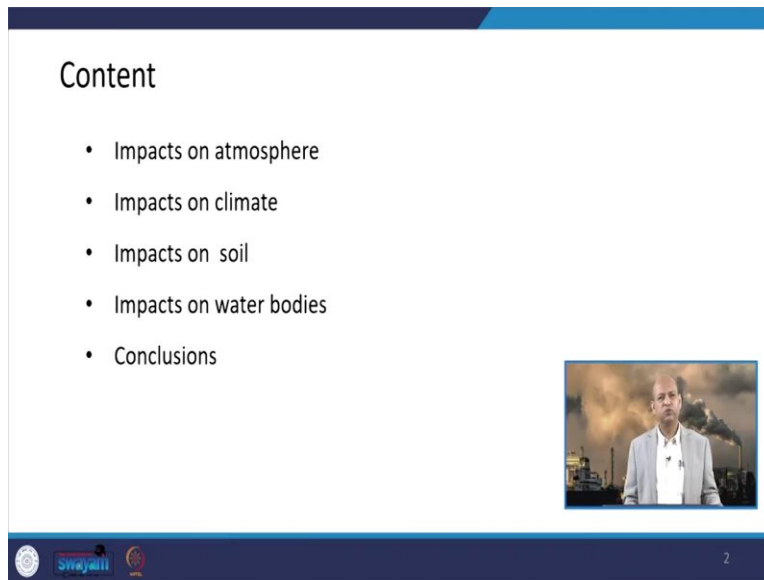


Air Pollution and Control
Professor Bhola Ram Gurjar
Department of Civil Engineering
Indian Institute of Technology, Roorkee
Lecture 06
Impact of Pollution on Atmosphere, Soil and Water Bodies


Hello, friends, today we will discuss impact of air pollution on atmosphere soil and water bodies.




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Content

- Impacts on atmosphere
- Impacts on climate
- Impacts on soil
- Impacts on water bodies
- Conclusions



   2

So this would be the content list of today's lecture, like impacts on atmosphere and when we are talking about impacts on the atmosphere basically we would also talk about impacts on climate because atmosphere and climate is interrelated through global warming effect induced by greenhouse gases and other issues of air pollutants.



Then we will also see impacts on soil because dry deposition or wet deposition through this process. Acidic pollutants interact with soil and they have negative impacts. Then we will talk about impacts on water bodies. Again, pollutants of different nature, basically the acidic content which can change the pH of water bodies, and on soil basically not only pH but those heavy metals also can take a toll on the soil quality. So that way we

will see the complete impact of air pollution on atmosphere, then soil, and water and climate.

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Impacts on atmosphere

- Air pollution in the form of Greenhouse Gases, e.g., CO₂ and CH₄, raises the temperature of earth/atmosphere.
- Air pollutants affect the albedo of the earth surface.
- Air pollutants such as CO₂, SO₂ and NO_x are main causes of the acidic rainfall.
- Visibility is also affected by the air pollution in the atmosphere.



Sources: Singh et al., 2017, www.britannica.com, 13 Oct 2021 Image: www.mindler.com

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Well when we talk about impacts on the atmosphere, so the largest impact on atmosphere through greenhouse gases, frequently say that greenhouse gases strictly not air pollutants but there are air pollutants also which are also having greenhouse gas impact. So that is why clubbing with carbon dioxide sometimes we also talk about greenhouse gases as part of air pollutants, like methane. So this is a pollutant as well as it has greenhouse gas impact, or ozone which is also pollutant also has greenhouse gas impact.

So this greenhouse gas impact of these pollutants like methane or ozone along with the carbon dioxide, they have this global warming impact because they avoids, or it does not allow the wavelength, the longer wavelength radiation to go out from the earth's surface because as you know the short wave radiation comes to the earth surface and it is absorbed by earth's, and then when earth radiates back the long wave radiation or infrared radiation.

So if these greenhouse gases are there, they capture it. They capture it. And because of capturing this temperature rises of the atmosphere, and of entire earth's surface. Then air

pollutants influences the albedo of the earth's surface. Albedo, we will see, like reflectivity, because of air pollutants the reflectivity also gets changed.


Air pollutants like sulphur dioxide or NO_x and of course, CO_2 is always there in the atmosphere, they also cause certain impacts which is known as acidic rainfall. So acid rain is contributed by NO_2 or oxides of nitrogen and oxides of sulphur. Visibility is also an issue. When aerosols are there or smog is produced by different kinds of air pollutants then visibility is reduced of the atmosphere, and it has several negative implications which we will see later on.

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Air pollution and visibility (1/2)

Example:

- In India, air pollution was reduced in lockdown period, hence visibility improved.



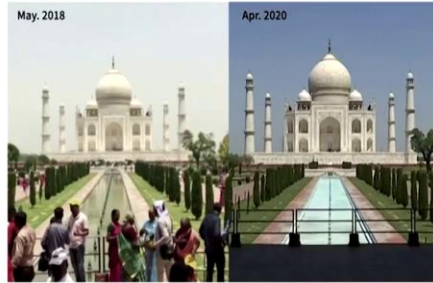
Sources: www.weforum.org

4

Air pollution and visibility (1/2)

Example:

- In India, air pollution was reduced in lockdown period, hence visibility improved.



Sources: www.weforum.org



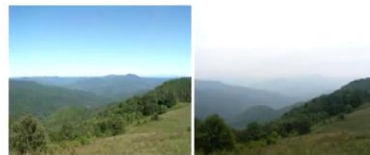
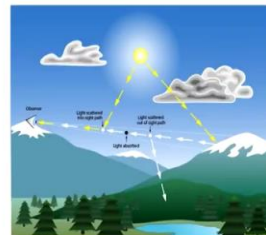
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You can see here, the air pollution and visibilities relation. Those periods when air pollution was high, so what was the visibility of, like you can see a particular place in Delhi, Rajpath. So November 2018, and you can see April 2020. So before lockdown and after lockdown, you can see the clear cut visibility related issue even in Taj Mahal also. So 2018 and 2020, these are the two very short videos which can easily give you the realization that how this clean air really helps us to have greater visibility.

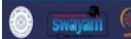
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Air pollution and visibility (2/2)

- Visibility is a measure of how well an observer can see a scene.
- If air pollution increases, the contrast may decrease, reducing our ability to see the object.



Sources: VALLERO, DANIEL A. 2008 Image: www.nps.gov



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Well, the visibility is basically a measure of how well we can see or observe an object or scene around us. So if air pollution increases, the contrast decreases. Contrast really helps us to see an object clearly. So when contrast is reduced the abilities to see the object clearly also reduces.

So you can see here, this, if there is a visibility issue then this kind of scene, the same place if atmosphere is clean then you can have very good scenic beauty. So aesthetic beauty or scenic beauty is dependent upon the clarity of the atmosphere. And that is dependent on pollution. If pollution is more clarity is reduced, contrast is reduced because of this scattering of sunlight etc.

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How Haze affects the visibility ?

- Haze is caused when sunlight encounters tiny pollution particles in the air.
- More pollutants mean more absorption and scattering of light, which reduce the visibility.

Sources: Rule & EPA, 2006 Image: www.sciencedirect.com

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And then, this haze effect is also there on the visibility. So haze is basically caused due to sunlight. When sunlight encounters tiny pollution particles they have this scattering effect. And then more pollutants are there so more scattering of light happens. So this reduces the visibility. So you can have these tiny particles which can contribute in reduction of visibility.

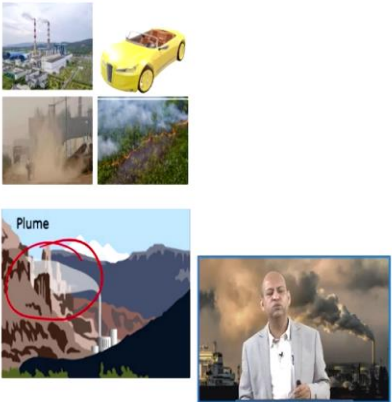
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Types of Haze (1/2)

- Haze is a phenomenon caused by interaction of air pollutants emitted from various sources and its interaction with atmospheric constituents.

There are three types of haze:

- Plume Haze: A plume is defined as a dense, vertically limited layer of air pollution emitted by a single point source.



Sources: vista.cira.colostate.edu, 12 Oct 2021 Image: <https://scroll.in>

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Well, there are several types of haze, basically. And haze is caused by interaction of these pollutants which are coming out of various anthropogenic sources or natural sources also and then they interact with atmospheric constituents. So when this man-made activity like industrial activity, power plant etc and plume is coming out of a stack, so within the dispersion of plume in that area visibility will be reduced.

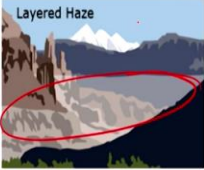
So it is called as plume haze. This much area only where this plume is passing through, haze will be created because of this scattering of light because this plume has lot of particulate matter.

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Types of Haze (2/2)



Layered haze is a confined layer of pollutants that creates a visible contrast between that layer and the sky or landscape behind it.

Layered Haze



Uniform Haze

- In an unstable atmosphere, plumes and layers mix with the surrounding atmosphere creating a uniform haze.



Sources: Vista.cira.colostate.edu, 12 Oct 2021

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Then there is this layered haze. So in layered haze because this contrast reduces and there may be one clarity related layer and reduced visibility related layer. So in that layer where this visibility is reduced significantly we call it layered haze. And in upper layer you can have better quality of the visibility and even lower also it can be there, greater visibility.

Then there is uniform haze. When the pollutants are dispersed properly, uniformly, and the whole atmosphere get affected in our range of the visibility, then this is the uniform haze. And the whole atmosphere is having very reduced level of visibility. We cannot see properly in the air.

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Effects of poor visibility (1/2)

Affect the transportation of goods and people, whether it is by rail, road, sea or air.

Low visibility can lead to accidents and thus is a concern for public safety.

Tourism is often dependent on good visibility for appreciation of scenic points of interest.

Sources: Singh et al., 2017
Image: tourism.gov.in, www.shutterstock.com

When we talk about the visibility then we also talk about negative impacts of the visibility. Because this transportation of goods, or people from different kinds of vehicles railroads, air traffic etc they are affected by reduced visibility. When dense fog is there then it is difficult to take off and landing of the flights.

Similarly speed of the rails gets reduced, you cannot see properly at good distances, and several safety issues emerges because accidents may happen on the roads when the visibility is very poor and you cannot drive your vehicle at the proper speed because you cannot see properly at larger distance.



Then even if the visibility is an issue at the tourist places where people try to see sunrise or sunset or they want to enjoy the sight scenes, so if visibility has an issue then they cannot enjoy that aesthetic beauty to full extent. So that is also one more negative impact, you can say.

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Effects of poor visibility (2/2)

Example:

- Sharp decrease in visibility due to increased particulate matter (PM) and NO_2 concentrations during a smog event in November 2012 in Delhi, India.



Sources: Singh et al., 2017 Image: www.hindustantimes.com



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And this is one example. You can see the sharp decrease in the visibility due to increase in particulate matter and oxides of nitrogen in Delhi in November 2012. So this was the picture you can see. Very poor visibility. And it was taken, may be taken, this picture was taken quite at the near distance but still, you cannot see properly. You cannot enjoy the scenic beauty or aesthetic beauty of that particular place.

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Effects on Albedo (1/4)

- Albedo, fraction of light that is reflected by a body or surface.
- It is a significant concern in climatology since recent decrease in albedo in the Arctic has increased heat absorption at the surface resulting in melting of surface ice.



Sources: www.britannica.com, 13 Oct 2021 Image: https://www.wbvtv.com

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Then there is this issue of effects on albedo. So albedo is basically the fraction of light which is reflected by a body or surface. So this reflectivity is influenced by particulate matter and air pollution because that surface is basically either damaged or it, the enhanced, the reflectivity may be enhanced depending upon the physicochemical characteristics of aerosols.

So basically when this albedo is decreased then absorption of sunlight increases, and temperature increases. So one negative impact is related to arctic ice. Because of pollution its albedo is reduced means the reflectivity is reduced and heat is being absorbed. So because of that surface ice melts. And this increases a kind of vicious cycle because surface ice melts then rough surface is there to absorb more, this solar radiation and to increase the heat content.

Here high albedo means like, very reflective surface. So 80 percent solar radiation is reflected. When low albedo is there because of soot or carbon particles etc, then the whole light is absorbed, only 10 percent is reflected. So those kind of pictorial representation is there.

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Effects on Albedo (2/4)

- When soot enters the atmosphere, it absorbs sunlight and generates heat, warming the air.
- When soot is deposited on snow and ice, it changes the albedo of that surface, absorbing sunlight and generating heat.
- This causes snow and ice to melt and causing even more warming effects.

Sources: www.windows2universe.org Image: <https://www.worldgreenbridge.org>

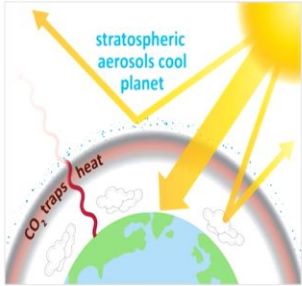
12

So as I said that because of this soot particles or those particles which can absorb sunlight, then it can generate the heat and it can warm the air. And when soot is deposited


on snow or ice it changes the albedo because its reflectivity is affected, and then it absorbs the sunlight and it generates the heat, and then it causes the melting of snow and ice and more warming effect, as I said, because of this vicious cycle kind of thing. More ice melts, then more surface is out to absorb the heat content and the heat and temperature rises.

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Effects on Albedo (3/4)



- Aerosol particles are released into the upper atmosphere to reflect sunlight back into space.
- As a result, aerosol particles increase the planet's albedo.
- The planet gets cooled as a result of this change in albedo.



Sources: <https://keith.seas.harvard.edu>

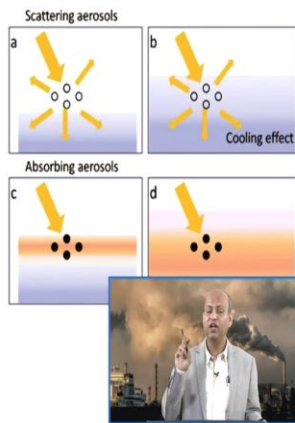
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Here you can see, the aerosol particles which contributes into affecting the albedo. So there are particles like sulphate particles or sea salts etc, they are reflective in nature. So they can reflect and they can have cooling effect. They can reflect the sunlight or solar radiation into the space and, but the other aerosols which have carbon aerosols or carbon particles, soot etc they absorb the light and they increases the heat content or they generate the warming effect.

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Effects on Albedo (4/4)

- Some aerosols, such as sea salt particles, reflect sunlight back into space, which can help to cool the atmosphere.
- Others, such as black carbon particles from burning of wood or fossil fuels, absorb most of the sunlight that hits them, which leads to warming.



Sources: <https://scied.ucar.edu>, 10 Oct 2021 Image: www.semanticscholar.org

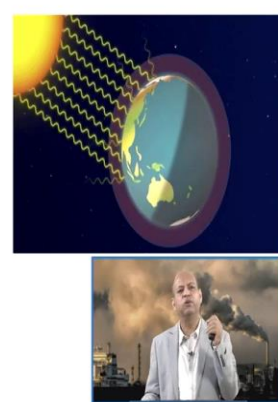
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So that is why these are the scattering aerosols, which are light in color. They reflect lot of this solar radiation. So they cause the cooling effect in the temperature. And those, the carbon particles, etc, soot etc, they absorb the light and they have the warming effect. So aerosols can have both effects depending upon their physicochemical characteristics.

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Impacts on Climate (1/7)

- Pollutant releases into the air via car exhaust, smokestacks at factories and power plants, agricultural emissions, and other sources can cause climate change.
- Greenhouse gases (such as CH_4 and CO_2 , and O_3) cause the climate change by inducing global warming due to trapping of outgoing longwave i.e. heat radiation emitted by the earth to the upper atmosphere.



Sources: <https://scied.ucar.edu>, 10 Oct 2021 Image: www.giphy.com

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Then if you talk about impacts on the climate, as you know the climate is basically governed by this solar radiation. So because of this disturbance in solar radiation through

albedo as well as through go this global warming effect, because of greenhouse gas contained in the atmosphere this can change the climate, and climate can change the temperature as well as the precipitation patterns also. So those are the impacts related to the climate, that it can change the heat radiation or it can change also the precipitation patterns.

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Impacts on Climate (2/7)

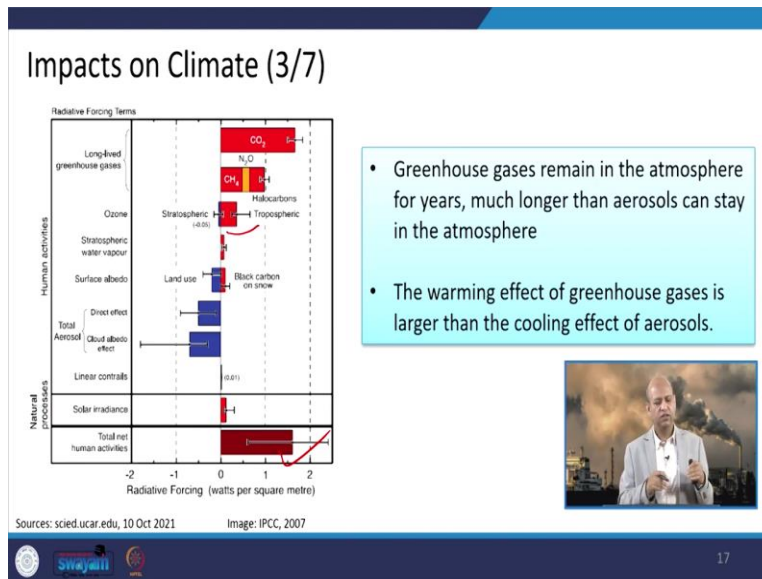
- Aerosols in the atmosphere can change the amount of solar energy reflected away from Earth.
- As we learned in Albedo, depending on their physicochemical characteristics the aerosols can induce either warming or cooling effects in the atmosphere.

Sources: <https://scied.ucar.edu>, 10 Oct 2021 Image: www.mrgscience.com

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So you can see here, like these, the reduced sunlight causes cooling effect because of those particles or aerosols which are reflective in nature, and then if lot of cloud formation is there then water content is there then the earth surface get this greenhouse gas effect more because warming effect is there because of clouds, clouds act as the, this blanket kind of thing. So albedo has a lot of change or role in changing the climate along with the greenhouse gases.

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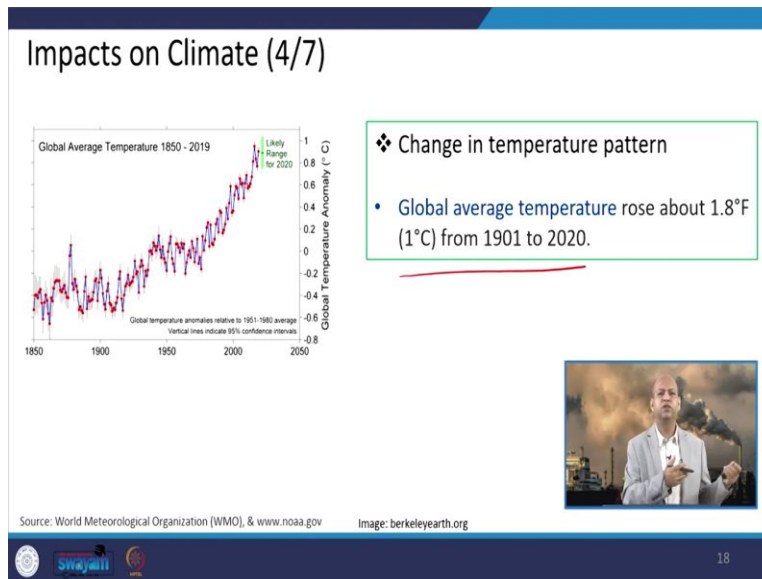


And this is a very good picture. You can see here radiative forcing is depicted because different greenhouse gases as well as natural phenomena and particles. Here CO₂, you can see the highest greenhouse gas impact or radiation impact of CO₂. Very positive. Then methane also has, in stratosphere this ozone has cooling effect in the stratosphere, but positive effect or warming effect in the troposphere.

Similarly this surface albedo, so black carbon on snow, they have positive impacts but in the land use you can have this negative impacts plus the total aerosols you can have the direct effect and cloud albedo effect. So they are the negative in the sense because they are reflecting the solar radiation so they are having the cooling effect.

Then lot of effect of greenhouse gas as well as in totality we can call the total impact is positive. Total impact is positive because this cooling effect you can minus and you can add all these positive impacts. So ultimately the, there is this impact on the climate or radiative forcing because of greenhouse gas and particles, the net result is positive. That means it will warm the atmosphere or the surface earth, earth's surface.

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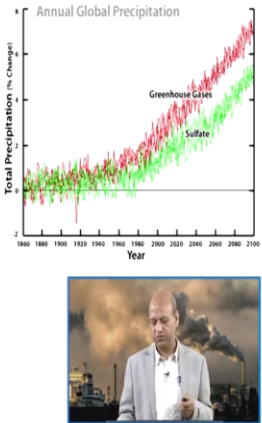
And when we talk about this change in the temperature pattern, so from this 1850 to 2050, this kind of hockey stick curve you can see here, so the temperature is increasing. So you can relate it with the industrial era. When this industrial revolution started then emissions of greenhouse gases especially CO₂ etc also increased and accordingly the temperature, overall temperature has increased.

And now the temperature rate increase has rapidly enhanced because of high concentration of greenhouse gases. And now you can see 1 degree Celsius from 1901 to 2020. This much rose this temperature between these 120 years, you can say. So that is a very rapid increase of temperature if you look into the context of several hundreds or thousands of years.

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Impacts on Climate (5/7)

- ❖ Change in precipitation rainfall pattern
 - There are many reasons for changes in precipitation. The leading cause is a change in atmospheric temperature due to GHGs.
 - Many scientists believe an increase in temperature could lead to a more intense water cycle.
 - Aerosols also influence the precipitation patterns



Source: <http://www.cofc.edu>, 14 Oct 2021

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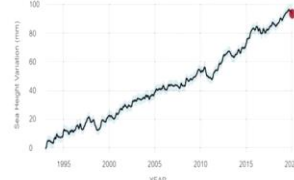
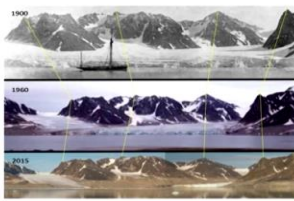
Well, the change of precipitation or rainfall is affected by climate change because of temperature change as well as change of the, these aerosols. Because aerosols have of different size and shape. Small aerosols, like they result into small droplets because they cause like nucleation for condensing of water vapor. So cloud formation because of very small particles tiny particles, so small aerosols, so that will hang around. It will suppress the precipitation.

So there are studies which show that because of these small particle emissions precipitation can be suppressed, but at the same time then if sizes of the particles are more they can enhance the precipitation. So that kind of two way effect may be there depending upon the, this aerosol size. But greenhouse gas impact because of this global warming, this temperature change, it can has this positive effect on the precipitation.


So it has been realized that this precipitation intensity will increase, and you can see, several times storms, this thunderstorm is increasing, at several places very high intensity rains occur. So these are the part of the climate change issues. And here the patterns of aerosols because of sulphates and greenhouse gases on the precipitation has been shown, relationship.

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Impacts on Climate (6/7)



- Glaciers are shrinking: the average thickness of 30 well-studied glaciers has decreased more than 60 feet since 1980.
- Sea level rise has increased from 1.7 mm/year throughout most of the twentieth century to 3.2 mm/year since 1993.



Source: www.noaa.gov, February 1, 2019 Image: climate.nasa.gov, Nov 5, 2020 & <https://climate.columbia.edu>, May 5, 2017

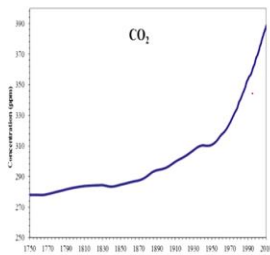
20

When we talk about these glaciers, because aerosols has deposited on the glaciers and they are having this trapping of the heat and that is why the thickness of 30 well-studied glaciers has decreased more than 60 feet since 1980. So its a huge, big issue in that sense because there are so many rivers which are fed by glaciers. If glaciers recede it will impact the complete water cycle and our irrigation patterns and availability of the water, all those things.


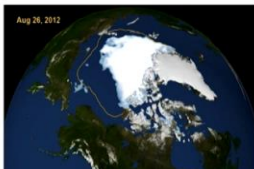
Similarly, at the same time when glaciers are receding, they are giving more water to the rivers etc, so the more water is going to the sea and sea level is also rising. And you can see this, around 1.7 millimeter per year throughout most of the 20th century this has been observed because of this global warming impact on the sea levels. And 3.2 mm per year since 1993. So the rate of increase of sea level has also increased. And that will have very negative impact on coastal cities and island countries, and all those issues are there.

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Impacts on Climate (7/7)



- The amount of **carbon dioxide** in the atmosphere has risen by 25% since 1958, and by about 40% since the Industrial Revolution.
- The area covered by **sea ice** in the Arctic at the end of summer has shrunk by about 40% since 1979.



Source: www.noaa.gov, February 1, 2019 Image: www.eea.europa.eu, 23 Jan 2013, www.nasa.gov

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Well, when we talk about this carbon dioxide in the atmosphere which has risen by 25 percent since 1958 and about 40 percent since the industrial revolution, and this has also related to this ice cover. The area covered by sea ice in the arctic region at the end of summer has shrunk or decreased by about 40 percent since 1979. So this is a very worrisome issue.

So CO₂ is increasing and this surface area covered by the eyes in arctic is decreasing. And this is not only a very simple association of the concentration of CO₂ and receding area of the ice cover on arctic, but there are well established facts, scientific facts and scientific studies which really relates the greenhouse gas impact through global warming on glaciers as well as on sea levels etc.

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Impacts on Soil (1/2)




Image 1





Image 2

- Air pollution can significantly affect the quality of soil.
- Acid rain can alter the productivity of the soil, which can affect plant growth.
- SO_x and NO_x are major causes of acid rain.



Sources: www.canada.ca, 11 Oct 2021 Image 1: www.psychologicalscience.org Image 2: www.momspresso.com

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Well, so now we can talk about like impact on the soil. We have seen the impact on the atmosphere and climate because of this air pollution, and air pollution is associated not only these toxic pollutants which we have discussed on, like negative healthy effects, but there are also greenhouse gases along with the air pollutants and they impact the atmosphere and climate.

Now we can see what is the impact on the soil. So air pollution they can also affect the quality of soil because of dry deposition and wet deposition occurs, and this acidic rains occur and the productivity of soil can be affected because this will change the pH level of the soil when lot of NO_x and sulphur dioxide are deposited through acid rain on the soil.

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Impacts on Soil (2/2)

- Acid rain is known to cause serious negative Impacts (like loss of nutrients, minerals and elements) on soil.
- As a result, acid deposition reduces the productivity of the soil.



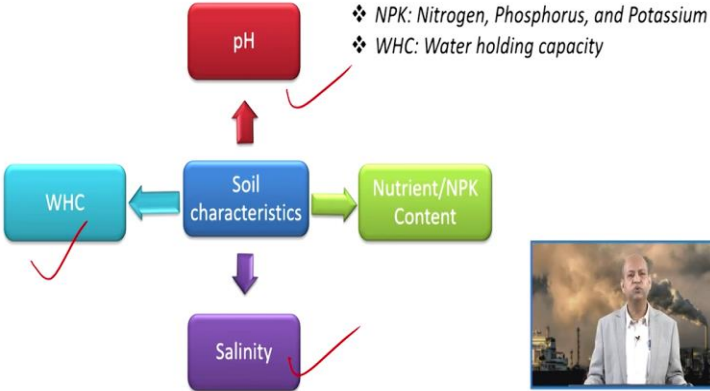
Sources: www.canada.ca, 11 Oct 2021 Image: www.pinterest.com

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So you can see here, acid rain, this can have the detrimental effects on the soil through, like loss of nutrients or loss of minerals and the elements which are required for the proper growth of the plant. And then as a result this acid deposition reduces the productivity of the soil. So total productivity is reduced and even soil can be unfertile also after some time if we do not really do some helping hand for revitalizing the soil.

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Soil characteristics (1/6)



❖ NPK: Nitrogen, Phosphorus, and Potassium
❖ WHC: Water holding capacity

Source: Mahapatra, M. (2020)

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Then if you see the characteristics of the soil which are important for plant growth etc, like pH level or this water holding capacity, salinity, nutrient or nitrogen phosphorus, potassium content, all these are the, like you might have heard about, like government of India is issuing soil health card to farmers.


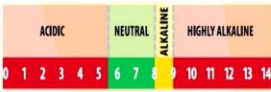
So these are the things if you see if they are in the real balancing then the plant growth occurs very nicely, otherwise if they are disturbed then growth is reduced. It affected negatively. So because of air pollution all these factors can be affected negatively.

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Soil characteristics (2/6)

pH

- ❖ The optimal pH range for soil is 6.2-6.8.
- ❖ If soil is too acidic, lacks the ability to retain certain important nutrients like magnesium, calcium and potassium.
- ❖ If soil is too alkaline, minerals such as iron and zinc will solidify and negatively impact the health of plants.



Source: Mahapatra, M. (2020) Image: <https://soilquality.org.au>

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For example pH level so the optimal pH range is right like 6.2 to 6.8, and there is the range acidic neutral and highly alkaline. All these, then, if soil is too alkaline then minerals such as iron and zinc will solidify. So because of pH level many things may happen. Its ability to retain some nutrients like magnesium and calcium, potassium, they reduces because of acid rain.

And similarly if alkalinity increases because of changes in the pH levels of the soil because of certain pollutants then can also, it can impact the iron and zinc, the concentration of iron and zinc which is also very important nutrient for the plants' growth.

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Soil characteristics (3/6)

- Sulfuric or nitric acid, that fall to the ground from the atmosphere in the form of wet deposition or dry deposition, leads to reduction of pH of the soils.

Source: <https://www.unep.org>, 17 Oct 2021 Image: <https://ocw.jhsp.edu>

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Soil characteristics, in terms of like, you can see these emissions of NO_x , and SO_2 etc, they come through dry deposition or bad deposition and it can reduce the pH levels of the soil.

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Soil characteristics (4/6)

Water Holding Capacity

- ❖ WHC is the amount of water soil can hold against the force of gravity. The ideal range is 40% - 50%.
- ❖ A low WHC will result in plants not having access to enough water.
- ❖ A high WHC will result in plant roots sitting in water and that may cut off the air supply to the plants root.

Source: Mahapatna, M. (2020) Image: Vengadaramana and Jashothan, 2012

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So, then another is part in terms of water holding capacity. This can also get affected because of interaction of soil with the air pollutants. So its holding capacity for the water,

it can be reduced or it can be enhanced depending how this chemical composition of soil is affected.

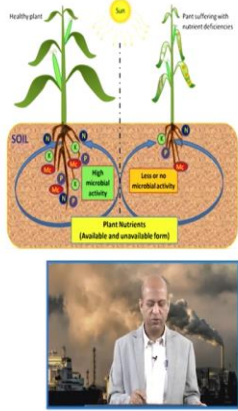
And both way, if the holding capacity water holding capacity is reduced, then drought may occur or it may not give the proper water to the roots. Similarly if lot of water is hold by the soil then again the roots sitting in water that can be damaged and the supply of nutrients becomes less in that term because roots will be damaged if a lot of water is there.

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Soil characteristics (5/6)

Nutrient/NPK Content

- ❖ NPK content refers to the amount of nitrogen, phosphorus, and potassium that soil contains.
- ❖ Plant growth and immunity are harmed when one or more of the three macronutrients are deficient.



Source: Mahapatna, M. (2020) Image: Mehta et al., 2016

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Then if you talk about like nutrients value nitrogen, phosphorous and potassium etc, so because of oxides of nitrogen the nitrogen imbalance may be there and that can have some impact on this soil quality and the plant growth because its immunity and the plant growth is harmed when one or more of the three micro nutrients are deficient or the imbalance occurs. So there must be some balance.

(Refer Slide Time: 24:04)

Soil characteristics (6/6)

Salinity

- ❖ Soil salinity is the amount of salt contained in soil.
- ❖ High soil salinity can adversely affect the plants.
- ❖ Subject to the laws of osmosis, salinity causes the water within plants to flow towards the soil and hydrate soil, leaving plants and crops dry.



Source: Mahapatna, M. (2020) Image: <https://ucanr.edu>

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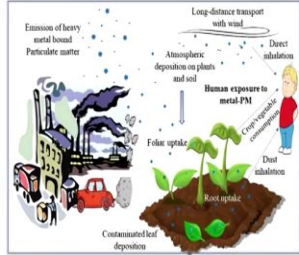
Well, salinity is also an issue. So soil salinity is the amount of salt which is contained in soil. And high soil salinity can adversely affect the plant growth. So it subjects to the loss of like osmosis. And salinity causes the water within plants to flow towards the soil when higher salinity is there.

So it can hydrate the soil and, leaving the plants and crops dry because that water will flow towards the soil because of this salinity. So if salinity increases because of air pollutants so negative impact on the plant growth can happen.


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Air pollutants and soil (1/2)

- ❖ Particulate matter is found in the air and can consist of dust, smoke, and dirt particles with various physicochemical characteristics.
- ❖ Depending upon their physicochemical and toxic characteristics Particulate Matters (PM), the nutrient content of soil can be severely affected.



The diagram shows emissions of heavy metal bonded particulate matter from a factory and a car. These particles undergo long-distance transport with wind. They can be directly inhaled by humans or deposited on plants and soil. From the soil, they can be taken up by plants through foliar and root uptake, leading to contaminated leaf deposition. This process results in human exposure to metal PM.



Source: Mahapatna, M. (2020) Image: Shahid et al., 2020

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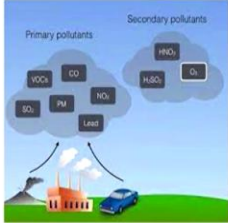
Then here you can see this particulate matter and they can change the physicochemical characteristics because particulate matters, several pollutants as coated ones, sulphates etc. Then depending upon physicochemical and toxic characteristics of particulate matter, the nutrient content of soil can also be affected. So in that way the total growth can be affected because of these air pollutants.

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Air pollutants and soil (2/2)

Oxides of Sulfur and Nitrogen contribute to acid rain and interfere with the chemical composition of soil.

Lead is absorbed in small amounts by vegetation through the soil, lowering its productivity.



The diagram illustrates primary pollutants (SO₂, CO, PM, NO_x, Lead) and secondary pollutants (HNO₃, H₂SO₄, O₃) originating from a factory and a car. Arrows indicate the flow from primary to secondary pollutants.



Source: Mahapatna, M. (2020) Image: <https://www.atmos.illinois.edu>



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And then oxides of sulphur and nitrogen, as we have seen because they contribute in acid rain, and this like lead is absorbed in small amounts by vegetarians, vegetation through the soil so it can also lower the productivity. So heavy metals and these acidic depositions etc, they will cause harmful effect on the soil quality. And then it will be translated into negative impacts on the plant growth.

(Refer Slide Time: 25:36)

Calcium carbonate (CaCO_3) rich soil

- Soils are not equal in their vulnerability or resistance to acid rain.
- As CaCO_3 chemically neutralizes acids, soils with higher CaCO_3 contents (such as limestone and dolomite) are more resistant to acid rain.


$$\text{SO}_2 + \text{H}_2\text{O} + \text{CaCO}_3 \longrightarrow \text{CaSO}_4 + \text{CaSO}_4 \cdot 2\text{H}_2\text{O}$$



Sources: www.canada.ca, 11 Oct 2021 Image: imggeo.egu.eu

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When we talk about, like calcium carbonate rich soil, then the negative impact of acid rain can be reduced because this carbon, this calcium carbonate acts like a buffer zone. It absorbs this acidic content through this reaction and that way the soil has kind of less vulnerability, or more resistance to acid related negative impacts.

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Calcium carbonate free soil



- Soils that contain lower levels of CaCO_3 are particularly vulnerable to acid rain.



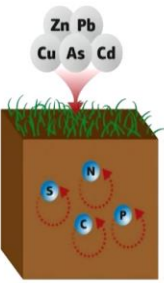
Sources: www.canada.ca, 11 Oct 2021 Image: www.britannica.com

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But if soil is not having this calcium carbonate that soil is basically affected severely by this acid rain, and its quality becomes very low and the nutrient capacity and enriching capacity to plants decreases very severely.

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Heavy metals contaminated soil



- Heavy metals accumulate at soil top. Their contamination increases in the soil with time.
- It leads to the absorption and accumulation of heavy metals in plants.



Sources: Ashraf et al., 2019 Image: www.phys.org

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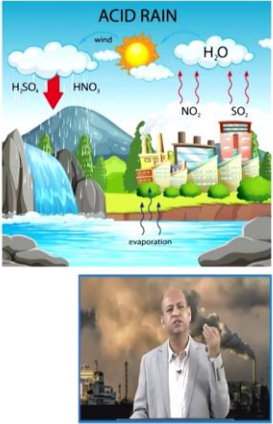
When we talk about heavy metals, they also accumulate in the soil top because of this dry deposition of the particulate matter and because of wet deposition also at the same time. So the increases in, in its concentration and it is absorbed and accumulated in the plants

also. And that way plants becomes unhealthy and when this plant is eaten by animals or it goes in the diet of human beings then it is also dangerous because of bio accumulation of heavy metals.

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Acidic Impacts on water bodies (1/2)

- If air is polluted, it also pollutes the precipitation that falls into water bodies.
- Some rivers, lakes or coastal areas may seem to be clean.
- But these areas still be polluted because of acid precipitation from rain, snow and particulate matter.



The diagram illustrates the process of acid rain. It shows a landscape with a waterfall and a lake. A sun is in the sky, and wind is blowing. A cloud is labeled 'ACID RAIN'. Arrows point from the cloud to the waterfall and lake, labeled with chemical formulas: H_2SO_4 , HNO_3 , NO_2 , and SO_2 . A cloud is labeled H_2O . A factory is shown emitting smoke, with an arrow labeled 'evaporation' pointing to the cloud. Below the diagram is a small photo of a man in a white shirt speaking into a microphone.

Sources: www.canada.ca, 11 Oct 2021 Image: www.freepik.com



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Now, we talk about negative impacts of acidic nature of precipitation to the water bodies. We have already discussed impact on atmospheric climate and soil, now on water bodies. So again, because of this acidic deposition of this nitrogen oxides and oxides of sulphur this pH of the water gets changed.

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Acidic Impacts on water bodies (2/2)

- ❖ Lethal effects of Acid rain
 - Acid precipitation in the form of snow is suddenly released into the water system during the spring melt, called acid shock.
 - This acid shock can be lethal for many aquatic organisms such as fish.



Sources: www.canada.ca, 11 Oct 2021 Image: <https://i.makkit.co>

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And when pH is changed, it can affect this, the aquatic life like, lethal effects may be there. For example acid precipitations in the form of snow is suddenly released into the water when in, during the spring period. And this gives the shock to the fish because this pH level drastically decreases suddenly, and they cannot survive in that particular environment.

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Acidic Impacts on water bodies (3/3)

Example:

- Study Location: Mosul province, Iraq
- Considered as the largest sulfur mine in the world.
- SO₂ was responsible for the acid rain in the area.
- At pH lower than 5, most fish eggs were not hatched and lower pH also killed the adult fish.



Sources: (Al-dahhan et al., 2017)


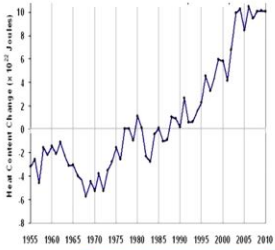
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There is one more example to illustrate this particular concept, like in Iraq, at a place this Mosul province, it was considered the largest sulphur mine in the world. And this SO₂ was responsible for the acid rain in that area because of mining activities and so. And the pH got reduced below 5, and this affected hatching process of the fish, and also, it also killed the adult fish also. So lot of damage was there in that particular water body.

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Thermal Impacts on water bodies (1/2)

- Global warming is a process where the average global temperature increases due to the greenhouse effect.
- The ocean absorbs most of the excess heat from greenhouse gas emissions, leading to rising ocean temperature.



Sources: www.water-pollution.org.uk, www.iucn.org/, 10 Oct 2021 Image: www.thegwpf.com



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Now, we come to thermal impacts on water body, because global warming is increasing the temperature of like sea. And this increase in the temperature of sea is really translating into negative impacts on the coastal ecosystem.

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Thermal Impacts on water bodies (2/2)

- The increasing ocean temperature affects marine species and ecosystems.
- For example, the bleaching of coral reefs all over the world is caused by rising sea temperatures.



Sources: www.water-pollution.org.uk, 10 Oct 2021 Image: pivot.mias.org.au

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For example, you can see this bleaching of coral reefs. This is so beautiful coral reef in the clean water but because of temperature increase this kind of bleaching happens. And other pollutants may also participate in that kind of activity, but thermal impact may be there in, in this particular fashion.

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Impacts of Nitrogen on water bodies

Eutrophication

- Dry/Wet deposition of nitrogen oxides (NO_x) results in rapid and significant increase in plant and algal growth because of extra availability of nutrient/nitrogen.
- This excessive growth within a water body is called eutrophication which leads to low levels of dissolved oxygen and threat to aquatic life.



Sources: Diatta et al., 2020, www.canada.ca, 11 Oct 2021

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Then there is impacts of nitrogen on water bodies, because as I said nutrients like nitrogen and phosphorus they are very important for the, enhancing or reducing the growth of the plants. In certain water bodies if nitrogen increases, which is micro nutrient, so this can result into the bloom of algae and those kind of plants in the water body.

And it results into reduction of oxygen. Because of eutrophication, oxygen is reduced, and anaerobic conditions may prevail and when oxygen content or dissolved oxygen of the water body reduces, then aquatic life suffers. They need certain amount of oxygen to survive. So that becomes kind of, if it is not properly checked or something, constructive measures are not implemented then that particular water body becomes like a mars or those, those kind of things.

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Conclusions

- Air pollution causes serious effects on the atmosphere, climate, soil, and water.
- Air pollution reduces the surrounding visibility that can cause accidents during transportation.
- Acid rain formation can make lakes, rivers, and streams unsuitable for aquatic life.
- Soil is mainly polluted by deposition of acids and heavy metals.
- Greenhouse gases is responsible for increase in the atmospheric temperature and cause various negative impacts including the bleaching of coral reefs.



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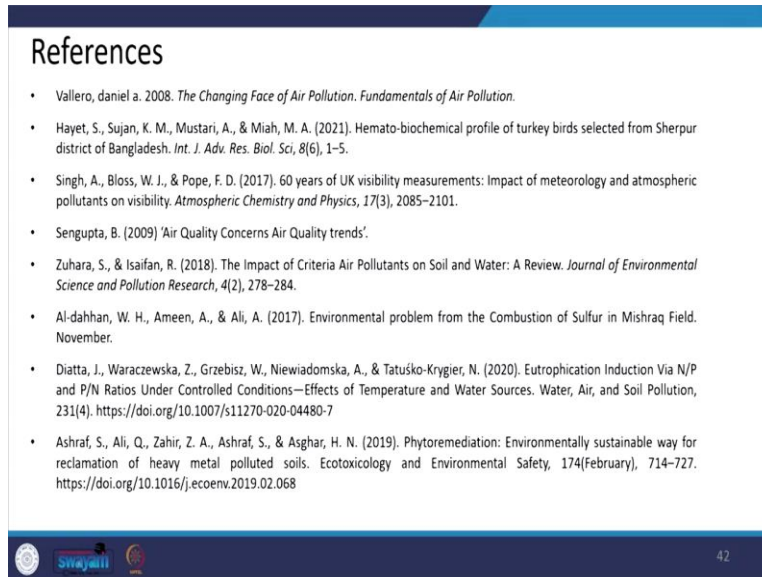
So this is all for today. In conclusion we can say that air pollution can cause different kind of effects on the atmosphere, climate, soil and water bodies. And it can reduce the surrounding visibility, this air pollution can reduce the surrounding visibility because of that scattering effect of particulate matter. And it can cause accidents during transportation, it can delay flights, all those effects may be there.

Then there is this acid rain formation. It can makes lakes and rivers acidic and it can disrupt the aquatic life. Similarly soil nutrients can be affected negatively because of heavy metals because of air pollutants and this acidic patterns of precipitation.

And these greenhouse gases is responsible for increasing the atmospheric temperature, and it can cause several negative impact through climate change as well as the thermal impact can be there on the, these coral reefs also. So there are multiple effects you can see on this environmental components, whether soil water and air because of this air pollution emissions.

So this is all for today, and we will continue to see other related aspects of air pollution in the same way. So see you in the next session.

(Refer Slide Time: 31:23)



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And before that, I request you to go through these references which gives the additional information about this topic.

So that is all for today. Thank you for your kind attention. See you in the next lecture.
Thanks.