Climate change, global warming, ozone layer depletion, Montreal and Kyoto protocols. Acid rain and impacts on human communities and agriculture.

Climate change is a change in the statistical distribution of weather patterns over a long period of time (i.e., decades to millions of years). Climate change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Certain human activities have been identified as primary causes of ongoing climate change, often referred to as global warming.

The Intergovernmental Panel on climate change (IPCC) is specialized body jointly established by United Nations Environment programme (UNEP) and World Meteorological Organization to prepare scientific assessment on various aspects of climate change. The fifth assessment report (AR5) of IPCC Suggests that world is destined to face temperature increase of at least 1.2-1.5^{0}C by mid 2030s.

Indian scenario: India ranked 13th most vulnerable country to climate change on the climate change vulnerability Index, 2014.India is the fourth largest GHG emitter contributing 5.8% of global emissions. According to AR5 net temperature in India will increase from 1.7-2.2^{0}C in 2030s with respect to 1970.The precipitation is also expected to increase.

These changes will have a cascading effect on health of economy and people of the world.

Global climate change is a scientifically more accurate term as effects such as changing patterns of rainfall and rising sea levels would probably have more impact than temperatures alone.

Greenhouse effect/ Global Warming

Green house /glass house is enclosure of glasses in which tropical plants are grown during winters in areas of colder climate as heat trapped by glass keeps the temperature inside greenhouse much higher than surrounding atmosphere. A natural greenhouse phenomenon exists in nature to keep earth warm at normal levels.

Solar energy striking the earth has much shorter wavelength ($\leq$ 3μm). Some of the radiant energy passes unaffected, some absorbed and some is scattered by various gases and aerosols in air. Many gases which are relatively transparent to incoming short wavelength from sun, tend to absorb long wavelength ($\geq$3 μm) radiated by earth (4 to 50 μm). Some of incoming and all outgoing thermal radiations are Infrared (IR ranges from 0.7um to 100um). When IR is absorbed by air molecules. It is re-emitted randomly in all direction. So, some is redirected back to earth and is reabsorbed and further heat's both surface and air. This phenomenon of redirection of thermal IR towards earth is called as greenhouse effect (Fig.). It is responsible

for average temperature of earth being $+15^0$C rather than -19^0C. The air molecules which absorb the IR are known as greenhouse gases (GHG)(Table).

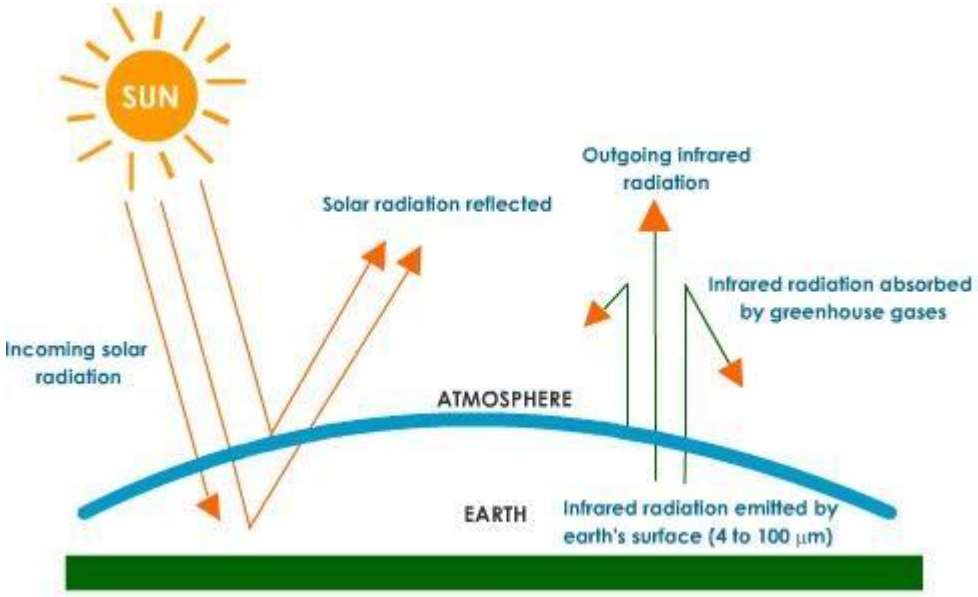

Fig: Greenhouse effect

The increase in concentration of trace gases (GHG) in air that absorbs thermal IR, has resulted in increase in average surface temperature of earth beyond 15°C. This phenomenon is known as enhanced greenhouse effect. This is leading to global warming. In a 2008, Erik M. Conway in a NASA article, defined global warming as the increase in Earth's average surface temperature due to rising levels of greenhouse gases while climate change was a long-term change in the Earth's climate, or of a region on Earth. As effects such as changing patterns of rainfall and rising sea levels would probably have more impact than temperatures alone, he considered global climate change a more scientifically accurate term.

Table: Sources, Concentrations and Global Warming Potential of major Greenhouse Gases

Greenhouse gases	Source	Global warming potential*	Concentration in 2011 (ppb**)
Carbon dioxide (CO_2)	Combustion of fossil fuels, forest clearing , cement production	1	3,90,000
Methane(CH_4)	Swamps ,wetlands , paddy fields, guts of livestock, biomass burning, landfills	12	1,803
Nitrous Oxide(N_2O)	Burning of fossil fuels, breakdown of nitrogen fertilizers, manures, nylon production	114	324
Chlorofluorocarbon-12 (CFC-12)	CCl_2F_2	10,900	0.527
Hydrofluorocarbon-23 (HFC-23)	CHF_3	14,800	0.024
Sulphur hexafluoride (SF_6)	Electricity transmission	22,800	0.0073
Nitrogen Trifluoride (NF_3)	Semiconductor manufacturing	17,200	0.00086

Source: Intergovernmental Panel on Climate Change IPCC

***** Global warming potential (GWP) is the ability of GHG to trap heat in atmosphere relative to an equal amount of CO_2.

**Atmospheric concentrations are all shown in (ppb).

Effects:

1. Rise in sea level: Global warming melts polar ice caps. Warm water expands so sea level will rise. Cities like shanghai, Mumbai, Dhaka, Sydney etc. may inundate. There can be inundation of coastal wetlands, drowning of coral reefs, increase in salinity of estuaries and aquifers and shoreline erosion.

Satellite observations reveal that the amount of spring snow cover in the Northern Hemisphere has decreased over the past five decades and that the snow is melting earlier. Glaciers in new Zealand, Southern Alps have lost 25% of their area in last 100 year. Glaciers on Mount Kenya and Kilimanjaro have lost over 60% of their area in last century, wastage of mountain glaciers during last century has raised sea level by between 0.2 to 0.4 mm/year.

2. Increase in global temperature: If current rate of emission of CO_2 continues, global temperature will surpass previous threshold of 2℃ average increase in temperature. 0.6℃ increase in temperature will increase 4% atmospheres' capacity to hold H_2O. This will bring greater storms and devastation. Ocean acidification is occurring due to increase atmospheric concentrations of carbon dioxide. The amount of carbon dioxide absorbed by the upper layer of the oceans is increasing by about 2 billion tons per year.

3. Ecological disturbance:

a) North America will be warmer and drier while North and East Africa, India, Western Australia, Mexico will be warmer and wetter.

b) Desert are expanding and there is loss of arable land.

c) Floods and droughts are likely to increase. As in Mahanadi river basin which sees increase possibility of floods in September and increase possibility of water scarcity in April.

d) Plants and animals are dispersing and migrating due to changing habitat. It can lead to extinction of many species which will not be able to migrate and worst affected are insect, butterflies and birds.

Migratory birds migrate long distances and their breeding season synchronises with their food. But climate change has led to shortage of food during breeding season, hence their population is showing decline.

It will cause extinction of more than 1 million sp. by 2050 AD

e) Forest: Forest fires are increasing, major change in vegetation and growth in new areas. E.g. we can see shift in cultivation of apple in Himachal Pradesh.

f) Wetland – They are drying and species diversity is decreasing.

4. Human Health: There is spread of vector borne diseases like malaria, dengue in temperate countries. For instance West Nile virus was not known in North America until a decade ago but now has infected 21,000 people in US and Canada and killed more than 800 people.

It has increased photochemical smog and increase water as well as air pollution. This has led to increase in respiratory diseases

5. Effect on Plants: Response of plant to elevated concentration of CO_2 is called as CO_2 fertilization effect. Under elevated CO_2 most plant species show higher rates of photosynthesis, increased growth, decreased water use and lowered tissue concentrations of nitrogen and protein. Rising CO_2 over the next century is likely to affect both agricultural production and food quality. The effects of elevated CO_2 are not uniform; but all beneficial effects are negated by ill effects such as increase evaporation, decrease soil moisture, increase pest growth. Rising atmospheric concentrations of CO_2 may therefore

lead to changes in the composition of plant communities. Plants with high CO_2 but low nitrogen content are nutritionally poor.

Climate change will have a substantial impact on mangrove ecosystems, due to rise in sea level, changing ocean currents, increased storminess, increased temperature, changes in precipitation and increased CO_2. Sunder bans (West Bengal) in India is one of visible victim of climate change.

Irregular rains have restricted cultivation to once in a year. It will lead to food crisis in future.

Measures to check global warming and climate change

1. Afforestation: We have to plant more and more trees because plants they not only release oxygen but take carbon dioxide during the process of photosynthesis. Reforestation to be done at deforested areas.

2. Climate-friendly alternatives: Fluorinated gases are used in refrigeration, air conditioning, in foams, aerosols, fire protection and solvents, and have a range of other industrial uses. GreenFreeze refrigeration technology developed in early 1990s uses hydrocarbons instead of HCFCs and HFCs. Hydrocarbons are ozone friendly, and have minimal GWP. Greenfreeze uses a mixture of propane (R290) and isobutane (R60Oa), or isobutane as a pure gas for the refrigerant.

3. Trap methane as fuel: Methane can be used to produce electricity, heat buildings and power garbage trucks. The researchers at Mexico have also found that change in diet of Cows can reduce methane emission.

4. **Energy-Efficient Appliances: B**uying products that are energy efficient. Energy-efficient products can help us save energy, save money and reduce our carbon footprint.

5. Use renewable and clean energy resources: We should use renewable and clean energy resources like solar, wind, geothermal and many more to reduce the amount of pollution. Electric, smart cars,

cars run on vegetable oil, etc. are great examples of using renewable energy. If we cannot afford electric cars, we should at least use cleanest fuel.

6. **Reduce Waste:** Reusing and recycling old items can reduce our carbon footprint as it takes less energy to recycle old items than to produce items from scratch. Refuging products which are contributor to Global warming is also required. Discourage plastic products.

7. Reduce pollution in Industries: Industries should install tall chimneys, use low sulphur coal, better designed equipment and smokeless fuels to reduce green house gases.

8. Improvement in Agriculture practices: No stubble burning, and covering bare soil with hay or dead vegetation so that it is protected from sun and it allows more water holding and more carbon capturing microbes.

9. **Save Energy:** When we consume less, the less carbon dioxide is released into the atmosphere. Turning off lights, electronic devices when not in use etc. can save energy.

10. Public awareness: More information is needed to be dissipated to populace so that they can reduce individual carbon footprints.

International initatives

Montreal protocol (1987): It is a global agreement to protect the stratospheric ozone layer by phasing out the production and consumption of ozone-depleting substances (ODS). ODSs are also greenhouse gases that contribute to the radiative forcing of climate change.

United Nations Framework Convention on Climate Change (**UNFCCC**):It is an international environmental treaty adopted at the Earth Summit in Rio de Janeiro 1992 and came into

force on 21 March 1994. The UNFCCC objective is to stabilize greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

The parties to the convention are meeting annually from 1995 in Conferences of the Parties (COP) to assess progress in dealing with climate change. In 1997, the Kyoto Protocol came into being and it established legal binding for developed countries, to reduce their greenhouse gas emissions in the period 2008–2012 (Binding targets for 37 nations was to reduce GHG by 5.2% against 1992 levels by 2008- 2012). The Protocol was amended in 2012 to encompass the period 2013–2020 in the Doha Amendment, but has not entered into force. In 2015, the Paris Agreement was adopted, it deals with GHG emissions, mitigations, adaptation and finance starting in year 2020.The Paris Agreement entered into force on 4 November 2016. Its main objectives are to hold global warming temperature below 2℃, 1.5℃ if possible and persuade developed world to contribute $100bn a year.

Following are India target to be achieve by 2030, under Paris agreement:

a. Reduce GHG emissions/ unit of GDP by 33-35% (as compared with 2005 levels).

b. At least 40% electricity generation from non fossil fuels

c. Increase forest cover to create additional carbon sink of 2.5-3 bn tonnes.

d. Increase solar, wind, biogas capacity.

It is of primary importance to mention that climate change and subsequent periods of glaciation are not only due to total amount of solar energy reaching the earth but below mentioned factors can also be considered.

1. Orbital Cycles (Milankovitch oscillations): Changes in orbit affects the amount as well as distribution of sunlight striking the earth both geographically and seasonally. There are three orbital cycles:

a) Orbital shape ranges between more and less elliptical on a cycle of about 100,000 year. It affects the amount of radiation received at the Earth's surface in different seasons.

b) Axial tilt is the inclination of the Earth's axis in relation to its plane of orbit around the Sun. Oscillations in the degree of Earth's axial tilt occur on a periodicity of 41,000 year from 21.5 to 24.5 degrees.

c) Earth's precession is Earth's slow wobble as it spins on axis. It has a periodicity of 23,000.

Although these orbital variations, changes total annual sunlight by about 0.1% but are enough to trigger climatic changes.

2. Solar cycle or solar magnetic activity cycle: It is periodic 11-year change in the Sun's activity (including changes in the levels of solar radiation and ejection of solar material) and appearance (changes in the number and size of sunspots and faculae). During peak magnetic activity Sun has large number of dark (sunspots) areas, accompanied by bright (faculae) areas. Sunspots dim the sun and faculae brighten it. These areas can cause variation of up to 0.2% in amount of sunlight reaching the earth during a solar cycle.

OZONE DEPLETION

Ozone and its Occurrence: Ozone is a pale blue, odorless gas composed of three atoms of oxygen (O_3), mainly present in stratosphere in the form of a thick sheet, called **ozonosphere.** The thickness of the ozone layer differs as per season and geography. The highest concentrations of ozone occur at altitudes from 26 to 28 km in the tropics and from 12 to 20 km towards the poles.

The ozone layer has the capability to absorb almost 97-99% of the harmful ultraviolet radiations that sun emit and which can produce long term devastating effects on humans beings as well as plants and animals. The ozone layer was discovered in 1913 by the French physicists Charles Fabry and Henri Buisson. Ozone has the same chemical structure regardless of where it occurs and can be useful or harmful depending on where it occurs in the atmosphere. When it is present in stratosphere it act as a protective layer but when the same is present in lower atmosphere near earth surface it is a pollutant.

Early 1960s scientists Rowland and Molina established that an ozone hole has occurred in the stratospheric ozone layer over Antarctica.

Causes of depletion of ozone layer: The main cause for the depletion of ozone is determined as excessive release of chlorine and bromine from various man-made compounds are found to have direct impact on the depletion of the ozone layer. These are categorized as ozone-depleting substances (ODS).

The problem with the Ozone-Depleting Substances (ODS) is that they are not washed back in the form of rain on the earth and in-fact remain in the atmosphere for quite a long time. With so much stability, they are transported into the stratosphere. The emission of ODS account for roughly 90% of total depletion of ozone layer in stratosphere. These gases are carried to the stratosphere layer of atmosphere where ultraviolet radiations from the sun break them to release chlorine (from CFCs) and bromine (from methyl bromide and halons).

The chlorine and bromine free radicals react with ozone molecule and destroy their molecular structure, thus depleting the ozone layer. One chlorine atom can break more than 1, 00,000 molecules of ozone. Bromine atom is believed to be 40 times more destructive than chlorine molecules.

Main Ozone Depleting Substances (ODS) are:

1.Chlorofluorocarbons (CFCs): It is the most extensively utilized ozone-depleting substance because it attributes to more than 80% of overall ozone depletion. It was utilized as a coolant in home appliances like freezers, refrigerators and air conditioners in both buildings and cars that were manufactured prior to 1995. It is usually contained in dry cleaning agents, hospital sterilants, and industrial solvents. It is also utilized in foam products like mattresses and cushions and home insulation.

2. Hydrofluorocarbons(HCFCs): Hydrofluorocarbons have over the years served in place of Chlorofluorocarbons. They are not as harmful as CFCs to ozone layer.

3. Halons: It is especially used in selected fire extinguishers in scenarios where the equipment or material could be devastated by water or extinguisher chemicals.

4. Carbon Tetrachloride: Also used in selected fire extinguishers and solvents.

5. Methyl Chloroform: Commonly utilized in industries for cold cleaning, vapor degreasing, chemical processing, adhesives and some aerosols.

Formation of ozone: Ozone is formed naturally in the upper stratosphere when wavelengths less than 240nm are absorbed by normal oxygen molecules which dissociate to give O atoms. The O atoms in combination with other oxygen molecules produce ozone. In the stratosphere, about 19 to 30 km above the Earth's surface, ozone is constantly being produced and destroyed naturally. This production and destruction makes stratosphere with ozone layer that filters the Ultra-Violet radiation from the Sun and protects life on Earth. Normally there is a fine balance between production and destruction of ozone thereby safeguarding life on Earth.

$$O_2 \xrightarrow{< 240nm} O + O$$

$$O + O_2 \longrightarrow O_3$$

Depletion of Ozone: Man-made chemicals such as Chloro fluoro carbons(CFCs) are used as aerosol sprays, refrigerants and coolants etc destroy ozone molecules in the stratosphere.

The CFCs themselves do not destroy ozone molecules but they decay ozone molecules at low temperatures. A small amount of chlorine atom and chlorine mono-oxide function as catalyst in the process of destruction of ozone. The equations involved are:

$$Cl + O_3 \longrightarrow ClO + O_2$$

$$ClO + O_3 \longrightarrow Cl + O_2$$

Hence, net effect:

$$O_3 + O = 2O_2$$

Chlorine atom in the above reaction functions as a catalyst and is not consumed in the reaction. Chlorine atom used in the reaction remains as chlorine atom even at the end of the reaction. Once chlorine has broken one ozone molecule, it is free to repeat the process until it is removed by another reaction in the atmosphere. Chloro-fluoro-carbons are very stable molecules and can live upto 100 years.

Dobson Unit

Dobson Unit (DU) is a unit of measurement for the total amount of ozone in the atmosphere above a point on the earth's surface, one Dobson unit being equivalent to a layer of pure ozone 0.01 mm thick at standard temperature and pressure.

Harmful effects of ozone layer depletion

Ozone layer protects all life forms on Earth from the Sun's harmful UV radiation. Any significant decrease in the amount of ozone in the stratosphere results in the amount of UV radiation reaching the Earth's surface leading to harmful effects on all living organisms.

1. **Effect on Human Health:** Human health is more prone to UV rays that reach the Earth's surface. Studies suggest that high levels of UV Rays cause non-melanoma skin cancer and play a major role in malignant melanoma development.

Direct exposure to UV rays can lead to development of cataracts which clouds the eye's lens. Permanent exposure to UV rays can also lead to weakening of the response of immune system and even permanent damage to immune system in some cases.

Extensive exposure to UV rays can lead to acceleration of the aging process of the skin. It means if humans will be overly exposed to strong UV rays they will look older than their age.

2. **Effect on Vegetation/Plants**

Many crops species are vulnerable to strong UV rays and overexposure may well lead to minimal growth, photosynthesis and flowering. Some of the crop species vulnerable to UV light include barley, wheat, corn, oats, rice, broccoli, tomatoes, cauliflower etc. Forests are equally affected by ozone depletion.

3. **Effect on marine life**

Exposure to strong ultraviolet rays also affects marine life, especially planktons. In the aquatic food chain, planktons appear high up. If planktons decrease in number due to ozone layer destruction, the marine food chain would be disrupted in many ways. Also, overexposure of sun rays could reduce the fortunes of fishers. On top of that, certain species of marine life have been greatly affected by overexposure to ultraviolet radiation at their early stage.

4. **Effect on animals**

In animals, particularly domesticated animals, too much Ultraviolet radiation could also lead to skin and eye cancer.

5. **Impacts certain materials**

Materials like plastics, wood, fabrics, rubber are massively degraded by exposure to too much ultraviolet radiation

Solutions to Ozone Depletion

1. **Utilize environmentally friendly cleaning products:** Most household cleaning products are loaded with harsh chemicals that find way to the atmosphere, eventually contributing to degradation of the ozone layer. Use natural and environmentally friendly cleaning products free from ozone depleting substances.
2. **Avoid using pesticides:** Pesticides are being used to rid of pests and weeds, but they contribute enormously to ozone layer depletion. Instead use alternative eco-friendly chemicals and other organic methods to check pests.
3. **Discourage driving of private vehicles:** The easiest technique to minimize ozone depletion is to limit the number of vehicles on the road. These vehicles emit a lot of greenhouse gases that eventually form smog, a catalyst in the depletion of ozone layer.
4. **Prohibit the use of harmful nitrous oxide:** The Montreal Protocol 1989 helped a lot in the limitation of Chlorofluorocarbons (CFCs). However, the protocol never covered nitrous oxide, which is a known harmful chemical that can destroy the ozone layer. Nitrous oxide is still in use today. Governments must take action now and outlaw nitrous oxide use to reduce the rate of ozone depletion.

ACID RAIN

Normal rain water is slightly acidic with a pH range of 5.3-6.0, because water and carbon dioxide present in the air react together to form carbonic acid, which is a weak acid. When the pH level of rain water falls below this range, it becomes acid rain. Thermal power plants, industries and vehicles release oxides of

sulphur and nitrogen into the atmosphere by burning of coal and other fossil fuels. When these gases react with water vapour in the atmosphere, they form acids and descend on earth as "acid rain" through rain water.

Two forms of acid depositions: From atmosphere, these acids are deposited over earth in two forms wet and dry.

a. **Wet deposition:** It occurs on earth in the form of rain, snow or fog.
b. **Dry deposition:** It refers to settling down of windblown acidic gases (oxides of nitrogen and sulphur) and other particles in dry state.

Due to the drifting of these gases in the atmosphere by wind, their presence is felt as far as 2000 km away. Air pollution in one nation can cause acid rain in another nation.

Thus, Acid rain or acid deposition refers to a mixture of deposited material, both wet and dry, coming from the atmosphere containing more than normal amounts of nitric and sulfuric acids, with the pH of less than 5.

A Scottish chemist, Robert Angust Smith, was first to discover this phenomenon in 1852 as a relationship between acid rain and atmospheric pollution in Manchester, England. But it gained public attention mainly after 1960s. Acidification of environment is a man made phenomenon. It is in fact a mixture of H_2SO_4 and HNO_3; the ratio of two acids varies depending on the relative quantities of oxides of sulphur and nitrogen present in the atmosphere. On an average, H_2SO_4 contributes 60-70% of acidity while HNO_3 contributes remaining 30-40%.

Main causes and formation of Acid rain:

Acid depositions may also be caused by natural causes such as **volcanic eruptions**, but **Oxides of sulphur and nitrogen (NO_x)** are the main causative agents for Acid rain and are primarily produced by **combustion of fossils fuels in smelters, industries, power plants, automobiles exhaust, domestic fires** etc. NO_x are also produced in atmosphere through lightening. In the atmosphere, SO_2 and NO_x are changed into Sulphuric Acid (H_2SO_4) and Nitric Acid (HNO_3) respectively by combining with oxygen and water.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$
$$SO_3 + H_2O \longrightarrow H_2SO_4 \text{ (Sulphuric acid)}$$
$$2NO + [O] \longrightarrow N_2O_5$$
$$N_2O_5 + H_2O \longrightarrow 2HNO_3 \text{ (Nitric acid)}$$

Simply, the formation of Acid rain can be depicted as**:**

$$SO_x + H_2O \longrightarrow H_2SO_4$$
$$NO_x + H_2O \longrightarrow HNO_3$$

Effects of Acid Rain

A. Effects on Environment and Biodiversity:

i. Acid rain increases acidity of soil, thereby affecting the chemistry of the soil and availability of nutrients to flora and fauna.

ii. Acid rain has been found to be very dangerous as it can destroy forests. In plants, it causes chlorosis, necrosis, defoliation of leaves etc., particularly at growing points.
Nearly half of the natural forests have been destroyed by acid rain in Europe (Germany, Sweden, Romania and Poland etc.,) and north-east United States. Most acidic rain (pH of 1.5) has occurred over West Virginia, U.S.A.

iii. It also results in acidification of water bodies, thus, affecting aquatic life. A pH of less than 5 kills planktons, molluscs and most of fishes in water bodies. Acid rain kills useful bacteria and blue green algae, in Sweden more than ten thousand lakes are acidic and in USA thousands of lakes are also turned acidic.

B. Effect of Acid Rain on human beings:

i. Acid rain has been found to be very dangerous to living organisms as it can destroy life. Human nervous system, respiratory system and digestive system are affected by acid rain.

ii. It can also cause premature death from heart and lung disorders such as asthma and bronchitis

C. Effect of acid rain on buildings

i. Acid rain corrodes houses, monuments, statues, bridges and fences. It corrodes metals, marbles painted surfaces, slate, stones etc.

ii. The **'Taj Mahal'** in Agra is affected from the acid fumes being emitted from 'Mathura Refinery'. Crystals of $CuSO_4$ and $MgSO_4$ are formed as a result of corrosion due to acid rain.

Thus, due to SO_2 and NO_x in the atmosphere, acids are formed and acid rain reacts with marble (Calcium Carbonate) of Taj Mahal and corrodes it. This phenomenon is known as **stone leprosy.** Chemical reactions involved are:-

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + CO_2 + H_2O$$

(Marble)

$$CaCO_3 + HNO_3 \longrightarrow Ca(NO_3)_2 + CO_2 + H_2O$$

Control Measures or solutions to Acid rain:

1. Use of clean fuel and pollution control equipments: Washing coal, use of coal comprised of low sulfur, and use of devices known as "scrubbers" can provide technical solution to So_2 emissions. "scrubbing". Power generation facilities can also shift to using fuels that emit much less So_2 such as natural gas instead of burning coal.

Similarly, No_x emissions from automobile fossil fuel combustions are mitigated upon by use of catalytic converters. Catalytic converters are fixed on the exhaust pipe system to reduce No_x emission. Improvement of gasoline that combusts cleaner is also a strategy for reducing emission of No_x gases.

2. **Use of Alternative sources of energy:** Besides fossil fuels, there is a wide range of alternative energy sources that can generate electrical power. These include wind energy, geothermal energy, solar energy, hydropower, and nuclear power. Harnessing these energy sources can offer effective electrical power alternatives instead of using fossil fuels.

3. **Restoring damaged environments:** Use of limestone or lime, a process called liming, is a practice that can be used to repair the damage caused by acid rain to lakes and rivers. Adding lime into acidic surface waters balances the acidity but it needs expertise. It's a process that has extensively been used, for instance in Sweden, to keep the water pH at optimum.

4. **Increasing Vegetation Cover:** More and more trees should be planted, aforestation and reforestation activites should be taken up at large scale as plants are the natural purifiers and reduce the concentration of these pollutants in air.

5. **Individual, national/state, and international actions:** Millions of people directly and indirectly contribute to So_2 and No_x emissions. Mitigation of this challenge requires individuals to be more informed about energy conservation and ways of reducing emissions such as, turning off lights or electrical appliances when not using them; use public transport; use energy efficient electrical appliances; and use of clean fuel etc.