Friend, Philosopher, Guide

Atmospheric Systems & Societies

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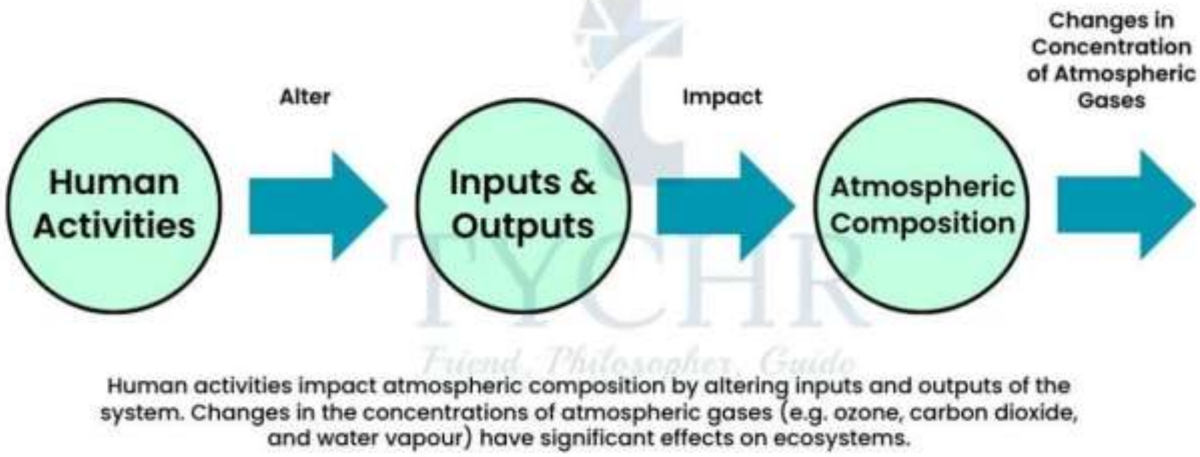


Figure 1 Human activities impact atmospheric composition by altering inputs and outputs of the system. Changes in the concentrations of atmospheric gases (e.g. ozone, carbon dioxide, and water vapour) have significant effects on ecosystems.

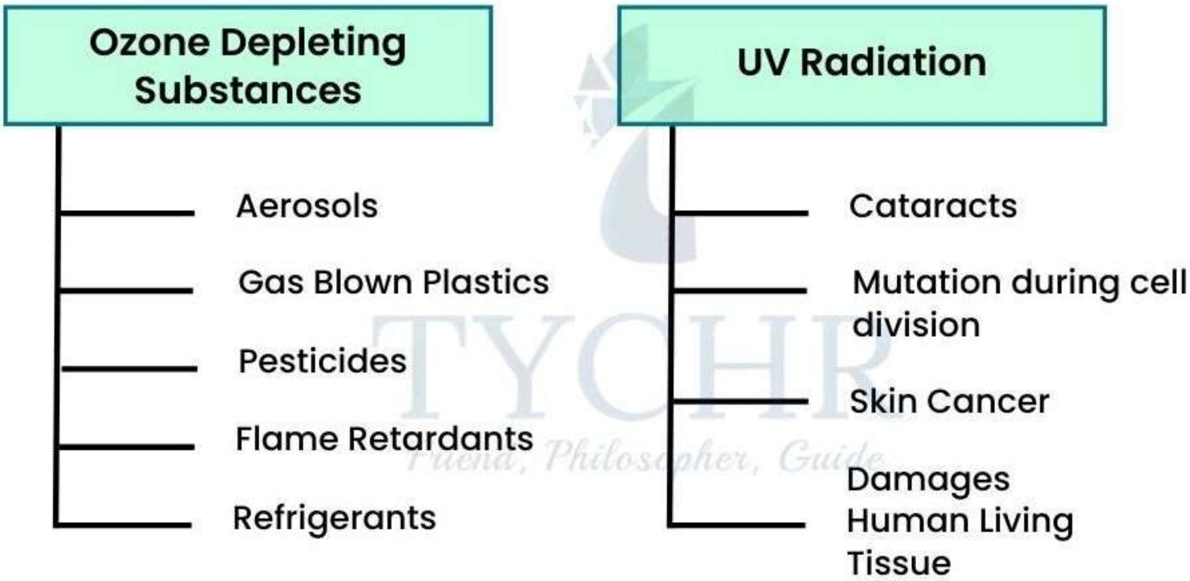


Figure 2 The Ozone-depleting substances (including halogenated organic gases such as chlorofluorocarbons, CFCs) are used in aerosols, gas-blown plastics, pesticides, flame retardants, and refrigerants. Halogen atoms (such as chlorine) from these pollutants increase destruction of ozone in a repetitive cycle so allowing more UV radiation to reach the Earth. UV radiation reaching the surface of the Earth damages human living tissues, increasing the incidence of cataracts, mutation during cell division, skin cancer, and has other effects on health.

6.1 Introduction To Atmosphere

6.1.1 Atmosphere As A Dynamic System

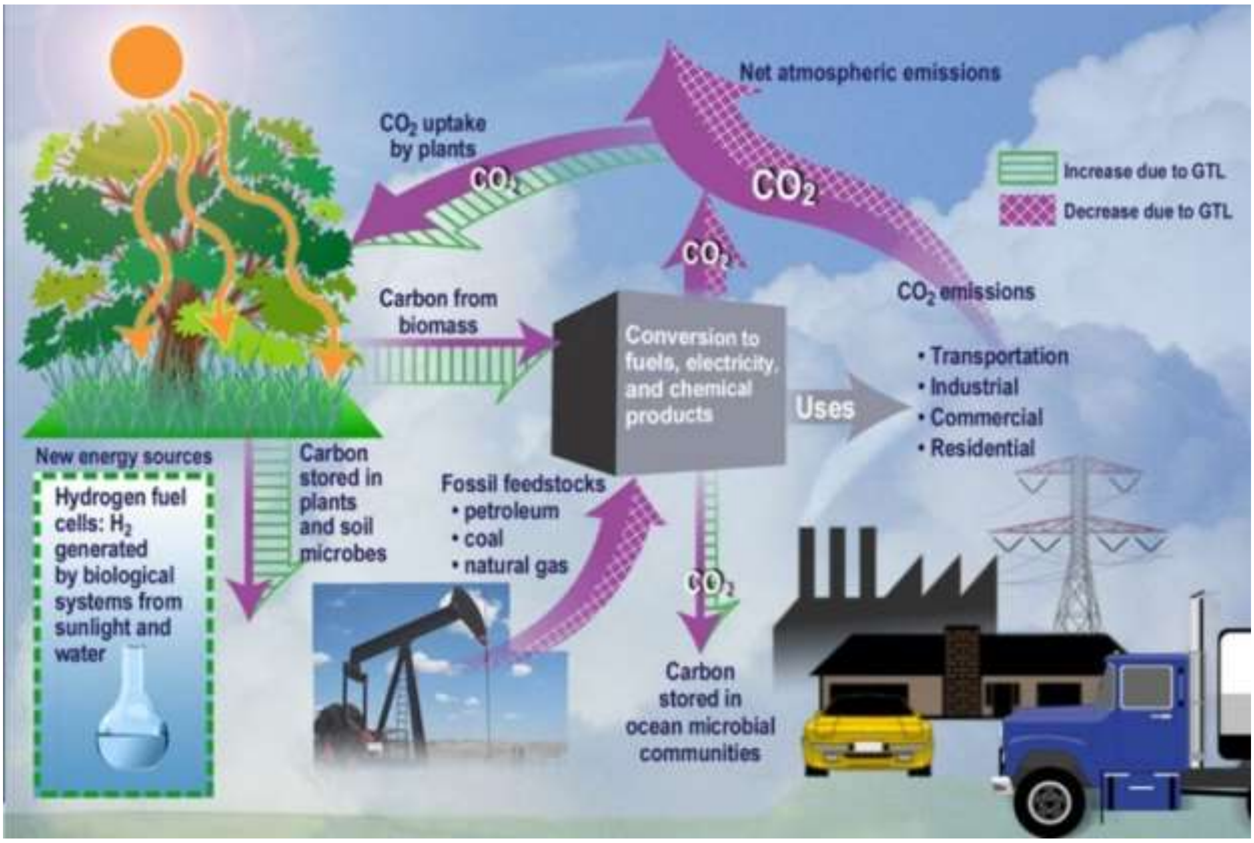


Figure 3 The climate system: components (in bold), processes and interactions (orange arrows), and some aspects that may change (white arrows).

The Earth's atmosphere is both influenced by the biosphere and influences the biosphere. The current atmosphere consists of nitrogen (78.1%), oxygen (20.9%), and carbon dioxide (0.4%). If the effects of the biosphere were removed, it is estimated that the atmospheric composition would be 1.9% nitrogen, 0% oxygen and 98% carbon dioxide. This illustrates the close relationship between the biosphere and the atmosphere.

The atmosphere continues to change as a result of natural and human-induced processes. The high levels of carbon dioxide in the atmosphere have resulted in higher temperatures since the dawn of industrialization. The following factors have contributed to the higher mean global temperatures every year:

- The onset of global industrialization and the subsequent production of pollution derived from fossil fuels
- Deforestation, particularly of rainforest
- Volcanic activity
- Sunspot activity.

Variations in Composition with Altitude

The concentrations of gases have an important effect on changes in temperature through the atmosphere. At the tropopause, there is a reversal in the temperature gradient. This acts as the upper limit of weather systems. In the stratosphere, the increase in temperature is related to the presence of ozone. Temperatures then fall in the mesosphere but increase again in the thermosphere.

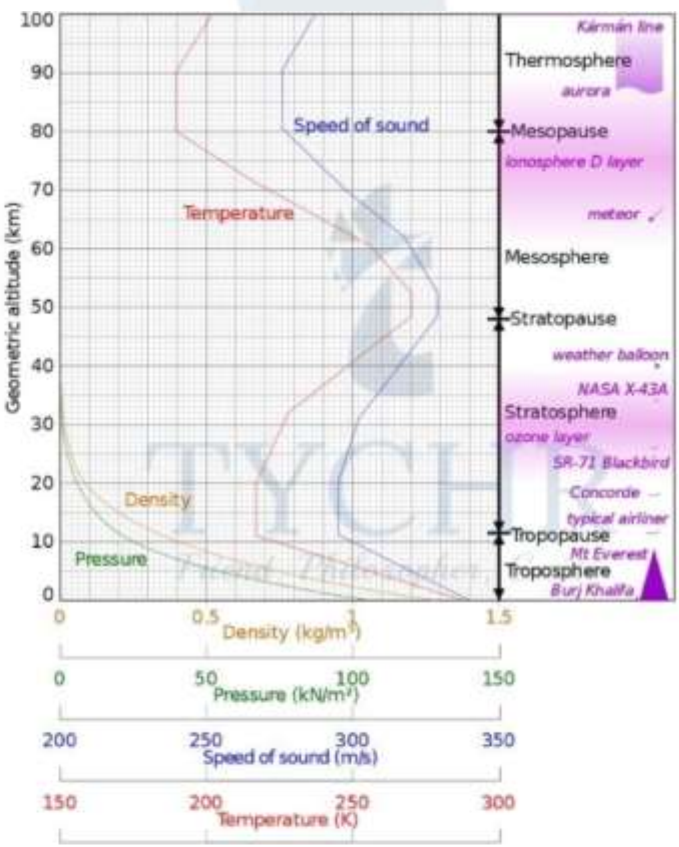


Figure 4 Changes in temperature and composition with altitude.

6.1.2 Earth's Energy Budget

The Earth's energy is mostly derived from the Sun. Insolation refers to incoming solar radiation. Solar energy (short-wave energy) is received by the Earth and its atmosphere and transformed in a number of processes as illustrated in the figure. For every 100 units of solar energy reaching the Earth's atmosphere, 31% is reflected back to space, and 69% is absorbed by the Earth and the atmosphere.

6.1.3 Human Activities And Atmospheric Composition

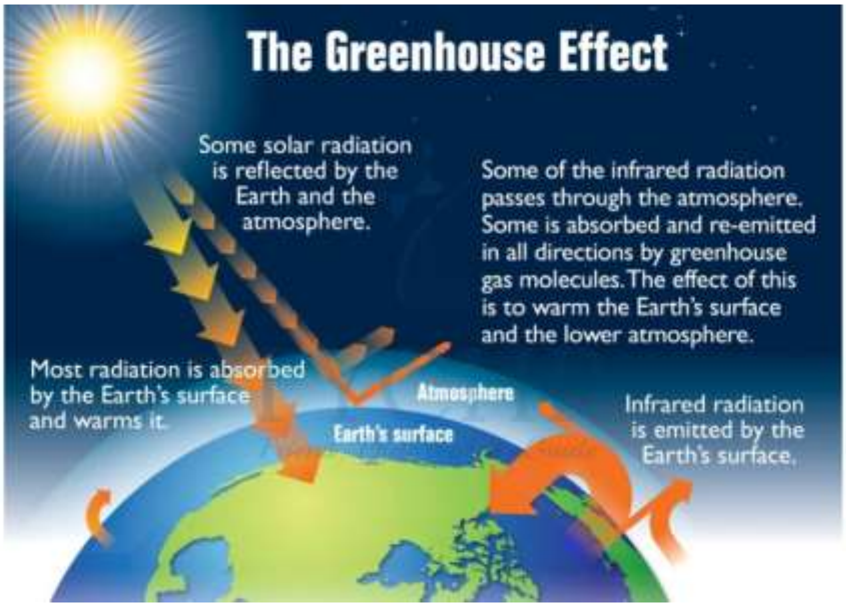
The main human activities releasing greenhouse gases are as follows:

- Burning of fossil fuels (that release carbon dioxide.
- Deforestation, which results in release of carbon dioxide due to breakdown in forest biomes.
- Increased intensive cattle farming has led to increased methane levels. This is because cattle ranching increases as the demand for beef increases.
- Fertilisers in agricultural systems has led to higher nitrous oxide (N2O) concentrations when the fertilisers break down.

6.1.4. The Greenhouse Effect

- The atmosphere maintains the temperature of the Earth.
- Within the atmosphere, certain gases trap the radiation that heats the surface.
- Shortwave ultraviolet (UV) light from the Sun is reflected from the surface of the Earth as infrared (IR) light (which has a longer wavelength). The process is sometimes known as 'radiation trapping'.

- This effect is caused mainly by water vapour and carbon dioxide. Other gases involved are methane (CH_4), nitrous oxide (N_2O), and ozone (O_3).
- The gases create a 'thermal blanket' that maintains an average Earth temperature that can support life.
- Because these gases act in the same way that glass acts in a greenhouse, they are called greenhouse gases and the effect they have is called the greenhouse effect.



Let's Revise

Troposphere – the lowest layer of the atmosphere extending from the ground's surface to the tropopause (between 10 km and 15 km).
Stratosphere – a layer of the Earth's atmosphere extending from the tropopause to about 50 km.
Albedo – the amount of incoming radiation that is reflected by the Earth's surface and atmosphere.

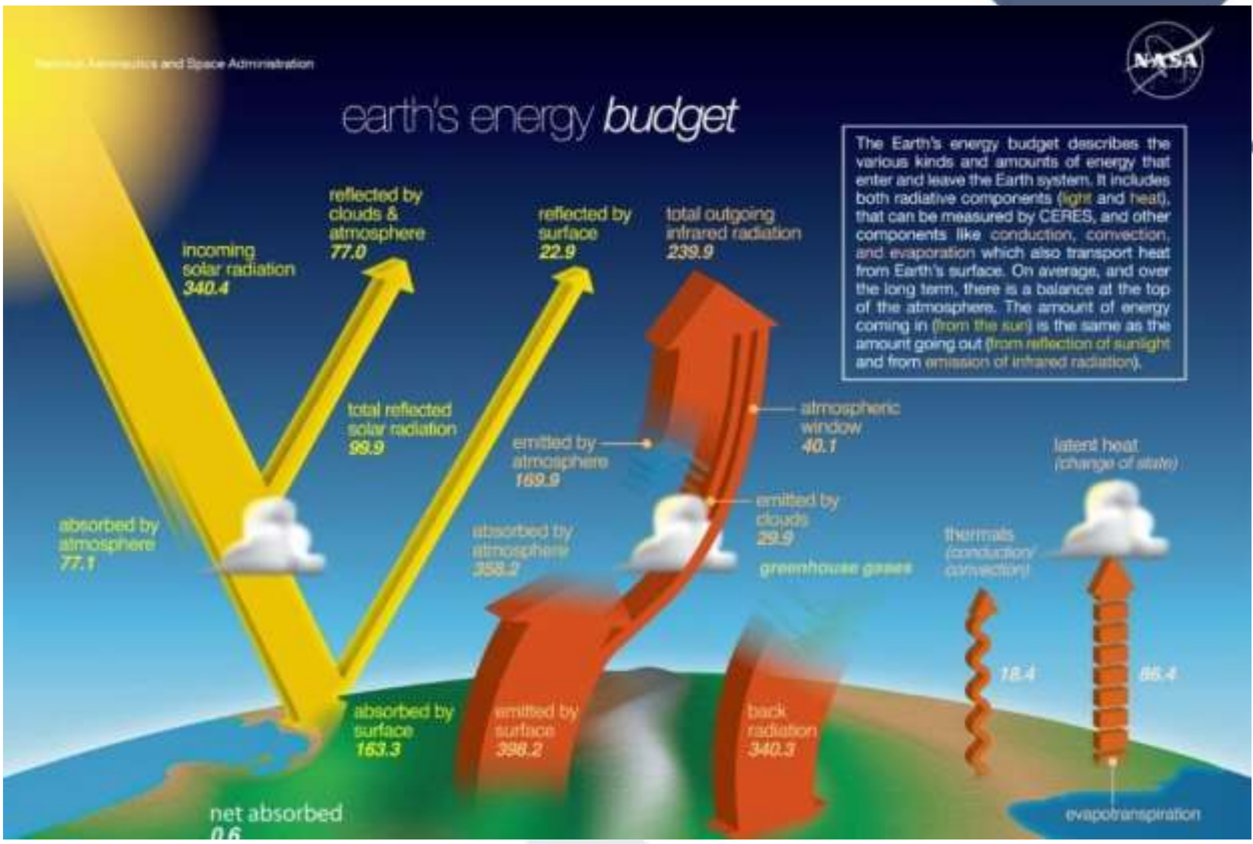


Figure 6 The greenhous effect.

6.2 Stratospheric Ozone

6.2.1 UV Radiation And Ozone

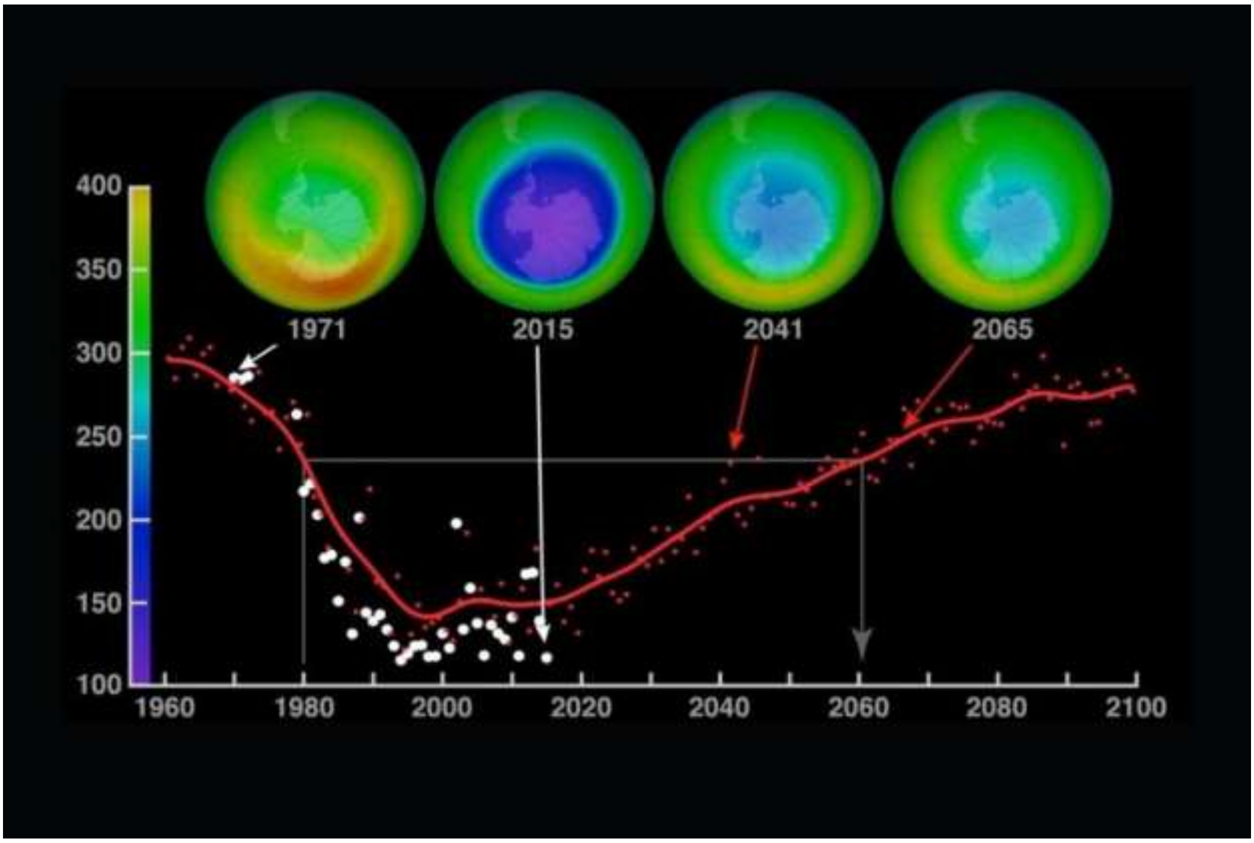


Figure 7 The ozone hole over Antarctica

Ozone is essential for sustaining life. The highest concentration of ozone occurs in the upper part of the atmosphere, the stratosphere, where it is formed through the action of UV radiation on oxygen. The ozone layer shields the Earth from harmful radiation that would otherwise destroy most life on the planet.

6.2.2 Ozone Depleting Substances Halocarbons

The chemicals that cause stratospheric ozone depletion include halocarbons. Halogens include chlorofluorocarbons (CFCs). These are found in many products, including aerosols and refrigerators. They can also be found in air, are sometimes found in pesticides and are also used for fire extinguishers and solvents.

Holes in the Ozone Layer

Pollutants increase the destruction of ozone. They change the equilibrium of the ozone production system. They cause “holes” in the ozone layer. The ozone hole is a thinning of the concentration of ozone in the stratosphere. The ozone “hole” allows more ultraviolet radiation to pass through the Earth’s atmosphere. This can be very damaging.

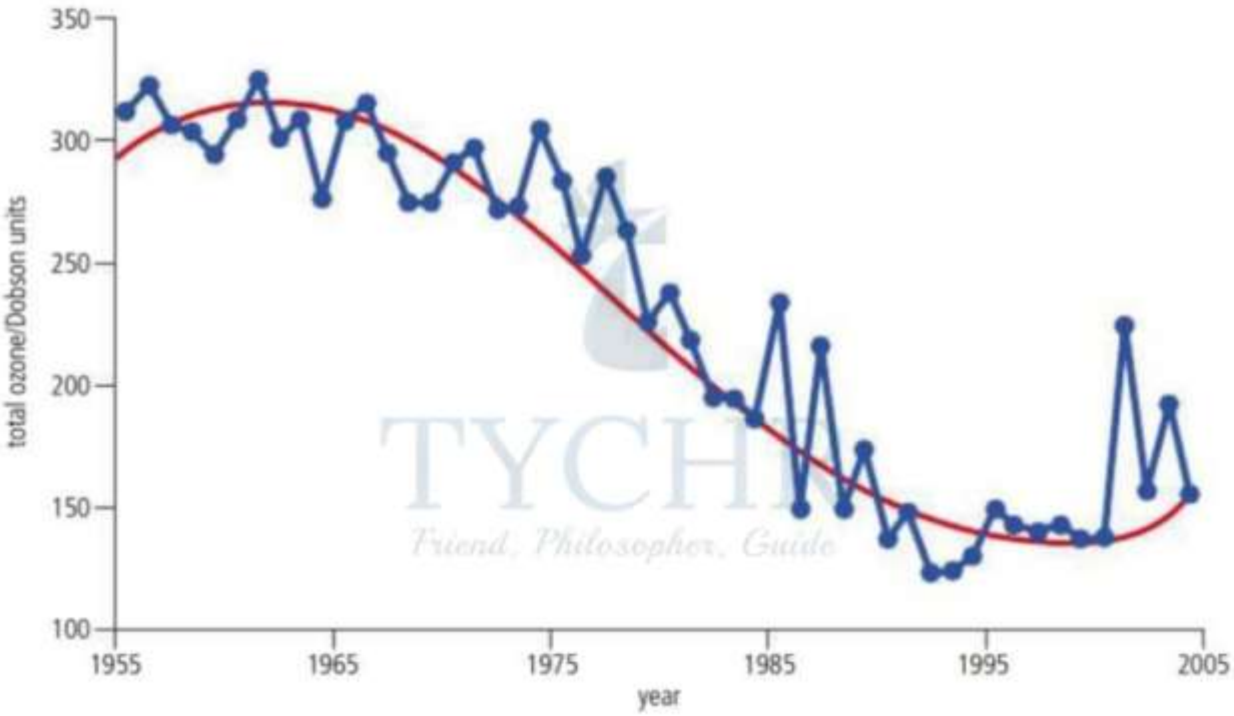


Figure 8 The October ozone levels over Antarctica 1955– 2005. The red line shows the trend in ozone levels whereas the blue line plo

6.2.3 Effects Of Ultraviolet Radiation On Human Health

- Increased ultraviolet radiation is damaging to ecosystems as it damages plant tissues and plankton.
- Effect on Aquatic Ecosystems- Ultraviolet radiation damages marine phytoplankton, which is one of the major primary producers of the biosphere. It causes reduced rates of photosynthesis. In aquatic ecosystems the organisms that live in the upper part of the water are most affected.

- UV radiation can also cause genetic mutations in DNA. There are also negative impacts on reproduction.
- Eye Damage and Skin Cancer- It causes cataracts. The effects of long-term exposure are irreversible and can cause blindness. It can also cause sunburn and eventually skin cancer. Research suggests annual loss of ozone is about 1% and there has been an increase in skin cancers of 4%.

6.2.4 Reducing Ozone-Depleting Substances

Recycling Refrigerants	**Alternatives To Gas- Blown Plastics And Propellants**	**Phase Out Of Methyl Bromide**
Fridges with ozone-depleting substances (ODSs) (halogenated organic gases (such as chlorofluorocarbons) and halogen atoms (such as chlorine), can be replaced with "greenfreeze" technology that uses propane and/or butane. Old CFC coolants in fridges and air conditioning units can be recycled.	Huge quantities of CFCs were used as propellants in aerosol sprays. Alternatives to aerosols can be used. A good example is using soap instead of shaving foam. Pump-action sprays and trigger sprays can be used instead of aerosols.	Methyl bromide gas has been used to control pests. There are alternative chemicals to methyl bromide. Some of these react in ultraviolet radiation to have an impact on germs. Other non-chemical alternatives include biofumigation and crop rotation. These are examples of organic farming. Cultivation of plants in water (hydroponics) can also reduce the risk of pests. An illegal market for ozone-depleting substances persists and

requires consistent monitoring. It exists because ODS substitutes are often more expensive than CFCs.

6.2.5 National And International Organizations And The Reduction Of ODSs

- The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer is the most significant and successful international agreement relating to an environmental issue. Nearly 200 governments have signed up and implemented the agreed changes according to the Montreal Protocol.
- It is believed that ozone could recover by 2050 as a result of the Montreal Protocol.
- Subsequent revisions have reduced the phasing out timescale because of success—phase-out in Europe was achieved by 2000. Total global phase-out is expected by 2030.
- The Protocol incentivized countries to find alternatives. It raised public awareness of the use of CFCs.
- Technology has been transferred to LEDCs to allow them to replace ozone-depleting substances. The success of the protocol depends on national governments agreeing to its requirements.

Figure 9 Antarctic ice melting at an increased rate because of rising global mean temperature due to increase in greenhouse gases.

6.3 Photochemical Smog

6.3.1 Source and Impact of Tropospheric Ozone

- Smog is formed as the result of pollution by volatile organic compounds (VOCs), carbon monoxide, carbon dioxide, black carbon or soot, unburned hydrocarbon, oxides of nitrogen (NOx), and oxides of sulphur.
- Primary pollutant- The main cause of photochemical smog (ground level/tropospheric ozone) is the volume of road transport concentrated in cities. Pollutants including hydrocarbons, carbon monoxide, carbon dioxide and nitrogen monoxide are released when fossil fuels are burned.
- Secondary pollutant- Tropospheric ozone—or ground-level ozone is formed by reactions involving oxides of nitrogen (NOx).
  Nitrogen monoxide reacts with oxygen in the presence of sunlight to form nitrogen dioxide (NO2). This is a brown gas that contributes to urban haze. It can also absorb sunlight and break up to release oxygen atoms that combine with oxygen in the air to form ozone.

Figure 10 Smog in Delhi in the past few years.

6.3.2 The Effects Of Tropospheric Ozone

- Effect on Forests and Crops
    - Interferes with the ability of sensitive plants to produce and store food
    - Damages the leaves of trees and other plants, harming the appearance of vegetation in urban areas, national parks, and recreation areas.
- Effect on Humans
    - Ozone can harm lung tissues, impair the body's defence mechanism, increase
    - Respiratory tract infections, and aggravate asthma, bronchitis, and pneumonia.
    - Even at relatively low levels, coughing, choking, and sickness increase.
    - The long-term effects include premature ageing of the lungs.

- Children born and raised in areas where there are high levels of ozone can experience up to a 15 per cent reduction in their lung capacity.

- Effects on Materials
  High levels of ozone can damage fabrics and rubber materials.
- Ozone and Smog Photochemical smog is associated with certain climates – in particular, high air pressure systems. This is because winds in a high-pressure system are usually weak. Hence pollutants remain in the area and are not dispersed.

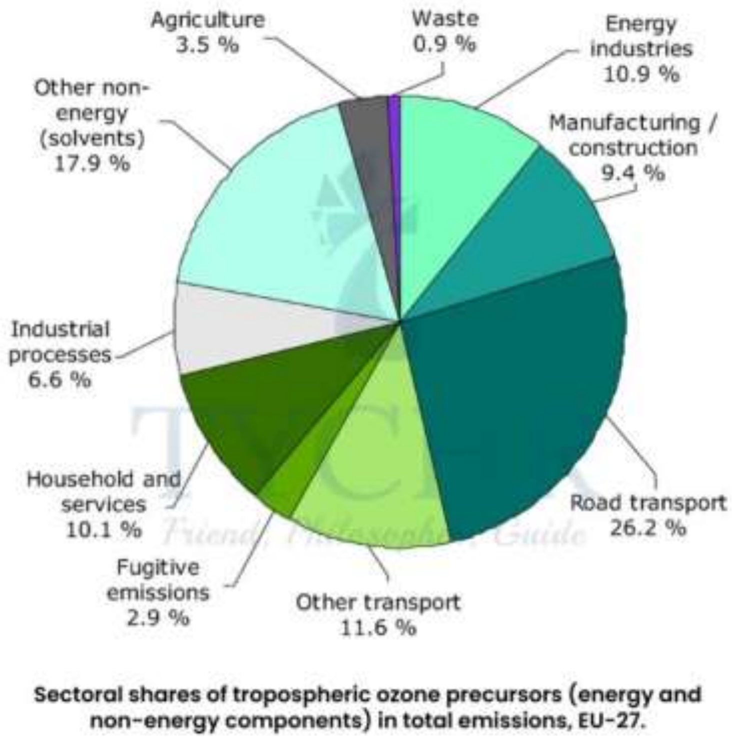


Figure 11 Sectoral shares of tropospheric ozone precursors (energy and non-energy components) in total emissions, EU-27.

6.3.3 Pollution Management Strategies

- Reduction in the burning of fossil fuels
- Greater use of energy-efficient technologies such as hybrid/electric cars
- Increased use of public transport rather than use of private cars
- Car pooling schemes
- Increased use of bicycles or walking

- Use of catalytic convertors to reduce emissions of NOx
- Greater enforcement of emissions standards
- Clean-up measures such as reforestation, re-greening, conservation areas
- Public information regarding air quality.

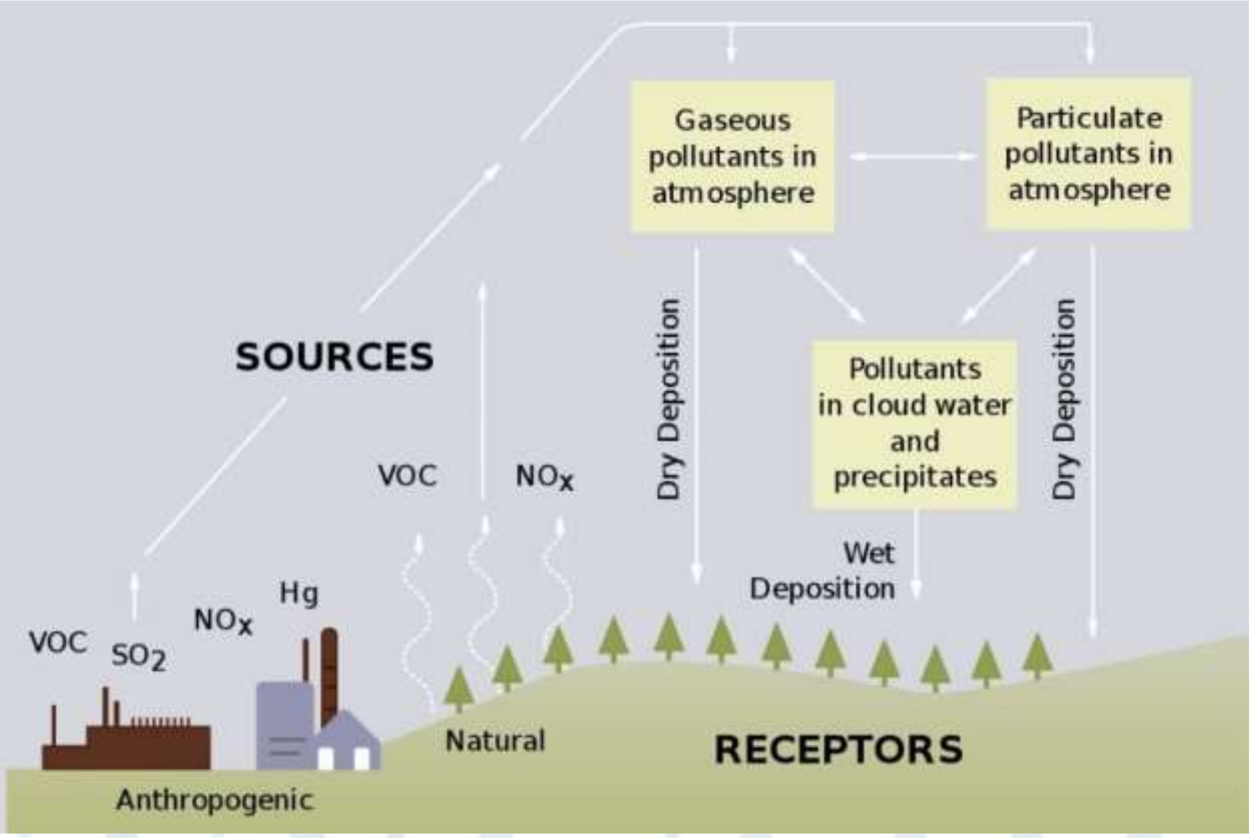


Figure 12 Temperature inversion may trap smog in valleys.

6.4 Acid Deposition

6.4.1 The Formation Of Acid Deposition

Acid deposition is the increased acidity of rainfall and dry deposition. This is largely as a result of human activity and is caused by carbon dioxide in the atmosphere combining with moisture in the atmosphere.
The major causes of acid rain are:

- The sulphur dioxide and nitrogen oxides produced when fossil fuels are burned.
- Sulphur dioxide and nitrogen oxides are released into the atmosphere. There they are absorbed by the moisture and become weak sulfuric and nitric acids.
- The pH can be as low as 3.
- Dry deposition typically occurs close to the source of emission and causes damage to buildings and structures.
- Wet deposition occurs when the acids are dissolved in precipitation and fall at great distances from the sources.

6.4.2 Direct Effects Of Acid Rain

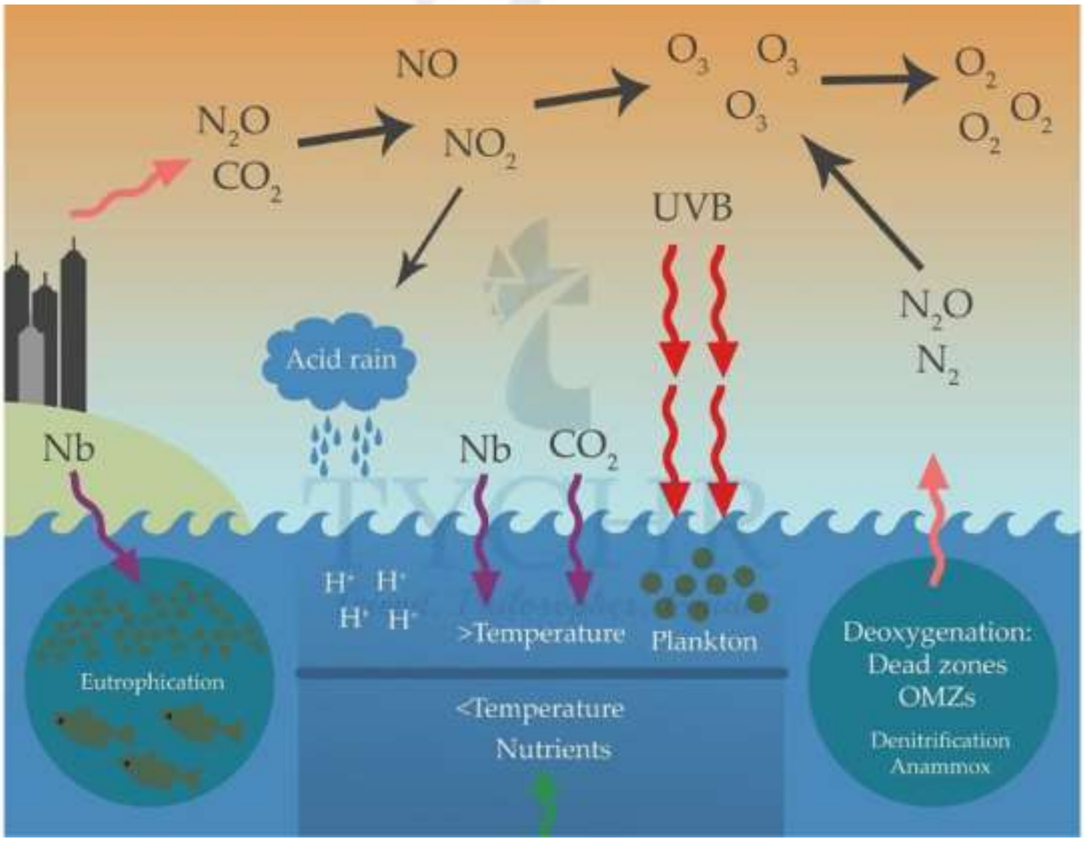


Figure 13 The formation of acid rain.fv

- When levels of acidity increase, many nutrients become unavailable to plants. These include nitrogen, phosphorus, molybdenum, and boron.

- Essential nutrients such as calcium and magnesium can be leached from a soil as it becomes more acidic, and this can be detrimental to plant growth.
- Other nutrients become more common and can be toxic to living organisms. Copper becomes more available in acidic soils. Iron and aluminium may be mobilised when soil pH becomes lower than 4.5.

Impact On Coniferous Trees	Impact On Living Organisms	Impact On Water
• Acid rain has many impacts on coniferous trees. This is because coniferous trees do not shed their leaves at the end of the year, so they are exposed to acid deposition all year round. • The trees may also take up toxic aluminium ions from the soil. • The trees fail to grow because of a lack of nutrients and the presence of too many toxins. • Root hairs may be damaged and so there is less uptake of water from the soil.	• Increasing acidity leads to falling numbers of fungi, bacteria and earthworms. Aluminium and mercury reduce the number of soil microorganisms. Earthworms cannot tolerate soils with a pH below 4.5. • Aluminium damages fish gills by causing mucus to build up, making breathing difficult.	• Iron and aluminium are washed from the soils into streams and lakes. The water may become too acidic to support fish.

- Needles are lost and there may be dieback of the crown.

6.4.3 Distribution Of Acid Depositio

- Areas producing the acid deposition are not the same as the regions receiving it. Coal fired power stations and heavy concentrations of vehicles emit vast quantities of sulphur dioxide and nitrogen dioxide.
- The main areas experiencing acid rain are those areas downwind of major industrial regions.
- Areas that are currently causing acidification include China and India. This is because both countries burn vast amounts of coal.
- Areas experiencing acidification usually have high rainfall and thin soils. Many of them have forests and lakes.
- Some environments are able to neutralise the effects of acid rain. This is called the buffering capacity. Chalk and limestone areas are very alkaline and can neutralise acids effectively.

6.4.4 Pollution Management Strategies

Altering Human Activity	Controlling The Release Of Pollutants
The first main type of strategy is to alter human activity and to reduce the production of pollutants. The most effective long-term treatment is to reduce the emissions of SOx and NOx. This can be achieved in a variety of ways, such as by: • Reducing the demand for electricity • Increasing the use of public transport and reducing the use of private cars • Using alternative energy sources that do not produce nitrate or sulphate gases.	The second method is to control the release of pollutants. Methods to achieve this include: • Using limestone scrubbers in the chimneys of power stations to neutralise the acid

- Removing the pollutants before they reach the atmosphere.

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+91 9540653900