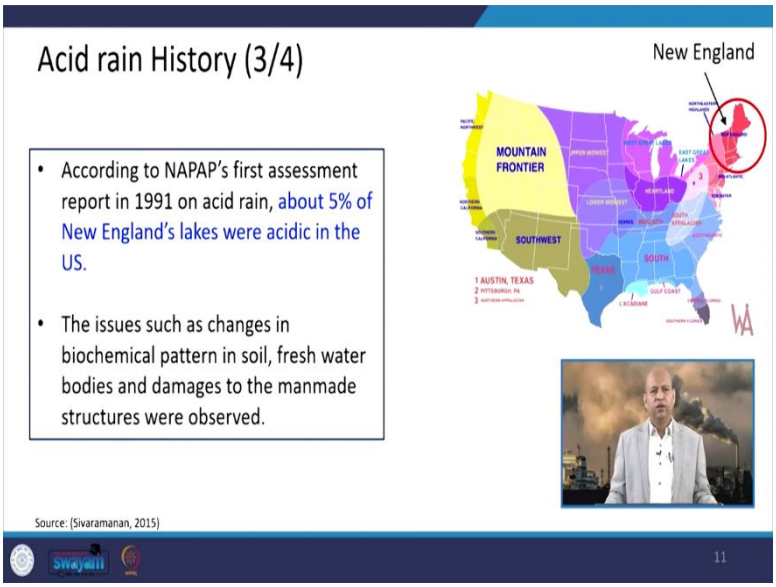

Well, when you look into further, down the timeline, then according to this particular program, the first assessment report published in 1991 on acid rain, and it was noticed that about 5 percent of New England's lakes were acidic in the US in that region of the New England in the US, and the issues such as changes in the biochemical patterns of the soil, characteristics or freshwater bodies and damages to the manmade structures were also observed, and they were associated with these acid rain precipitations.

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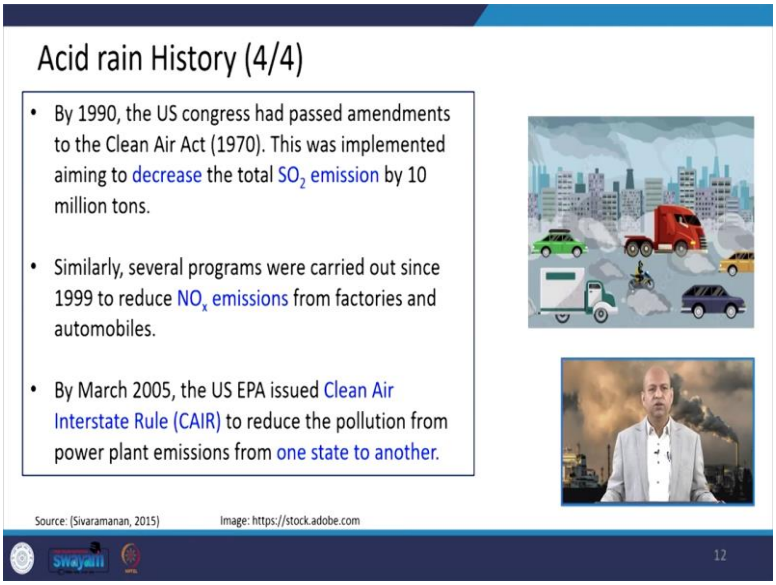

By 1990, the US Congress had passed amendments to the Clean Air Act of 1970. And this was implemented aiming to decrease the total emissions of sulfur dioxide by 10 million tons. So, those kind of vary big targets were aim to achieve. Similarly, several programs were carried out since 1990 to reduce NOx emissions also because not only the sulfur dioxide emissions, but NO_x emissions are also equally responsible for the acid rain. So, the emissions of the NO_x from factories and automobiles they were also targeted to get reduced.

By March 2005, the US EPA that is Environmental Protection Agency of the US issued Clean Air Inter State Rule (CAIR) to reduce the pollution from power plant emissions from one state to another. So, those kind of transboundary pollutions were tread and it was decided that how to control those emissions in other states which also affect the states in the downwind direction.

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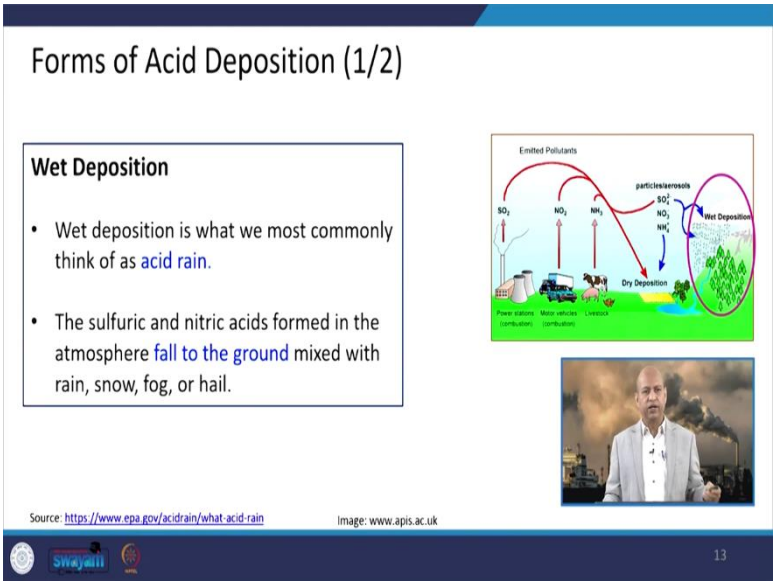

Well, when we talk about the forms of acid deposition in what way they get deposited, so, we briefly touch that wet deposition is there, dry deposition is there. So, if we talk about wet deposition basically it is commonly known as the acid rain basically that wet deposition is the acid rain because precipitation is coming and the pH of that acid rain is less than 5 it is around 4 or so, and that is the particular acid rain.

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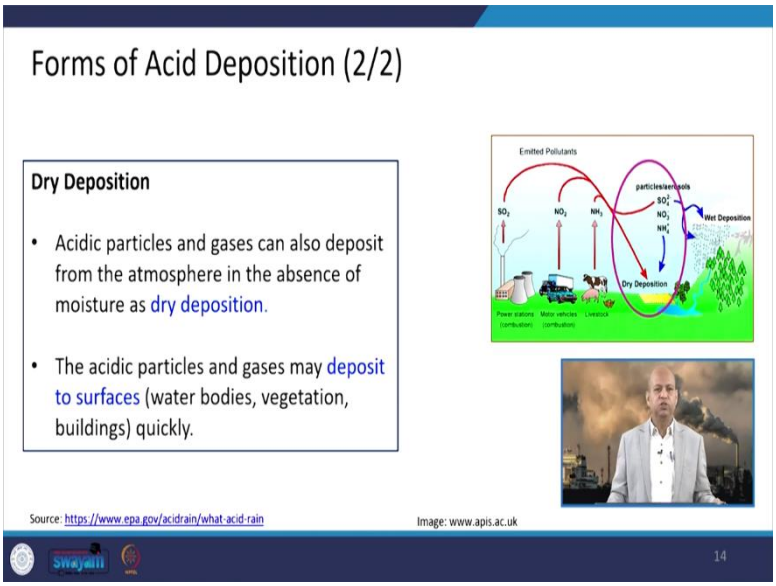

Dry deposition will also take place and there the that is because of acidic particles and then even gases also even if it is not reacting with the moisture and the gaseous component of the acidic nature and the particles of the acidic nature they get descend because of gravity and then this dry deposition process happens and they can get deposited on surfaces of water bodies or

vegetation or buildings and this becomes this phenomena becomes quite quick counterintuitive, sometimes we do not feel that this may happen, so, quickly but it happens in the nature quite quickly.

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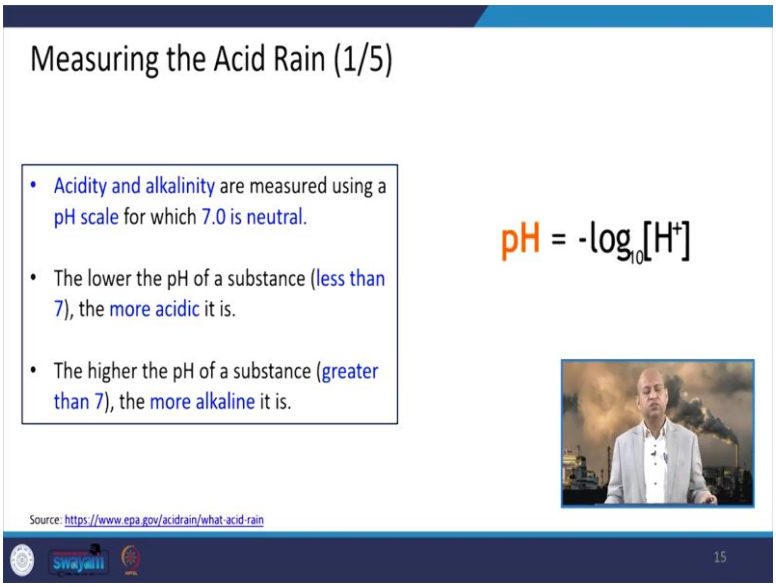

When we talk about like measuring of the acid rain. So, basically, the phenomena of pH is important, the pH of this at the log scale this H^+ ions concentration, how much it is present in the solution. So, that is the basic pH, pH is the indicator of that those H^+ Ions or hydrogen ions present in the solution.

So, the acidity and alkalinity are measured using this at the pH scale for which we assume that 7 is the neutral and the lower the pH of a substance less than 7 the more acidic it is known as and the higher the pH beyond the 7 like 8, 9 then we call it alkaline. So, those particularly definition of acidic and alkaline solutions are there.

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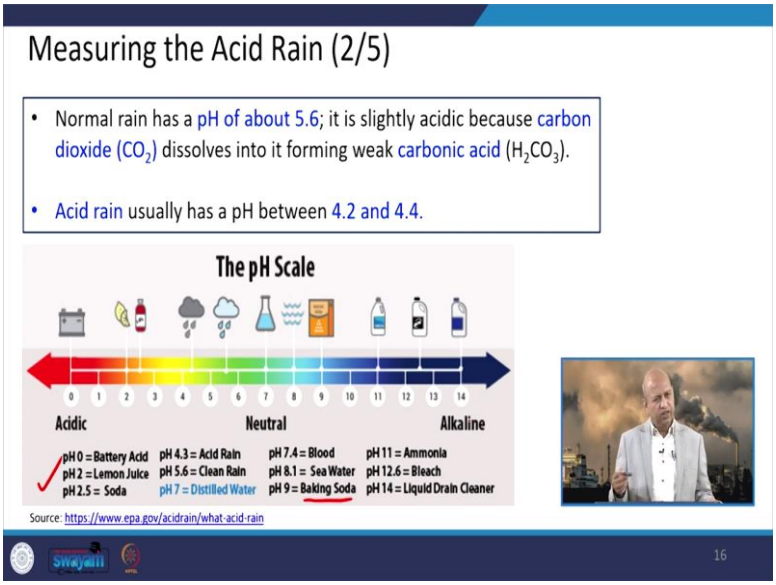

And the normal rain has a pH about 5.6 or so, it is not 7, the reason is because this slight acidic is due to this carbon dioxide which is present in the atmosphere and it dissolved into these moisture this rainwater forming weak carbonic acid H_2CO_3. And the acid rain usually has a pH, between 4.2 to 4.4.

So, means up to 5.6 you cannot say that this is acid rain or so, this is natural rain. But if less than 5 the pH is there, then you should be alert that there may be some sources of acidic nature of gaseous components, which have reduced the pH of the rainwater and that is because of the presence of like sulfur dioxide, NO_x etc.

So, the pH scale basically, it has been shown for all kinds of things like battery, acid; pH = 0, lemon juice; pH = 2, soda; pH = 2.5, acid rain; pH= 4.3 or so, distilled water; pH = 7, because neutral, then blood; pH = 7.4 or so, seawater has pH = 8.1 very alkaline saline water, then this baking soda; pH =9, ammonia; pH =11, bleaching powder; pH =12.6. Liquid drain cleaner; pH = 14. So, different solutions have different kinds of pH according to the nature.

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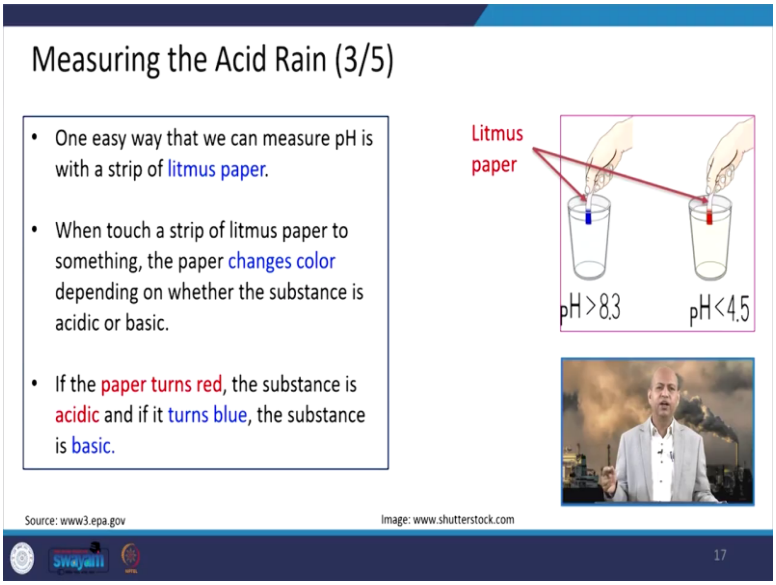

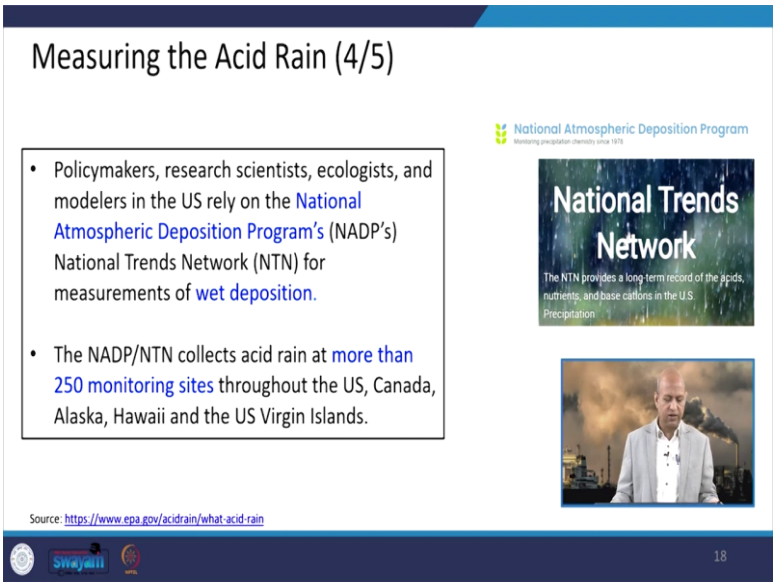

Well, the very easy way to kind of look at that whether this pH is lower than 7 or higher than 7 Litmus test is there Litmus, that is basic thing which you might have seen in the chemistry lab. When this paper turns to the red, the substance is acidic as we know, because it tends changes the color and when it turns blue, then the substances basic like if it is pH is less than 4 then it turns to the red and when pH is more than 8.3 then it can transcend to the blue, those kinds of things are there.

So, this National Atmospheric Deposition Program was launched and national trends network was established for measurement of wet deposition in the US and nearby areas. So, this was basically conglomeration of more than 250 monitoring sites throughout the US, Canada,

Alaska, Hawaii and US Virgin Islands. So, very large area was covered to monitor these whether acid rain is occurring or not.

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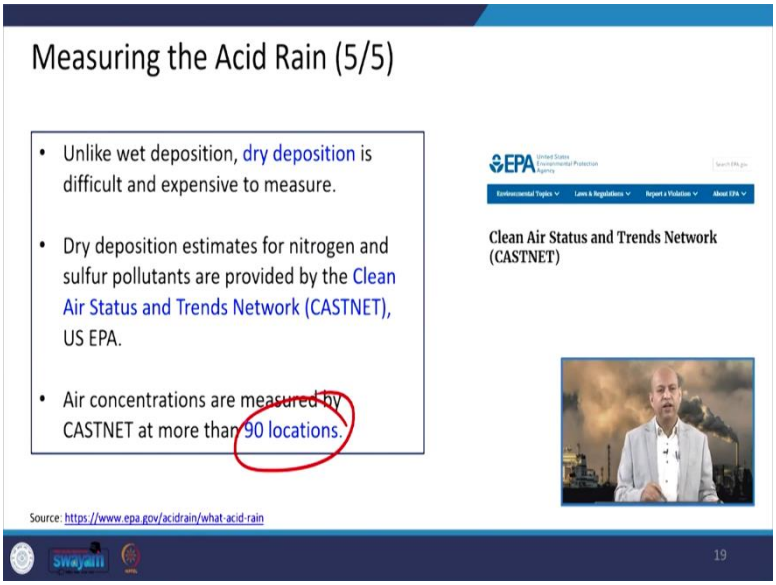

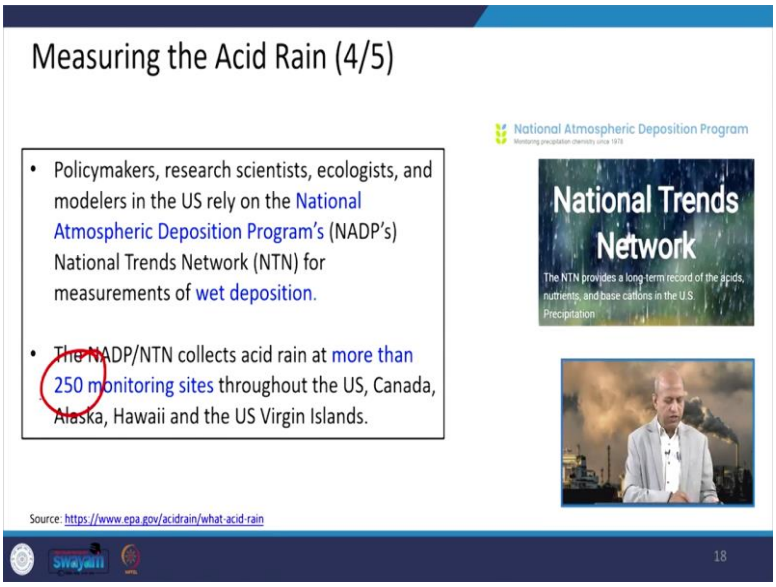

So, unlike this wet deposition, if we talk about that dry deposition, then dry deposition is difficult and expensive to measure because acid rain pH you can easily measure but dry deposition measurement is more expensive, but still there are programs like to estimate the nitrogen and sulfur pollutants in terms of dry deposition through clean air status trends network. And this air concentrations are measured by this particular program at more than 90 locations. Because it is expensive. So, the number of locations is much smaller than the number of locations like it is around 250 networking sites, here only 90 locations.

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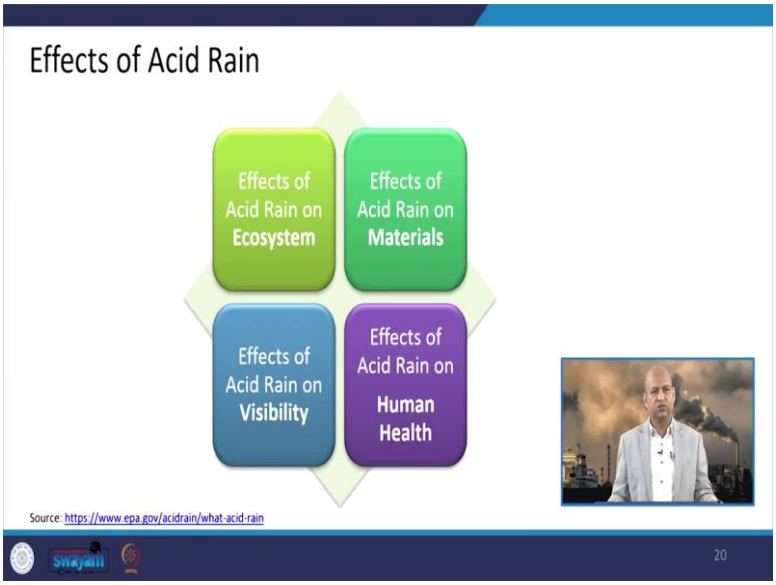

Now, if you talk about the effects of acid rain, then basically the effect can be on the ecosystem, effects can be on the materials, when it come into contact with the materials, effects can be on the visibility also, and effects can be on the human health or animal health.

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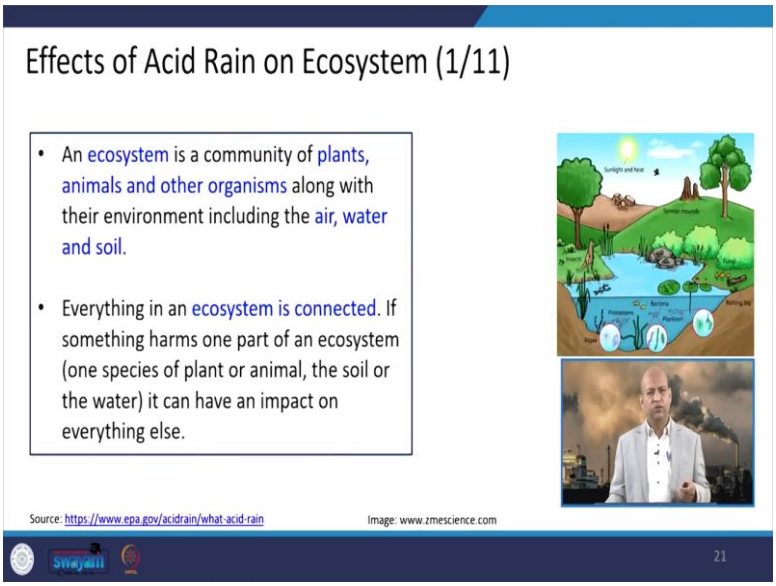

So, we will see one by one, like, if you talk about the ecosystem, then this ecosystem is nothing but the community of plants, animals and other organisms along with their environment including air, water and soil. So, a particular integrated kind of thing is there, so, everything is in ecosystem, well connected with each other. If something happens to one part, if it is harmed, then the other parts can get affected negatively, because they are interdependent, like one like

in the food chain, if one animal or plant is destroyed, then the whole chain can be completely disturbed. So, that is the characteristic of ecosystem.

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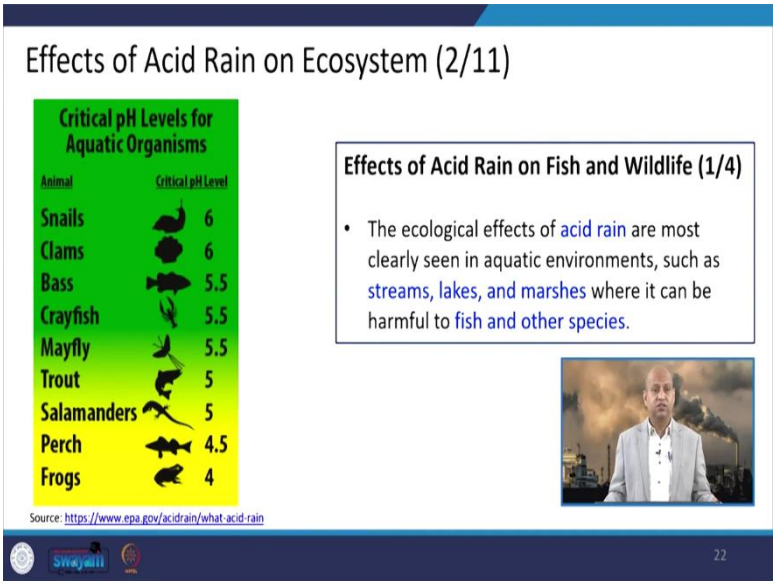

So, when we talk about the effects of acid rain, on fish and wildlife, different kinds of fish has tolerance limits to different levels of pH. So, the ecological effects of the acid rain are most clearly seen in the aquatic environment such as streams, lakes, and marshes, where it can be harmful to the fish and other species like the frogs up to 4, this critical pH levels, after that, it is very negatively affecting those particular species.

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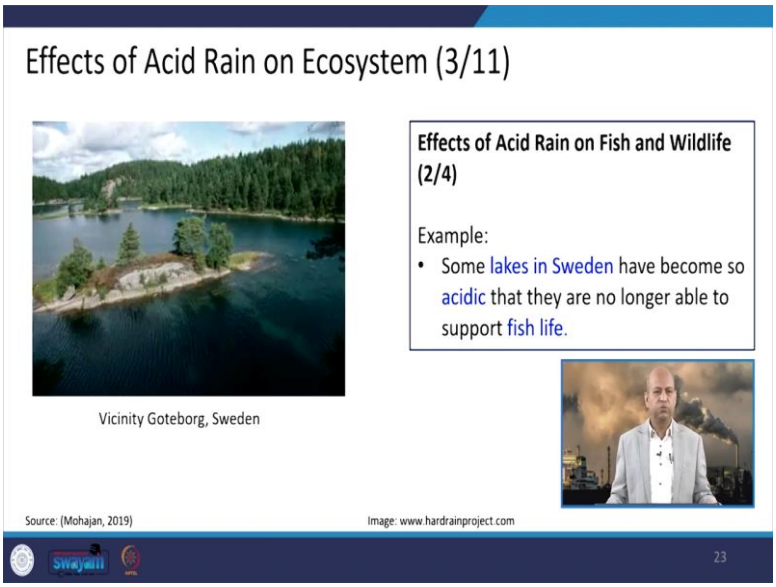

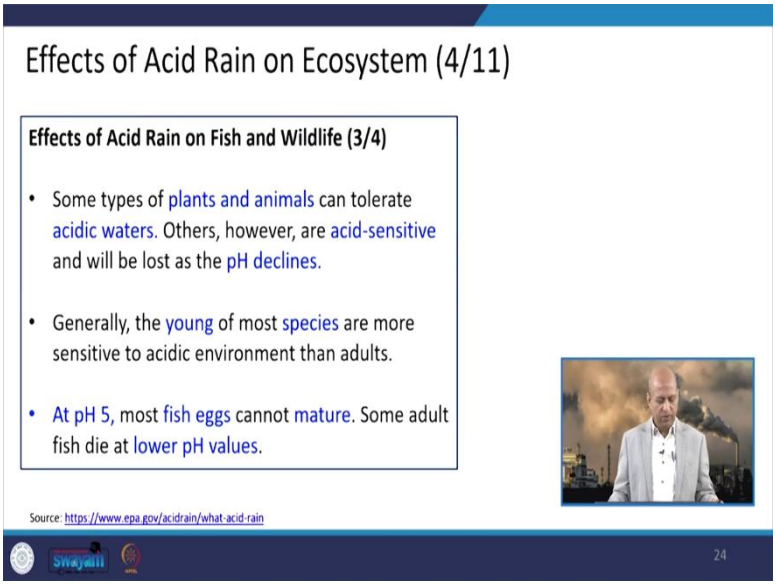

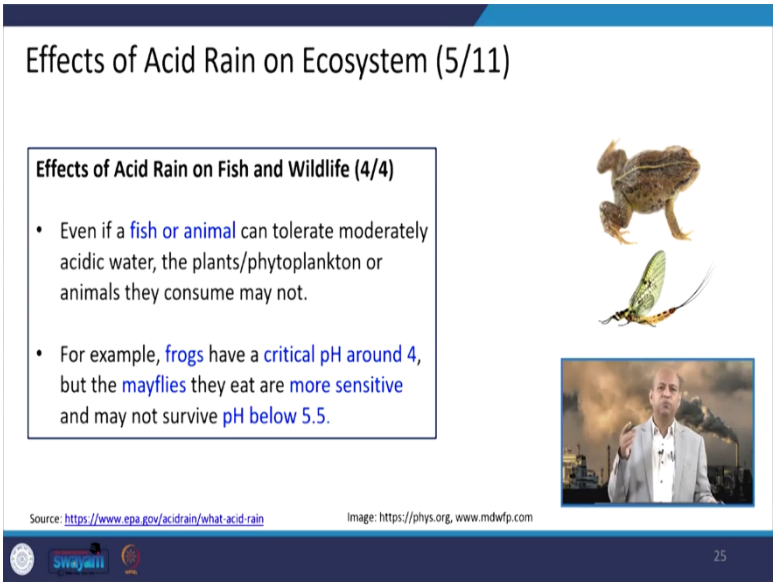

When we talk about like some lakes because of this acidic nature aquatic life get disturbed, like there is one example of one Lake in Sweden and it is quite acidic and no longer able to support the fish life. So, aquatic life is completely disturbed, because of this acidic nature of the water due to this acid rain. Well, some types of plants and animals can tolerate acidic waters, but others may not because acid sensitive it may be different. So, they can get lost because of these pH declination is there in the environment. And then they can disturb the complete ecosystem.

Generally the young and most species of the most species are more sensitive to acidic environments than adults because they are this tolerance limit is very, very low at pH = 5 most fish eggs cannot mature. Some adult fish die at lower pH values. So, this is kind of drastic negative impact on the aquatic life particularly fish.

When we talk about like fish or animal which can tolerate moderately acidic water, the plants or phytoplankton bones, like fish dependent on they can be damaged or their losses can be in huge quantity and then they can indirectly affect the fish population because then there is no availability of the food.

Similarly, in Animal Kingdom also, if the lower level animals which are not very tolerant to the acidic environment, if they are lost then the complete chain get disturbed and the higher in the ladder food chain, a higher level of animals may get also affected. For example, frogs have a critical pH around 4 but these mayflies they eat are more sensitive and may not survive at the pH below 5.5. So, those flies are not available, then frogs may also die even if the pH is not up to the 4.

So, at 5 if it is food is not available then frogs will also be dying. Well these on the plants and trees, the negative impacts are there because of region they can destroy these leaves and photosynthesis is completely deteriorated and even there is this disturbance of the minerals in the soil. So, the growth rate is disturbed of the plants and trees. So, that is again negative impact of the acid rain.

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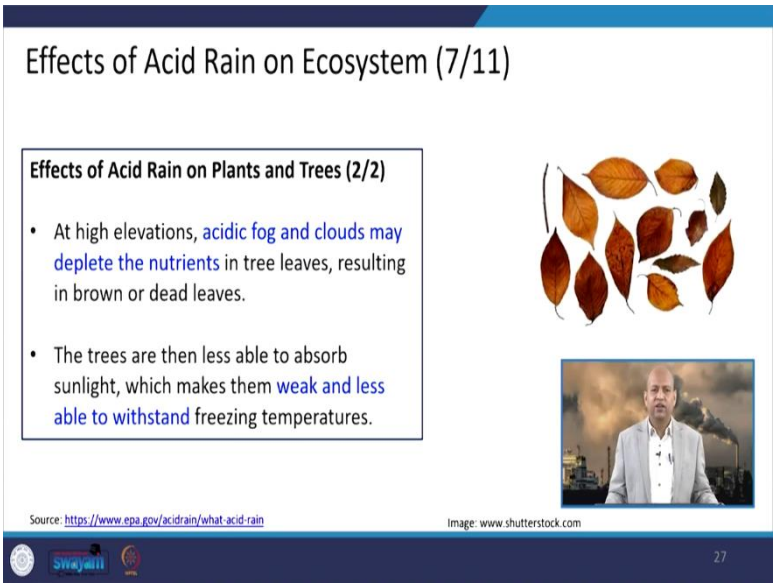

And at high elevations like in mountains etc. these acidic fog and clouds may deplete the nutrients in the tree leaves resulting in brown or dead leaves and because of that, this photosynthesis is completely disturbed, because they absorb very less amount of sunlight when there is no green cover and there is no sufficient amount of the leaves.

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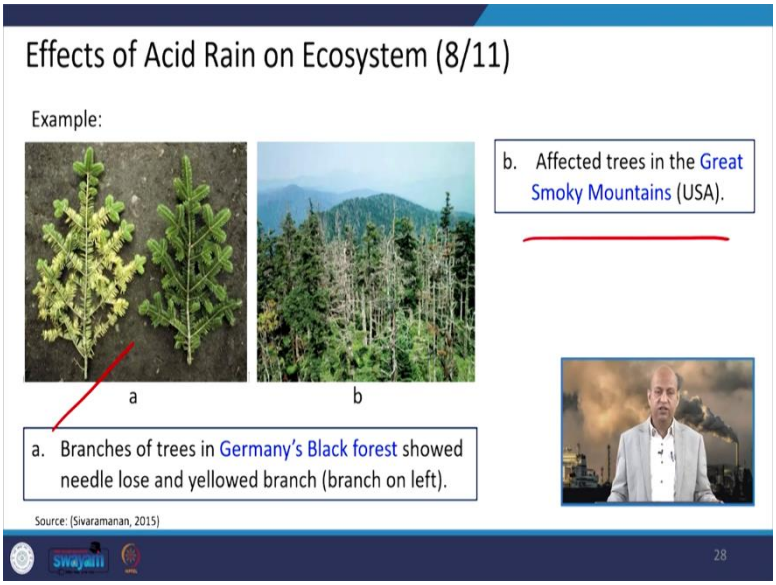

Like in Black Forest in Germany, this kind of negative impact was there this green color was destroyed. So, food products and buy these leaves was completely harmed disturbed, and in this Smoky Mountains, Great Smoky Mountains USA, these trees were affected because of acid rain, so, their lives were destroyed and again the photosynthesis was completely disturbed.

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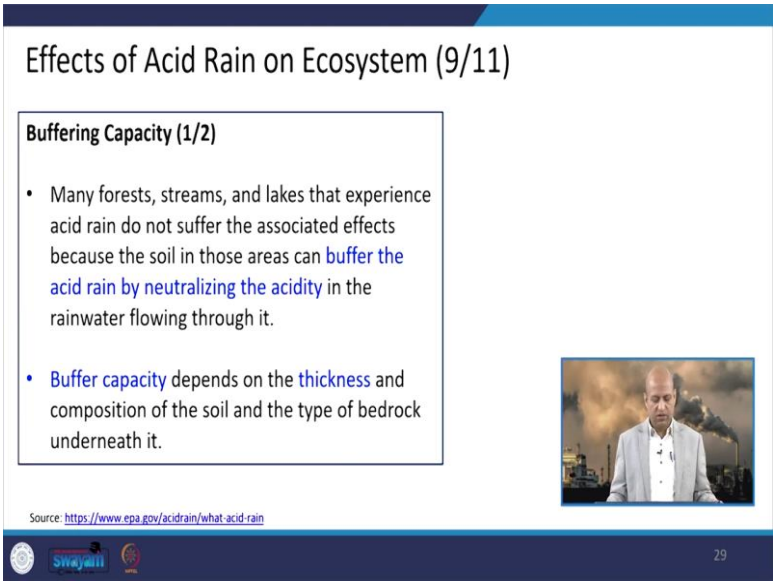

Well, but there may be some other issues like buffering capacity of different soils are different because of their thickness because of certain minerals available in those soils. So, if buffering capacity is there, then sometimes that negative effect on the plants may not be translated in that form, because that soil can do buffering kind of activity that means they absorb that acid and they that negative impact is not translated to the plants etc.

But it depends upon the quality of the soil and the different minerals or inorganic materials etc. or calcium carbonate etc. present in the soil, which can neutralize the acid rain. So, those kinds of buffering capacity may be available.

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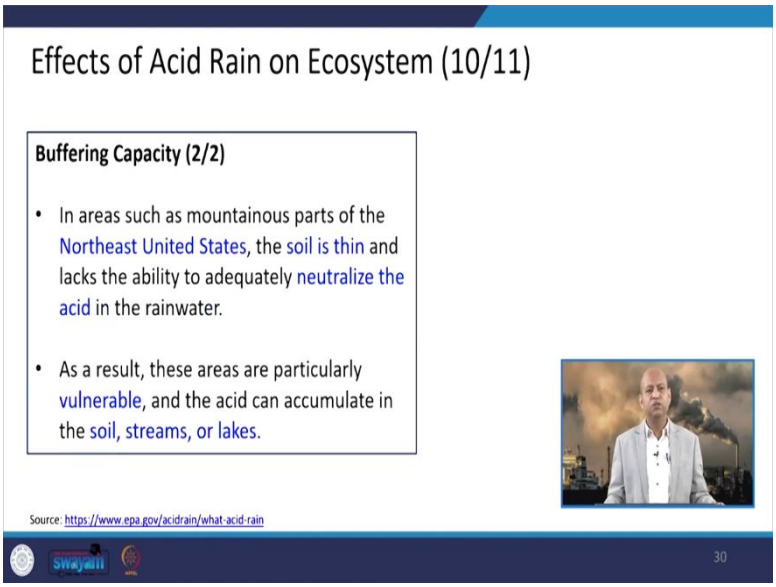

But it depends upon the location like in areas such as mountainous parts of the Northeast United States, the soil is thin, and this lacks the ability to adequately neutralize the acid and rainwater. So, negative impact is more there. So, as a result, these areas are particularly vulnerable and the acid rain accumulate in the soil streams and lakes in those particular areas.

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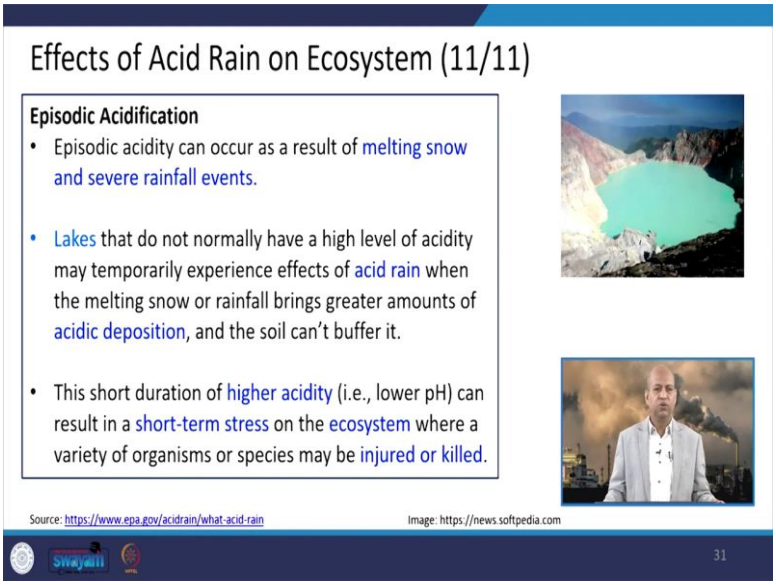

When, at some times this episodic acidification may also occur, because, like snow melts and suddenly, it takes with it a lot of acidic water to particular lakes, and then the pH drastically reduces for some small period, but that small period may be quite disturbing for aquatic life in those particular ecosystems. So, episodic acidification may also occur and then again other rainwater neutralize this acidic component and then again life thrives, but that particular disturbing period may be quite problematic for aquatic life.

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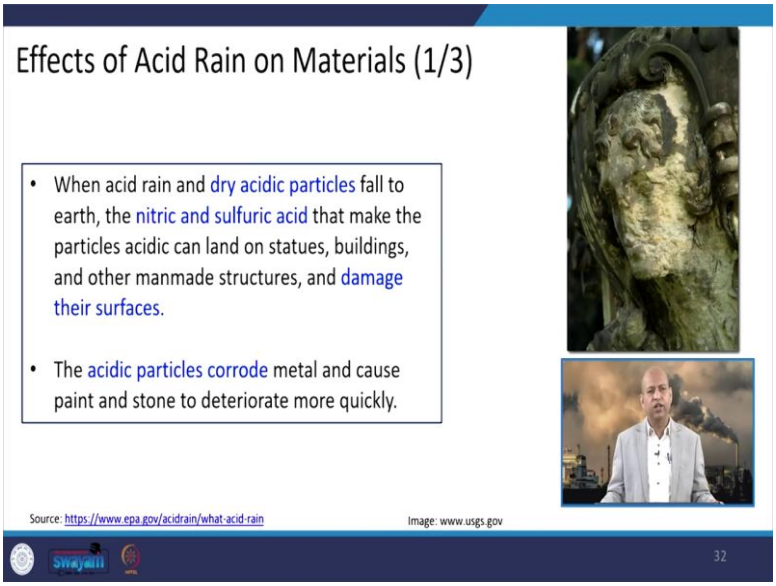

When we talk about the impacts of acid rain on materials, then you may visualize about different monuments, which are deteriorated whose surfaces are deteriorated by these acid rain particles and acid rain itself like sulfuric acid etc. Because the statues or the building materials

of the stone and they can get affected very severely. These acidic particles may corrode the metals or they can cause paint and the stones to deteriorate more quickly because of their chemical reactions.

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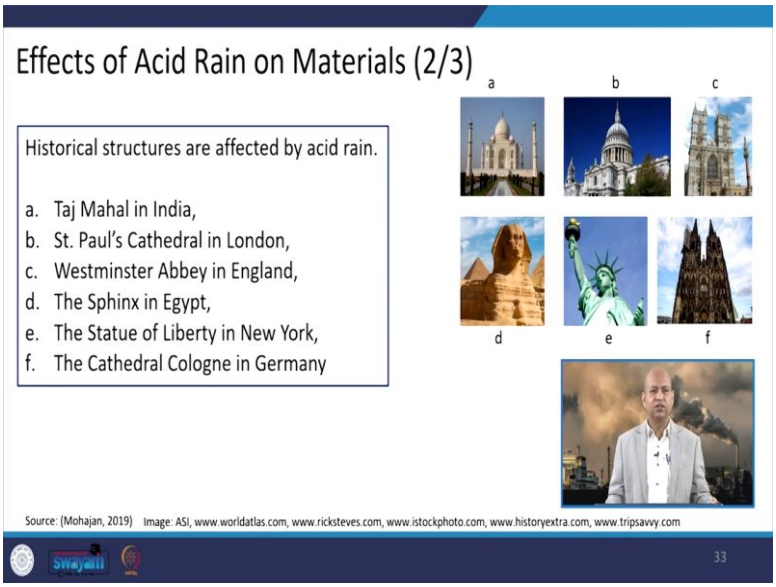

So, like if you talk about whether Taj Mahal in India or St. Paul's Cathedral in London or this Westminster Abbey in England and the Sphinx in Egypt or the Statue of Liberty in the New York or the Cathedral in Cologne in Germany, all those their surfaces got deteriorated because of the acidic component in the air and in the rain water. So, that this is a global issue, otherwise it is local and regional issue the acid rain. But in that way, it is kind of global issue nowadays.

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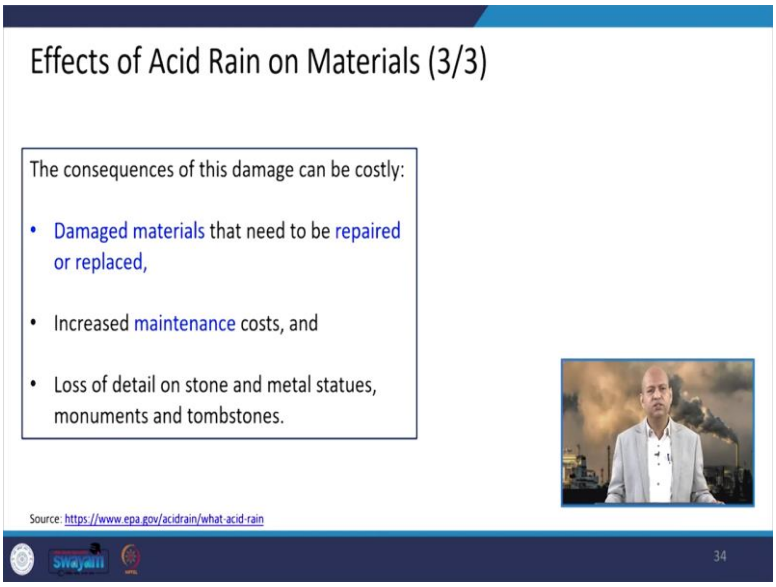

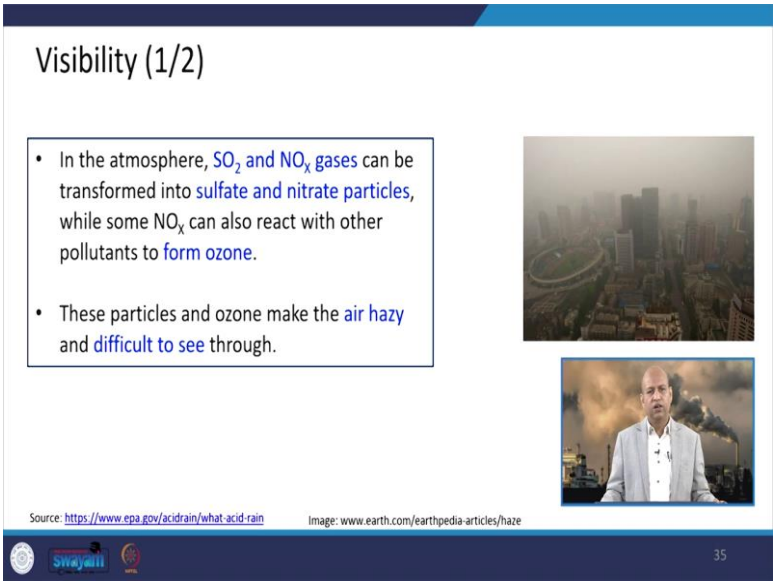

The consequences of this damages can be costly because then we have to repair them or are replaced them and sometimes these monumental, they are kind of very precious because it is very difficult to recreate them. So, not only the maintenance related but their value that historical value or their cultural value, we cannot convert into any monetary terms and that loss maybe for whole time and it is not affordable.

So, we should be careful that in those areas we should stop these kind of phenomena which is known as acid rain so, that whatever emissions which are affecting precipitation in those areas, they must be curtailed particularly the emissions of SO_x, NO_x etc. Well, in terms of visibility also there is, there are issues because, these particles like sulfate etc., they are reflecting a light and sometimes NO_x emissions, they also play as a precursor role to produce the ozone and smog is created in those areas.

So, visibility is reduced very significantly and those hazy and difficult to see kind of days are there because of these particles and because of smog, and again these acidic components in the air they participate in these kind of visibility problem.

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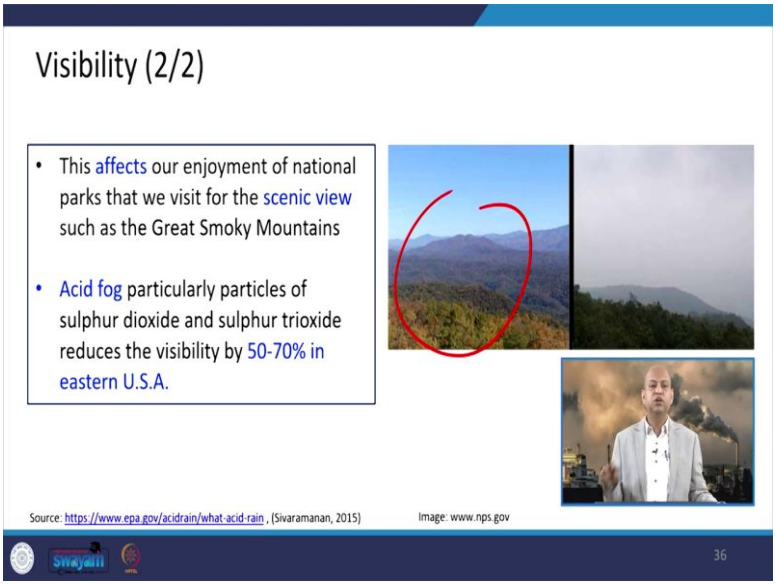

Like this can affect even those enjoyment of national parks that we visit for the scenic beauty otherwise, they are clear then it is beautiful, if it is hazy that we cannot see the beauty that aesthetic value of those particular locations may be deteriorated. And the acid for particularly particles of sulfur dioxide and sulfuric trioxide which reduces visibility around 50 to 70 percent in Eastern USA, it has been observed.

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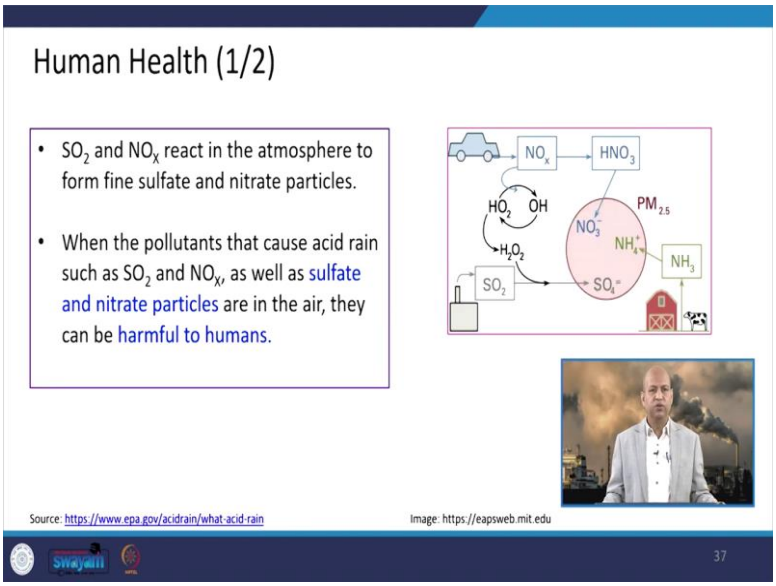

Well then when we come to this human health aspect, then again because of these toxicity, nature of sulfur dioxide and NOx etc, because when we inhale they damaging our respiratory system and those particles, those secondary aerosols etc, because of these sulfate and nitrate particles, they are again part of these respiratory related issues.

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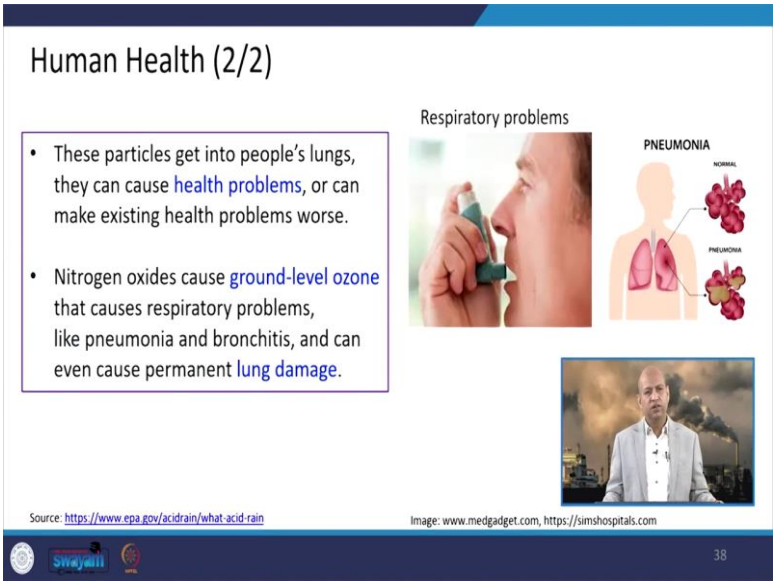

So, those people who are having health issues like lung related problems, bronchitis related issues, if those particles are present in the air, then they can further aggravate those kind of problems, they can damage in even the lungs, etc. So, those are the health issues.

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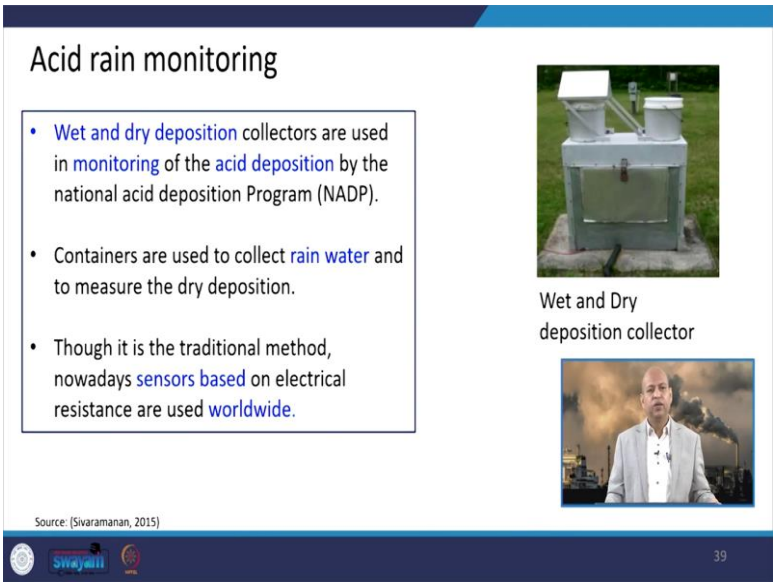

Now, if you talk about that, how to monitor the acid rain, so, like, there may be containers which can get these acid rain water, rainwater which the pH of which we can observe in the laboratory similarly, there may be other container which can get these dust particles the dry particle deposited that way we can really know how much acidity is present in that rainwater.

But nowadays, these are the traditional way but they are now sensor based electrical resistance, which are used worldwide nowadays, which can give the quick results basically.

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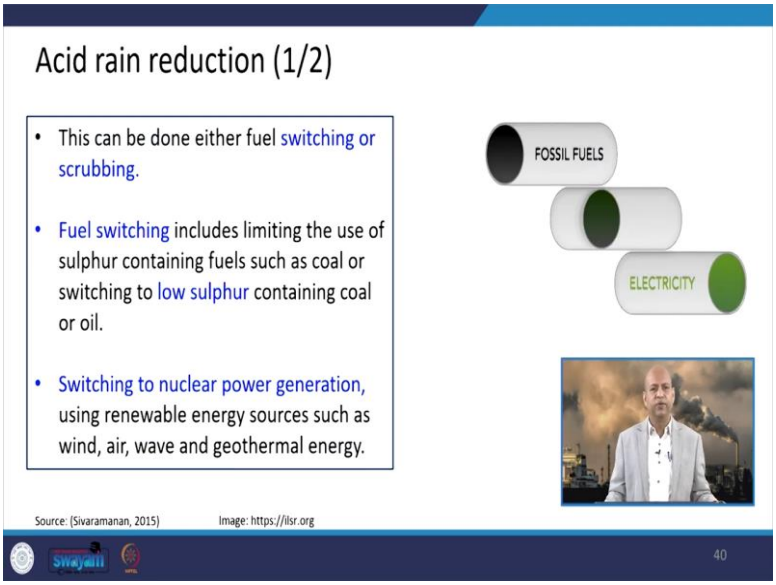

And if you want to reduce the acid rain, then naturally we have to cut the burning of the fossil fuel or we have to switch the fuel or we have to scrub that means, we have to control those emissions of SO_x and NO_x kind of gaseous exhaust gases. Otherwise, if they go into that atmosphere then they will result into the acid rain. So, there will be two broad categories of solution like either switch the fuel which are not emitting sulfur dioxide, NO_x etc or if they are emitting then control them, scrubbed them, remove them.

So, the fuel switching includes like limiting the use of sulfur containing fossil fuels for example, coal kind of things. And then switching to nuclear power generation or using renewable energy sources like wind, solar, air, geothermal energy, they really help us because they are not emitting any kind of these emissions which caused the acid rain.

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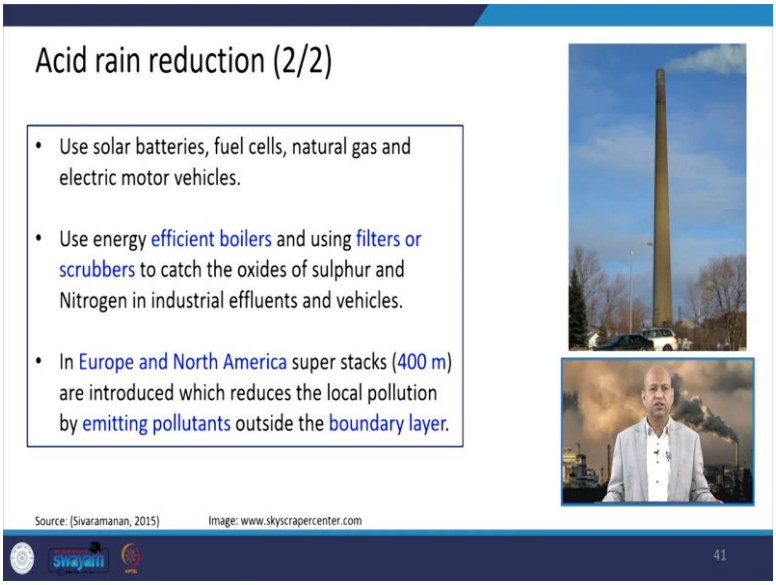

Then the use of solar batteries, fuel cells, natural gas, in electric motor vehicles promotion, all these are in that direction to remove or to reduce the emissions of SO_x and NO_x. Huge energy, efficient boilers and using those filters which can scrub or catch those sulfur and nitrogen related effluents from the vehicles or industrial emissions, they are part of that reduction of the emissions of NO_x and SO_x

In Europe and North America people are also using very tall stacks like 400 meter or so, so that the local pollution get reduced completely because it goes up to very high levels of the boundary layer and when it get diluted in the atmosphere, then at least in the local region, it is not there. But it is kind of transferring the problem from local to regional scale because ultimately it will come down whether in the form of rainwater or dry deposition.

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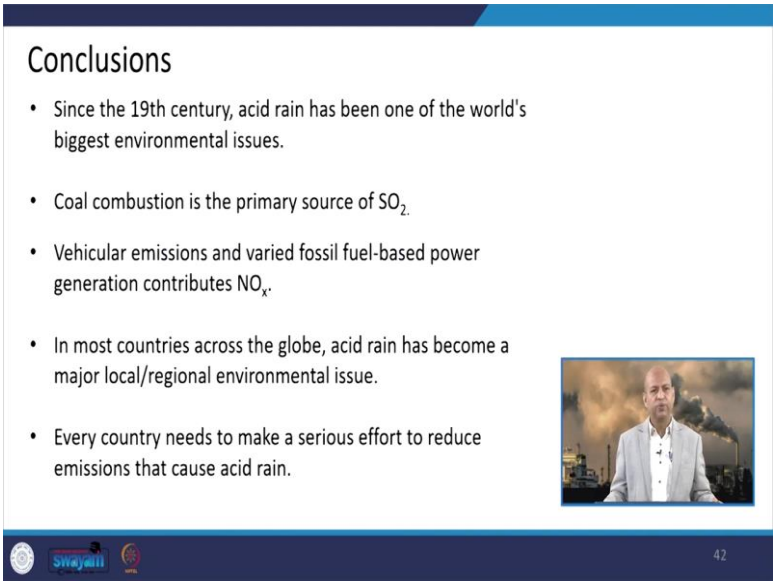

Well, so, in conclusion, we can say that, because of these fossil fuel burning and increase in the emissions of SO_x and NO_x, this acid rain phenomena occurred since the nineteenth century and it is increasing day by day and the coal combustion is the primary source of sulfur dioxide. So, we need to reduce this coal combustion and shift our energy needs to other sources of renewable nature.

Vehicular emissions and varied fossil fuel based power generation, they contribute NO_x emissions. So, if we go for those kind of energy sources like electric vehicles, etc in terms of reduction of vehicle emissions that is also a good strategy. In most countries across the globe, now, acid rain has become a major local or regional scale environmental issue. So, every country needs to make sincere efforts to reduce the emissions of SO_x and NO_x kind of emissions, which are responsible for acid rain.

So, the acid rain can be reduced if we can control the emissions of those cause factors like SO_x and NO_x that is the basic thing in this particular lecture. So, you have seen in this lecture that what are the causes of the acid rain and how can we deal with it. So, I hope you liked this lecture in that term, and this is not only the local problem, but the regional scale problem and the global network also because in most of the countries, some sort of the monuments are getting affected by acid rain. So, this is in that sense it is also the global issue. So, this is all for today.

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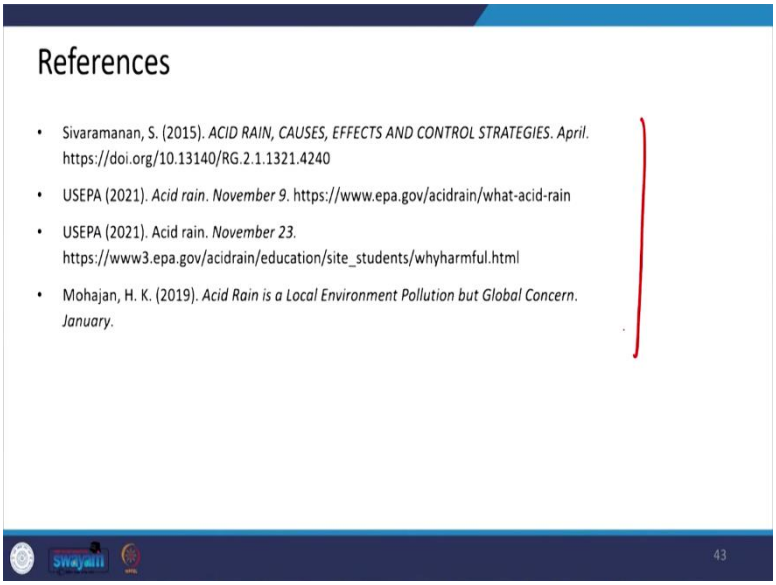

These are the references for additional information for you, you can go through in the free time through these references. So, thanks to you and see you in the next lecture. Thanks for your kind attention. Thanks a lot.