



General Studies Manual for UPSC and State Public Services Examinations 2014

Environment, Biodiversity and Climate Change
Module-4: Environment Related Issues and Concepts-1

www.gktoday.in

First Published in 2010

Last Updated: June 2013

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Chapter 1. Land Degradation & Land Use Basics in India

Land degradation is any change or disturbance to the land perceived to be deleterious or undesirable. Land degradation can be caused by both manmade and natural reasons such as floods and forest fires. It is estimated that up to 40% of the world's agricultural land is seriously degraded.

Causes and Outcomes of Land Degradation

The main causes of the land degradation include

- ✓ Climate Change
- ✓ Land clearance and deforestation
- ✓ Depletion of soil nutrients through poor farming practices, Overgrazing and overgrafting, inappropriate irrigation.
- ✓ Urban sprawl and commercial development
- ✓ Soil Pollution.

The major outcomes of land degradations are:

- ✓ Decline in the productive capacity of the land (temporary or permanent)
- ✓ Decline in the lands "usefulness".
- ✓ Loss of biodiversity

Land rehabilitation is the process of returning the land to some degree of its former state, after some process (industry, natural disasters, etc.) has resulted in its damage.

Land rehabilitation has been a major priority since Independence, and several policies and government agencies address desertification and degradation. These include various programmes such as **Desert Development Programme**; **Integrated Wasteland Development**; **National Watershed Development Project for Rainfed Areas**; Soil Conservation in the Catchment of River Valley Projects; National Afforestation Programme; Arid Zone Research; Mahatma Gandhi National Rural Employment Guarantee Scheme; National Rural Drinking Water Programme etc.

- ✓ Increased vulnerability of the environment or people to destruction or crisis
- ✓ Accelerated soil erosion by wind and water
- ✓ **Soil acidification** and the formation of acid sulfate soil resulting in barren soil
- ✓ **Soil alkalinisation** owing to irrigation with water containing sodium bicarbonate leading to poor soil structure and reduced crop yields
- ✓ **Soil salination** in irrigated land requiring soil salinity control to reclaim the land
- ✓ **Soil waterlogging** in irrigated land which calls for some form of subsurface land drainage to remediate the negative effects.
- ✓ Destruction of soil structure including loss of organic matter.

The extent of net sown area, forest cover and fallow land in India

India has total geographical area of 328.73 Million hectares. Out of this, 146.82 Million hectares of land is degraded land, which is little less than half of total area.

The land has suffered degradation due to many reasons such as water and wind erosion and other complex problems like alkalinity/salinity and soil acidity due to water logging. According to a 2005-06 classification of the land use in India, approx. 43% of the total land area in India is **net sown area** which is the largest segment. It is followed by **forests which cover 23%** and **fallow land** which is 8%.

What is Fallow Land?

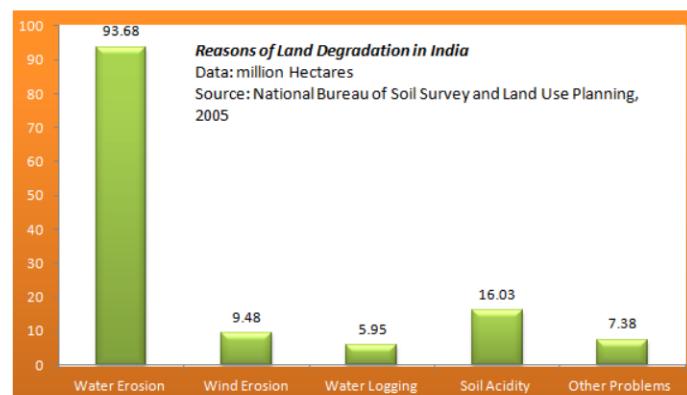
Fallow land is Undeveloped but potentially useful land. If a land is generally cultivated but is not seeded in current growing season, it is called Current Fallow Land.

The most prominent reason of land degradation

If we analyze the degraded land area by the prominent reason of degradation, we find that **Water Erosion is the most prominent reason of land degradation** in India, followed by **Soil acidity**. The adjacent graphics shows this.

The driver of Land Degradation

The important drivers of the land degradation are deforestation, cutting beyond the silviculturally permissible limits, unsustainable fuel-wood and fodder extraction, shifting cultivation, encroachment into forest lands, forest fires, over-grazing high natural hazards, nonadoption of adequate soil conservation measures, improper crop rotation, indiscriminate use of agro-chemicals such as fertilizers and pesticides, improper



planning and management of irrigation systems and extraction of groundwater in excess of the recharge capacity.

The net sown area versus the net irrigated area

Out of India's total geographical area (328.7 million hectares), 141.89 million hectares is the net sown area, while 192.80 million hectares is the gross cropped area. The net irrigated area is 60.20 million hectares, which is around 42% of the total net sown area. *This implies that less than half of net sown area in India is net irrigated.* Over the past fifty years, while India's total population increased by about three times, the total area of land under cultivation increased by only 20.2 per cent (from 118.75 Mha. in 1951 to 141.89 Mha. in 2005-06). Most of this expansion has taken place at the expense of forest and grazing land. Despite fast expansion of the area under cultivation, less agricultural land is available on per capita basis.

The environmental impact of land use patterns

The land use pattern is directly related to the Environment. Direct consequences of agricultural development on the environment arise from **intensive farming activities**, which contribute to soil erosion, land salination and loss of nutrients. The introduction of Green Revolution in the country has been accompanied by over-exploitation of land and water resources and excessive usage of fertilizers and pesticides. Shifting cultivation (or Jhum cultivation) has also been a major factor responsible for land degradation in hilly areas. *Leaching due to extensive use of pesticides and fertilizers* is a major source of contamination of water bodies. Enhanced *intensification and extensification also leads to salination, alkalization and water logging in irrigated areas, along with eutrophication of water bodies and ill health of oceans, leading to loss of biodiversity.* For achieving and maintaining food security and sustainable forestry, controlling of land/soil erosion is extremely vital.

The Impact of Shifting Cultivation

The current practice of shifting cultivation in the eastern and north-eastern regions of India is an extravagant and unscientific form of land use. According to a recent estimate, India's 0.59 percent of the total geographical area is under shifting cultivation. The effects of shifting cultivation are devastating and far-reaching in degrading the environment and ecology of these regions. *The earlier 15–20 years cycle of shifting cultivation on a particular land has reduced to two or three years now.* This has resulted in large-scale deforestation, soil and nutrient loss, and invasion by weeds and other species. The indigenous biodiversity has been affected to a large extent. The current statistics say that *India's largest area under shifting cultivation is in the state of Odisha.*

Discrimination in Chemical fertilizers usage

There is excessive use of urea and a bias against micronutrients. *Because nitrogenous fertilizers are subsidised more than potassic and phosphatic fertilizers,* the subsidy tends to benefit the crops and

regions which require higher use of nitrogenous fertilizers as compared to crops and regions which require higher application of P and K. The excessive use of urea has also affected the soil profile adversely.

Environmental Impact of Burning Straw

Burning of wheat and rice straw and other agricultural residue **has also contributed to loss of soil fertility**, apart from causing air pollution. Open field burning of straw after combine harvesting is a common practice in states like Punjab, Haryana and Uttar Pradesh **in order to ensure early preparation of fields for the next crop**. Punjab alone produces around 23 million tonnes of rice straw and 17 million tonnes of wheat straw, annually. This straw is rich in nitrogen, phosphorus and potassium. However, instead of recycling it back into the soil by mulching, it is burnt in the fields. This raises the temperature of the soil in the top three inches to such a high degree that the carbon:nitrogen equilibrium in soil changes rapidly. The carbon as CO₂ is lost to the atmosphere, while nitrogen is converted into a nitrate. This leads to a **loss of about 0.824 million tonnes of NPK from the soil**. This is about 50 per cent of the total fertilizer consumption in the state.

Impact of Mining

Land degradation is considered to be unavoidable by-product of mining and has reached alarming proportions, mainly due to over-exploitation and mismanagement of natural resources. Mining activity often leads to environmental problems like land degradation, particularly in opencast mining and land subsidence in underground mining. Open-cast mining in areas with forest cover causes deforestation.

Impact of Floods

The increasing frequency of floods in India is largely due to deforestation in the catchment areas, destruction of surface vegetation, change in land-use, increased urbanization and other developmental activities. The main reason, however, is the increased sedimentation and reduced capacity of drainage systems. Consequently, streams and rivers overflow their banks, flooding the downstream areas.

Aridity and Deserts

In India, 228.3 Mha. of geographical area comprises arid (50.8 Mha.), **semi-arid (123.4 Mha.)** and dry sub-humid regions (54.1 Mha.). Western parts of Rajasthan and Kutch are chronically drought affected. As a matter of fact, droughts occur frequently in the areas affected by desertification.

Soil Pollution

Soil pollution from heavy metals due to improper disposal of industrial effluents, along with the excessive use of pesticides and mismanagement of domestic and municipal wastes, is becoming a

major concern. Some commercial fertilizers also contain appreciable quantities of heavy metals, which have undesirable effects on the environment.

Chapter 2. Soil Pollution

Soil pollution is defined as the build-up in soils of persistent toxic compounds, chemicals, salts, radioactive materials, or disease causing agents and other xenobiotic (man-made) chemicals or other alteration in the natural soil environment.

- ✓ Soil contamination can be caused by:
- ✓ Application of pesticides and fertilizers
- ✓ Mining
- ✓ Oil and fuel dumping
- ✓ Disposal of coal ash
- ✓ Leaching from landfills
- ✓ Drainage of contaminated surface water into the soil
- ✓ Discharging urine and faeces in the open
- ✓ Burning of wheat and rice straw
- ✓ Rapture of underground storage tanks

The most common chemicals involved in soil pollution are petroleum hydrocarbons, solvents, pesticides, lead, and other heavy metals.

A soil pollutant is any factor which deteriorates the quality, texture and mineral content of the soil or which disturbs the biological balance of the organisms in the soil. Pollution in soil has adverse effect on plant growth.

Pollution in soil is associated with_:

- ✓ Indiscriminate use of fertilizers
- ✓ Indiscriminate use of pesticides, insecticides and herbicides
- ✓ Dumping of large quantities of solid waste
- ✓ Deforestation and soil erosion

What are Soil sediments?

Soil sediments refer to the depositions of trace elements or metals such as Hg, As, Sb, Cd, Ni, Co, Mo, Cu and Cr.

The process of sedimentation is a comprehensive natural geomorphologic process, which operates through the chain of erosion of soils, transportation of sediments (eroded material) and deposition of the eroded material in different paths of water bodies. Sediments thus consist of soil and mineral particles washed away from land by storms and floodwaters, from geological process of denudation, which is both inevitable and universal. Eroded soil becomes a serious pollutant because of the absorbed chemicals that it carries to the particles surface.

The have been objectively discussed below:

Indiscriminate use of fertilizers

- ✓ Fertilizers contaminate the soil with impurities, which come from the raw materials used for their manufacture. Mixed fertilizers often contain ammonium nitrate (NH_4NO_3), phosphorus as P_2O_5 , and potassium as K_2O . *The Arsenic, Lead and Cadmium present in traces in rock phosphate mineral get transferred to super phosphate fertilizer.*

- ✓ Since the metals are not degradable, their accumulation in the soil above their toxic levels due to excessive use of phosphate fertilizers, becomes an indestructible poison for crops.
- ✓ Further, over use of NPK fertilizers reduce quantity of vegetables and crops grown on soil over the years.
- ✓ It also **reduces the protein content of wheat, maize, grams**, etc., grown on that soil. The carbohydrate quality of such crops also gets degraded. Excess potassium content in soil decreases Vitamin C and carotene content in vegetables and fruits. The vegetables and fruits grown on overfertilized soil are more prone to attacks by insects and disease.

Indiscriminate use of pesticides

- ✓ The most important pesticides are DDT, BHC, chlorinated hydrocarbons, organophosphates, aldrin, malathion, dieldrin, furodan, etc. The remnants of such pesticides get adsorbed by the soil particles, which then contaminate root crops grown in that soil.
- ✓ The consumption of such crops causes the pesticides remnants to enter human biological

The First Insecticides and Biomagnification

The first widespread insecticide use began at the end of World War II and included DDT (dichlorodiphenyltrichloroethane) and gammexene. Insects soon became resistant to DDT and as the chemical did not decompose readily, it persisted in the environment. Since it was soluble in fat rather than water, it biomagnified up the food chain and disrupted calcium metabolism in birds, causing eggshells to be thin and fragile. As a result, large birds of prey such as the brown pelican, ospreys, falcons and eagles became endangered. DDT has been now been banned in most western countries. Ironically many of them including USA, still produce DDT for export to other developing nations whose needs outweigh the problems caused by it.

systems, affecting them adversely.

- ✓ Pesticides not only bring toxic effect on human and animals but also decrease the fertility of the soil. Some of the pesticides are quite stable and their bio-degradation may take long times such as years.

Sources of Solid Waste

Agriculture as source of Solid Waste

The lignocellulosic biomass generated by agricultural activities is a primary source of solid waste.

In addition, the use of fertilizers and pesticides in agricultural practices can limit the ability of soil organisms to process waste, which in turn makes the soil less productive or in the worst-case scenario, useless or even poisonous.

Some pesticides can remain in the environment for many year and pass from one organism to another. When pesticides are present in a stream, small fish and other organisms build up even larger amounts of pesticides in their flesh and will eventually pass them on to us through the food chain. There are many other human activities, which can damage soil. The irrigation of soil in dry areas with poor drainage can leave fields flooded. When this standing water evaporates, it leave salt deposits behind, making the soil too salty for growing crops.

Industries as source of wastes

Disposal of industrial waste is the major problem responsible for soil pollution. These industrial pollutants are mainly discharged from pulp and paper mills chemical industries, oil refineries, sugar factories, tanneries, textiles, steel, metal processing industries, drugs, glass, cement, petroleum and engineering industries.

Mining as source of wastes

Mining operations can leave soil polluted with toxic heavy metals. Many scientists believe acid rain can also reduce soil fertility. In surface mining and strip mining top soil and sub-soil is removed. This leaves deep salt in the earth.

The uncontrolled mine fires may also destroy the productivity of certain land areas permanently. Soil damage and environmental degradation during surface mining is inevitable as vegetation has to be removed and huge quantities of top soil and waste rocks are to be shifted to a new location, mining leads to loss of grazing and fertile land, soil erosion from waste dumps, sedimentation or silting, danger to aquatic life, flora and fauna as well as water and soil pollution.

Municipal and urban waste

This waste comprises both commercial and domestic wastes consisting of dried sludge of sewage. All the urban solid wastes are commonly referred to as refuse.

Solid wastes and refuse, particularly in urban area contribute to soil pollution. This refuse contains garbage and rubbish materials like plastics, glasses, metallic cans, fibres, rubbles, trash from the streets, fuel residues, leaves containers, abandoned vehicles and other discarded manufactured products.

Municipal waste is largely categorized into three type; waste that can be incinerated (generally called "combustible waste") waste that is treated by non-incineration intermediate treatment measures (generally called "incombustibles") and materials that directly go to recycling or re-use procedures through separate collection or voluntary group collection.

The waste generated from agriculture, municipal and commercial activities are putrid solid waste and is known as garbage. There are four broad categories of garbage.

- ✓ Organic waste
- ✓ Kitchen waste, vegetables, flowers, leaves and fruits.
- ✓ Toxic waste

Old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries and so on.

Recyclable Waste

paper, glass, metals and plastics.

Resistant objects

large resistant objects such as cans, plastic, tyres, polythene, metallic junk, glasses or even old cars, refrigerators, washing machines destroys the beauty of landscape. In India, most of this is

purchased by hawkers and resold. In industrialized countries, used vehicles are creating a serious threat to environment.

Dumping of Soil Waste

Solid waste includes garbage, domestic refuse and discarded solid materials such as those from commercial, industrial and agricultural operations.

The portion of solid waste that is hazardous such as oils, battery metals, heavy metals from smelting industries and organic solvents are the ones we have to pay particular attention to. These can in the long run, get deposited to the soils of the surrounding area and pollute them by altering their chemical and biological properties.

Deforestation & Soil Erosion

- ✓ Forests and grasslands are an excellent **binding material** that keeps the soil intact and healthy. They support many habitats and ecosystems, which provide innumerable feeding pathways or food chains to all species. Their loss would threaten food chains and the survival of many species. The depletion of forest cover leads to increased run-off of rainwater and diminished storage in the soil. The structure of the soil is thus, greatly influenced by lack of organic matter as a result of which run-off increases
- ✓ Deforestation is slowly destroying the most productive flora and fauna areas in the world, which also form vast tracts of a very valuable sink for CO₂.

Destruction of pastures and overgrazing

- ✓ A property managed, lightly grazed pasture might form a permanent protection to soil because it provides an efficient cover for preventing erosion and reducing run-off.

Shifting cultivation

In Shifting cultivation, plots of land are cultivated temporarily, then abandoned. This system often involves clearing of a piece of land followed by several years of wood harvesting or farming, until the soil loses fertility. Once the land becomes inadequate for crop production, it is left to be reclaimed by natural vegetation, or sometimes converted to a different long-term cyclical farming practice. Slash-and-burn is one element of their farming cycle. Land clearing without any burning is also used.

The major characteristic of Shifting Cultivation is that the cultivated or cropped area is shifted regularly to allow soil properties to recover under conditions of natural successive stages of re-growth. It is known as Jhum Cultivation in India and Ladang in Malaysia.

The longer a field is cropped, the greater the loss of soil organic matter, the reduction in the cation-exchange-capacity and in nitrogen and phosphorus, the greater the increase in acidity, the more likely soil porosity and infiltration capacity is reduced and the greater the loss of seeds of naturally occurring plant species from soil seed banks.

The indiscriminate destruction of forest for shifting cultivation has also reduced the forest cover. Shifting or jumping cultivation is mainly practiced by the tribal communities for raising food.

Effect of Soil Pollution

- ✓ Pollutants runs off into rivers and kills the fish, plants and other aquatic life
- ✓ Crops and fodder grown on polluted soil may pass the pollutants on to the consumers
- ✓ Polluted soil may no longer grow crops and fodder
- ✓ Soil structure is damaged (clay ionic structure impaired)
- ✓ Corrosion of foundations and pipelines
- ✓ Impairs soil stability
- ✓ May release vapours and hydrocarbon into buildings and cellars
- ✓ May create toxic dusts
- ✓ May poison children playing in the area

Chapter 3. Vermicompost

Vermicompost is the product or process of composting utilizing various species of worms, usually red wigglers, white worms, and earthworms to create a heterogeneous mixture of decomposing vegetable or food waste, bedding materials, and vermicast.

Benefits for Soil

- ✓ Vermicast, similarly known as worm castings, worm humus or worm manure, is the end-product of the breakdown of organic matter by a species of earthworm.
- ✓ Vermicompost is an excellent, nutrient-rich organic fertilizer and soil conditioner.
- ✓ Vermicompost improved the physical make up of upper layers of soil, enriches soil with micro-organisms (adding enzymes such as phosphate and cellulose).
- ✓ The microbial activity in worm castings is 10 to 20 times higher than in the soil and organic matter that the worm ingests, it also attracts deep-burrowing earthworms already present in the soil and the mucus present in vermicast improves water holding capacity
- ✓ **Benefits for Plant growth**
- ✓ Vermicompost enhances germination, plant growth, and crop yield and improves root growth and structure.
- ✓ It enriches soil with micro-organisms (adding plant hormones such as auxins and gibberellic acid)

Economic Benefits

- ✓ Biowastes conversion reduces waste flow to landfills. Elimination of biowastes from the waste stream reduces contamination of other recyclables collected in a single bin (a common problem in communities practicing single-stream recycling).

- ✓ The production also creates low-skill jobs at local level. Vermicompost has low capital investment and relatively simple technologies make vermicomposting practical for less-developed agricultural regions

Environmental Benefits

- ✓ Vermicompost helps to close the "metabolic gap" through recycling waste on-site. Large systems often use temperature control and mechanized harvesting, however other equipment is relatively simple and does not wear out quickly. Production reduces greenhouse gas emissions such as methane and nitric oxide (produced in landfills or incinerators when not composted or through methane harvest)

Disadvantages / Issues

- ✓ Moisture, air circulation and compost quantity need regular monitoring otherwise the Vermicompost will smell like an old garbage. The quality of Vermicompost deteriorates in anaerobic environment.
- ✓ Vermicompost can be carried out at relatively low temperatures (under 25 °C) only. It is vitally important to keep the temperature below 35 °C, otherwise the earthworms will be killed.
- ✓ Vermicompost is time consuming. It can take many months, or even years, to build up a large working population of earthworms capable of vermicomposting significant quantities of waste. As well as this, earthworms (sometimes in large numbers) tend to escape during damp weather conditions or when food is in short supply.

Chapter 4. Air Pollution and Air Quality Control

Reasons of Air Pollution

Apart from population pressure, air pollution and its resultant impacts can be attributed to emissions from vehicular, industrial and domestic activities. India's urban air quality ranks amongst the world's worst. Of the three million premature deaths in the world that occur each year due to outdoor and indoor air pollution, the highest numbers are assessed to occur in India. Air borne emissions emitted from various industries are a cause of major concern. These emissions are of two forms, viz. solid particles (SPM) and gaseous emissions (SO₂, NO_x, CO, etc.).

Primary & Secondary level Air pollutants

Air Pollutants can be solid particles, liquid droplets, or gases. They can be natural or manmade. The pollutants have been classified into primary and secondary categories.

- The **primary pollutants** are "directly" emitted from the processes such as fossil fuel consumption, Volcanic eruption and factories. The major **primary pollutants** are Sulphur

oxides, Nitrogen Oxides, Carbon dioxide, particulate matter, Methane, Ammonia, Chlorofluorocarbons, Toxic metals etc.

- The **secondary pollutants are not emitted directly**. The secondary pollutants form when the primary pollutants react with themselves or other components of the atmosphere. Most important **secondary level Air Pollutants** are **Ground Level Ozone, Smog and POPs**.

Primary Air Pollutants

The **Sulphur Oxides** are generally a product of the Volcanoes, Industrial processes, Coal and petroleum, because most of them have Sulphur as a component. The Sulphur Dioxide in presence of a catalyst such as NO₂ causes Acid Rain, because of the formation of Sulphuric Acid. The Indian Coal is though low in sulphur content but still coal consumption is a major danger of acid rain because of the coal based power plants.

Most of the **Nitrogen Oxides** are produced due to high temperature combustion. In the cities the brown haze dome above the cities is mostly because of the Nitrogen Oxides. The most important toxic gas is Nitrogen dioxide which is brown, with sharp odor.

Carbon Monoxide, which is colourless, odourless and non irritating but very poisonous gas is the product of incomplete combustion of the natural gas, coal or wood. The vehicle exhaust is the major source of CO.

The Carbon *Dioxide is associated with the Ocean Acidification* and is emitted from combustion, factories and respiration of living organisms.

Then, we have primary pollutants such as **Volatile Organic Compounds or VOCs** which are methane (CH₄) and **non-methane (NMVOCs)**.

- Methane is a GHG which contributes to Global Warming.
- The NMVOCs include the aromatic compounds such as Benzene, Toluene, Xylene which are proved or suspected carcinogens.
- Another dangerous compound is the 1,3-butadiene, often associated with industrial uses.

The particulate matters are the fine particles which may be either solid or liquid, suspended in a gas. They are different from the Aerosols. Aerosols are particle and gas referred together. The aerosols which are created by the Human activities are anthropogenic aerosols. They account for around 10% of the total aerosols in the atmosphere.

- Another category of the primary air pollutants is toxic metals such as Cadmium, Lead and Copper, which are products of the Industrial processes.

The Chlorofluorocarbons (CFCs) are proved to be harmful to the ozone layer emitted from products currently banned from use. In agriculture process, Ammonia is emitted which has characteristic

pungent odor. It is a precursor to foodstuffs and fertilizers. Ammonia is also a building block for the synthesis of many pharmaceuticals.

Secondary Air Pollutant – Ground Level Ozone

The most important secondary pollutant is the Ground Level Ozone or Tropospheric Ozone. Ground Level Ozone is formed by the reactions of the nitrogen oxides (NOx), Carbon Monoxide (CO) and Volatile Organic Compounds (VOCs) and NMVOCs such as Xylene in the atmosphere in the presence of sunlight.

In the last 100 years, the emission of **Methane** (a Volatile Organic Compound) has increased dramatically and it has contributed to the increased concentration of Ground Level Ozone.

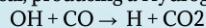
Thus, the Precursors to the Ground Level Ozone are NOx, CO, VOCs and NMVOCs.

Smog

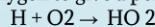
Formation of Ground Level Ozone

The formation of the Ground Level Ozone involves a long complex series of the reactions in which carbon monoxide and VOCs are oxidized to water vapour and carbon dioxide. The series of the reactions begins with the Hydroxyl OH radicals, which is one of the main chemical species controlling the oxidizing capacity of the global Earth atmosphere. They are produced by many pathways but most notably they are formed from the decomposition of hydro peroxides (ROOH) and by reaction of excited atomic oxygen with water. The reaction involves the following steps:

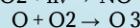
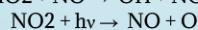
The Carbon Monoxide reacts with the Hydroxyl Radical, producing a Hydrogen atom.



The hydrogen atom formed by this reacts rapidly with oxygen to give a peroxy radical HO 2



Peroxy radical then reacts with the NO and gives NO2 which, in presence of Sunlight is photolysed to give atomic oxygen and through reaction with oxygen a molecule of ozone.



In total, the reaction is as follows:



The above reaction is simple demonstration. The Chemical processes that involve the VOCs are the complex ones. But the result of these reactions is the Ozone.

Another most important secondary pollutant is the Smog, which has made up of Smoke and Fog. Traditionally, the smog has resulted from large amounts of coal burning in an area caused by a mixture of smoke and sulfur dioxide. Now-a-days, the Vehicle emissions and Industrial emissions that are acted on in the atmosphere by ultraviolet light from the sun to form secondary pollutants that also combine with the primary emissions to form photochemical smog.

Deaths due to Air Pollution

As per the WHO estimates, around 24 Lakh people in the world die due to direct impact of the air pollution. Out of which 15 Lakh people die due to Indoor pollution, due to the cardiopulmonary disease linked to breathing fine particle air pollution. The Air pollution has caused several short term disasters. In 1984, the **Bhopal Disaster** was caused on December 2-3, 1984, due to a leak of methyl isocyanate gas and other chemicals from the plant resulted in the exposure of hundreds of thousands of people. It killed more than 25,000 people outright and injured 150,000 to 600,000 people. Similarly in 1952, in UK , the **Great Smog of 1952** was formed over London on December 4. It was in the cold weather, combined with an anticyclone and windless conditions that the collected airborne

pollutants mostly from the use of coal formed a form a thick layer of smog over the city. In six days more than 4,000 died, and 8,000 more died within the following months. In 1979, there was an accidental leak of anthrax spores from a biological warfare laboratory in the USSR near Sverdlovsk caused death of many people.

Top CO₂ emitting countries

As per the 2011 estimations by the European Commission and Netherlands Environmental Assessment Agency, China leads the world in CO₂ emissions. As shown in the following table.

Country	CO ₂ emissions	Emission per capita
World	33,376,327	4.9
China	9,700,000	7.2
United States	5,420,000	17.3
India	1,970,000	1.6
Russia	1,830,000	12.8
Japan	1,240,000	9.8
Germany	810,000	9.9
South Korea	610,000	12.6
Canada	560,000	16.2

The annual CO₂ emission worldwide is estimated to be around 33 billion metric tons. China with 9.7 billion metric tons annual emission of CO₂ is on top. **Qatar tops the list of the nations with Highest per capita CO₂ emission in the world.** The following table shows the highest per capita CO₂ emission countries of the world. India is third largest CO₂ emitter in the world, however, per capita emission of CO₂ in India is well beyond many countries.

Chapter 5. Greenhouse Gases (GHGs)

Greenhouse gases are those natural as well as anthropogenic gaseous constituents of the atmosphere that absorb as well as emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect.

Water vapour (H₂O), carbon dioxide (CO₂), nitrous oxide (N₂O), methane (CH₄) and ozone (O₃) are the primary greenhouse gases in the Earth's atmosphere.

Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine and bromine containing substances, dealt with under the Montreal Protocol.

Beside CO₂, N₂O and CH₄, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF₆), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Forcing GHGs

The most dominant greenhouse gas overall is water vapour, but it has a very short atmospheric lifetime (about 10 days) and is very nearly in a dynamic equilibrium in the atmosphere, so it is not a forcing gas in the context of global warming. Scientists have identified carbon dioxide as the

dominant greenhouse gas forcing. Methane and nitrous oxide are also major forcing contributors to the greenhouse effect.

GHG Emission by sectors

Maximum anthropogenic GHG emission is by Power Stations (over 21%) as shown in the following chart. It is followed by the Industrial Processes (around 17%).

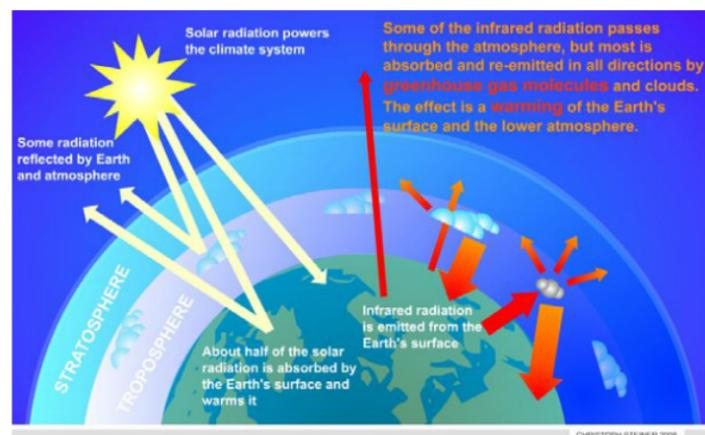
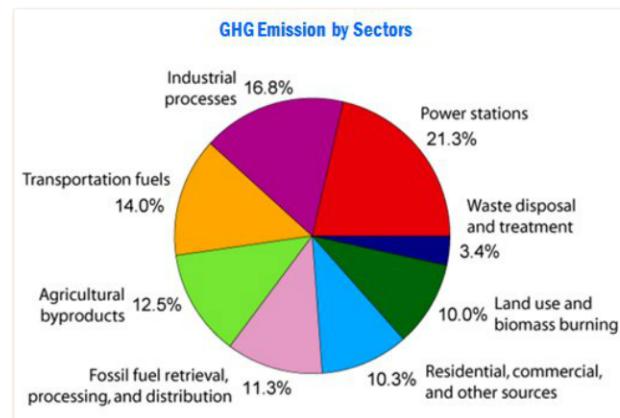
Green House Effect

In the Green House Effect, the thermal radiation from a planetary surface is absorbed by atmospheric greenhouse gases, and is re-radiated in all directions. The result is that the temperature is higher than it would be if direct heating by solar radiation were the only warming mechanism. Names of three scientists are associated with the Green House Effect. Joseph Fourier discovered it in 1824. John Tyndall in 1858 carried out some reliable experiments and Svante Arrhenius in 1896 reported quantitatively on the impacts.

Process of Green House Effect

Earth receives the energy from Sun in the form of Ultraviolet, Visible and Near Infra Red radiation. Except most of the UV radiation, almost all of them pass through the atmosphere without being absorbed. Out of this 50% is absorbed by the surface of the Earth. When it becomes warm, its surface radiates the far Infrared thermal radiation, which has longer wavelengths than that of the radiation absorbed. This thermal radiation is absorbed by the atmosphere, and the atmosphere reradiates it both upwards and downwards. The radiation that is sent downward again raises the temperature of the Earth.

Thus the long wave radiation is trapped and the equilibrium temperature of earth is higher than if there



Green House Effect versus Planetary Albedo

If Earth was an ideal black body which absorbs all the radiation from the Sun and emit the radiation due to this heating, its temperature would have been approximately 5.3 °C. The Earth and other planets are not perfect black bodies, as they do not absorb all the incoming solar radiation but reflect part of it back to space. The ratio between the reflected and the incoming energies is termed the planetary albedo. Earth reflects 36-37% of this incoming light and it corresponds to the Earth Albedo 0.367. So, Earth's mean temperature is 14 °C. If there were no atmosphere and no radiation was lost due to reflection, its mean temperature would have been -19 °C. This difference is due to the Green House Effect.

was no atmosphere. This is known as Green House Effect. The Incoming sun light is mostly in the form of visible light and nearby wavelengths, in the range 0.2–4 μm. The loss of the Radiation is almost nothing at the surface level but maximum at higher in the atmosphere because of the decreasing concentration of water vapor, an important greenhouse gas. While the major atmospheric components (Nitrogen and Oxygen) absorb little or no radiation, some of the minor components are effective absorbers. Particularly effective is water vapor and CO₂ which absorb effectively in the IR wavelength range.

These absorbing gases and their surrounding air warm up, emitting radiation downward, towards the Earth's surface, as well as upward, towards space. This effectively traps part of the IR radiation between ground and the lower 10 km of the atmosphere. This reduction in the efficiency of the Earth to lose heat causes the surface temperature to rise above the effective temperature until finally, enough heat is able to escape to space to balance the incoming solar radiation. The effect is analogous to that of a blanket that traps the body heat preventing it from escaping into the room and thus keeps us warm on cold nights.

Anti-greenhouse effect

Many planetary bodies show the Green House Effect. In our solar System, **Mars and Venus show the Green House Effect, but Titan, the largest planet of Saturn and Pluto, show Anti-Green House Effect.**

Greenhouse effect occurs because the atmosphere transparent to solar radiation, but largely opaque to infrared and far infrared emitted by the planet / body. But in anti-greenhouse effect, the atmosphere is opaque to solar but lets out infrared. The effect is that the body is cooler than the actual temperature would have been. In case of Titan, both Green House Effect and Anti Green House Effect have been proved. Due to Green House Effect, the temperature goes up by 21K while, due to Anti-Green House effect, the temperature goes down by 9K. The result is that surface temperature is 12 K warmer than without atmosphere. At Pluto, there is different mechanism. Here, the sunlight causes the Nitrogen ice to sublime which cools the body.

Indoor Air Pollution

Use of solid fuel (wood, animal dung, crop residue/grasses, coal, and charcoal) exposes people to high levels of toxic air pollutants, which result in serious health consequences. According to the National Family Health Survey-3 :

- *71 per cent of India's urban households and 91 per cent of rural households use solid fuels for cooking purposes.*
- *There is a great deal of variation in the prevalence of TB according to the type of cooking fuel the household uses. It ranges from a low of 217 per 100,000 residents, (among households using*

electricity, liquid petroleum gas, natural gas, or biogas), to a high of 924 per 100,000 (among households using straw, shrubs, or grass for cooking).

- *High TB prevalence is also seen amongst households using agricultural crop residue or other.*

Studies have found that besides TB, acute respiratory infections, chronic obstructive pulmonary disease, asthma, lung cancer, ischaemic heart disease and blindness can also be attributed to indoor air pollution.

Chapter 6. Ozone Depletion

Ozone or Trixygen is an allotrope of oxygen that is__:

- **Much less stable** than the diatomic allotrope (O₂)
- **Paramagnetic** compared to the Diamagnetic O₂.
- Present in **low concentration in atmosphere** and has **harmful effects** on the respiratory systems of animals
- **Creates Ozonosphere** in the upper atmosphere and is beneficial, preventing potentially damaging ultraviolet light from reaching the Earth's surface. Ozonosphere is located 10-18 kilometers of Earth's surface.

Is Ozone hole over only Antarctica?

It is incorrect to say that Ozone Hole is on only Antarctica. The *Ozone depletion has been seen everywhere beyond tropics and there is a severe depletion in the Polar Regions* due to some reasons which are explained here.

The Antarctic ozone hole is an area of the Antarctic stratosphere in which the recent (since about 1975) ozone levels have dropped to as low as 33% of their pre- 1975 values.

- The ozone hole occurs during the Antarctic spring, from September to early December; as strong westerly winds start to circulate around the continent and create an atmospheric container.
- In this container over 50% of the lower stratospheric ozone is destroyed.
- Announcement of polar ozone depletion over Antarctica in March 1985 prompted scientific initiatives to discover the ozone depletion processes, along with calls to freeze or diminish production of chlorinated fluorocarbons.
- A complex scenario of atmospheric dynamics, solar radiation, and chemical reactions was found to explain the anomalously low levels of ozone during the polar springtime.
- Recent expeditions to the arctic regions show that similar processes can occur in the northern hemisphere, but to a somewhat lesser degree due to warmer temperatures and erratic dynamics patterns. However, this ozone layer has been destroyed by chlorofluorocarbons and other factors, creating an ozone hole nearly twice the size of Antarctica in 1998.

- Every summer (December to January) the hole repairs itself when stratospheric temperatures rise and the air above Antarctica mixes with the rest of the world's atmosphere. This cycle of ozone hole formation and reparation is repeated every year.
- The ozone hole over Antarctica has been forming every year since the early 1970s. In recent years the hole has become both larger and deeper, in the sense that more and more ozone is being destroyed.
- Every March to April during the Northern Hemisphere springtime similar, but less pronounced ozone hole forms above the Arctic.
- The natural circulation of wind - the polar vortex - which isolates Antarctica from the rest of the world during the Southern Hemisphere winter and early spring, contributing to the ozone loss there, is much less developed in the Northern Hemisphere above the Arctic.
- In addition, stratospheric temperatures at Arctic, are not as low as in the Antarctic, and consequently the loss of ozone is not as severe. However, the formation of even a moderate ozone hole above the Arctic region can give cause for considerable concern due to the greater populations in the higher latitudes of the Northern Hemisphere.
- Many were worried that ozone holes might start to appear over other areas of the globe but to date the only other significant, localized depletion is much smaller ozone dimple, observed during the arctic spring over the North Pole.
- The Antarctic hole is a warning that if conditions become more Antarctic, i.e. cooler stratospheric temperatures, more stratospheric clouds, more active chlorine; and then ozone will decrease at a much greater pace.
- Some of the more popular scenario of global warming predict that these changes could occur in larger portions of the stratosphere. When the Antarctic ozone hole does break-up, the ozone-depleted air tends to drift out into nearby areas.
- Decreases in the ozone's level of up to 10% have been reported in New Zealand in the month following the break-up of the Antarctica ozone hole.

How does Ozone Hole get created?

We all know that the Polar Regions get a much larger variation in sunlight than anywhere else and during the 3 months of winter spend most of time in the dark without solar radiation.

Temperatures reduce around or below -80°C for much of the winter and the extremely low Antarctic temperatures cause cloud formation in the relatively "dry" stratosphere.

These polar stratospheric clouds (PSCs) are composed of ice crystals that provide the surface for a multitude of reactions, many of which speed up the degradation of ozone molecules.

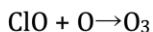
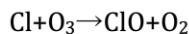
A complex interplay of chemistry, dynamics, and radiation lead to conditions conducive to significant ozone loss in the Polar Regions.

The sequence of events leading to the spring time depletion of ozone is initiated of the earth's orbit at about 23.5° causes the polar regions to experience continual darkness during their winter season.

The air above the pole cools and a vortex is formed that isolates sets the stage for the rapid depletion of ozone by catalytic cycles. A catalytic cycle is a series of reactions in which a chemical family or a particular species is depleted, leaving the catalyst unaffected.

The odd-oxygen family is composed of ozone (O_3) and atomic oxygen (O). In the presence of a chlorine atom, the net result is the conversion of an oxygen atom and ozone molecule into two molecules of molecular oxygen (O_2).

Chlorofluorocarbon-bonds (CFCs) themselves are not involved in the catalytic process; upon reaching the stratosphere. They are subject to higher levels of ultraviolet radiation that decompose the CFCs and release atomic chlorine. The basic set of reactions that define the catalytic cycle involving chlorine and odd-oxygen appear below :



- Chlorine (Cl) is initially removed by reaction with ozone to form chlorine monoxide (ClO) in the first equation, but it is regenerated through reaction of ClO with any oxygen atom (O) in the second equation.
- The net result of the two reactions is the **depletion of ozone and atomic oxygen**.

The catalytic cycle involving chlorine and ozone was not discovered until 1973. The suspected cause of the depletion was catalytic cycles involving chlorine and nitrogen. Further studies described the multiphase process involving polar found to be involved in the extensive ozone loss.

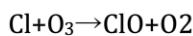
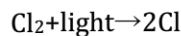
Field studies in 1987, which involved flights from south America over the Antarctic continent, showed the role of chlorine monoxide (ClO) in the ozone depletion picture.

A clear anti-correlation between chlorine monoxide and ozone concentration- that is, an increase in chlorine monoxide correlates to a decrease in ozone- inside the polar vortex has been reported. Similar processes lead to depletion in the arctic, but to a lesser limits formation of PSCs.

The potential for significant depletion in the arctic does exist, however measurements taken from the microwave limb sounder (MLS) on the upper atmosphere research satellite (UARS) platform in 1992 show concentrations of chlorine monoxide in the arctic similar to those found in the Antarctic vortex. The break-up of the polar vortex following polar spring time leads to mixing of ozones and pulses to down to lower latitude regions.

Important Observations: Antarctic Ozone hole

- ⇒ Antarctica is surrounded by oceans on all sides. Its unique geographic location causes the clouds in the stratosphere to be really cold. The coldness causes the formation of polar stratospheric clouds which provide an ideal surface for production of ozone depleting chlorine compounds. These polar stratospheric clouds are relatively lesser in the Arctic.
- ⇒ As mid-May brings on the onset of winter, the Antarctic stratosphere cools and descends closer to the surface. The Coriolis effect (caused by the earth's rotation) sets up a strong westerly circulation around the south pole, forming an oblong vortex, which varies in size from year to year. Current theory holds that the vortex is like a semi-sealed reaction vessel with most of the Antarctic air staying trapped inside the vortex. As temperatures in the lower stratosphere cool below -80°C, polar stratospheric clouds (PSCs) begin to form.
- ⇒ Most of the Antarctic chlorine ends up in reservoir compounds such as ClONO₂ or HCl. Reservoir compounds are so named because they hold the atmospheric chlorine in an inactive form but can react later, usually after a hit by ultraviolet radiation, and release reactive chlorine molecules. On the surface of the PSC crystals, nitrogen compounds are readily absorbed and chlorine reservoir compounds are converted to far more reactive compounds such as Cl₂ and HOCl.
- ⇒ The small amounts of visible light during the Antarctic winter are sufficient to convert much of the atmospheric Cl₂ to ClO :



- ⇒ Ordinarily much of the ClO would be captured by atmospheric NO₂ and returned to the ClONO₂ reservoir, but the polar clouds have absorbed most of the nitrogen compounds such as NO₂.
- ⇒ Spring brings an increase of ultraviolet light to the lower Antarctic stratosphere, providing the energy needed for the rapid catalytic breakdown of ozone by ClO and its dimer ClOOCl. Over 50% of the stratospheric ozone is destroyed by these two mechanisms, most of the damage occurring in the lower stratosphere.
- ⇒ Towards the end of spring (mid-December) the warm temperatures cause the vortex to break up; ozone-rich air from the surrounding area comes flooding in and masses of ozone-depleted air go

As per a 2013 study, a hole in the Antarctic ozone layer has changed the way waters in the southern oceans mix, which researchers say could impact global climate change. As per scientists this phenomenon has the potential to alter the amount of CO₂ in the atmosphere. *It has been found that subtropical intermediate waters in the southern oceans have become "younger" as the upwelling, circumpolar waters have gotten "older" - changes that are consistent with the fact that surface winds have strengthened as the ozone layer has thinned.* This is significant as southern oceans play a crucial role in the absorption of heat and carbon dioxide, so any alterations in southern ocean circulation have the potential to change the global climate.

wandering, temporarily lowering the ozone content in areas of south America and new Zealand by up to 10%.

⇒ One more important reason of that Antarctic Hole is bigger than Arctic Hole because **Earth's magnetic field** directs more positively charged solar wind particles to Earth's south pole. These are largely hydrogen, hydrogen oxidizes to water vapor, and water vapor both destroys ozone, and blocks one path of ozone production (not really important when UV-C is not available to make ozone anyway).

Dobson units in context with Ozone Depletion

Please note that ozone in the atmosphere can be measured in the PPT but that is not the units of Ozone Depletion. The Ozone hole is measured in terms of reduction in the total column ozone, above a point on the Earth's surface, expressed in "**Dobson units**".

One DU is 2.69×10^{16} ozone molecules per square centimeter, or 2.69×10^{20} per square meter or 0.4462 milli moles of ozone per square meter.

The base unit for an ozone hole was fixed 220 DU because total ozone values of less than 220 Dobson Units were not found in the historic observations over Antarctica prior to 1979.

The instrument used for adjudging the decreases in column ozone in the Antarctic spring and early summer compared to the early 1970s was Total Ozone Mapping Spectrometer (TOMS).

The observed and projected decreases in ozone have generated worldwide concerns. This led to adoption of the Montreal Protocol that bans the production of CFCs and halons as well as related ozone depleting chemicals such as carbon tetrachloride and trichloroethane.

Vienna Convention for the Protection of the Ozone Layer 1985

This was the first multilateral Environmental Agreement in context with the Ozone depletion. It was agreed upon at the Vienna Conference of 1985 and entered into force in 1988, thus paving the way for a legally binding treaty as its protocol called Montreal protocol. Please note that Vienna Convention itself has not placed legally binding reduction goals for the use of CFCs.

Montreal Protocol 1989

"Montreal Protocol on Substances That Deplete the Ozone Layer" or simply Montreal Protocol is the protocol to the Vienna Convention for the Protection of the Ozone Layer. This international treaty was designed to protect the ozone layer by phasing out the production of substances believed to be responsible for ozone depletion.

- ⇒ Opened for signature on September 16, 1987
- ⇒ Ratified by 197 Countries
- ⇒ Entered into force on January 1, 1989.

The Montreal Protocol opened for signature on September 16, 1987. This date is observed as International Ozone Day every year.

The Montreal Protocol stipulates that the production and consumption of compounds that deplete ozone in the stratosphere-chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform-are to be phased out by 2000 (2005 for methyl chloroform). These compounds significantly deplete the stratospheric ozone layer that shields the planet from damaging UV-B radiation. To date, 197 countries have signed the Protocol. As per the latest amendment, the treaty calls for complete phase out of HCFC by 2030.

It is believed that if the international community adheres to this treaty, the ozone layer will be recovered by 2050. Thus this protocol is hailed as most successful international agreement to date.

Theme of Montreal Protocol:

The Montreal Protocol revolves around the CFCs. Under the Protocol, the Executive Committee (ExCom) 53/37 and ExCom 54/39 and Parties to this Protocol agreed to set year 2013 as the time to freeze the consumption and production of HCFCs under a Hydrochlorofluorocarbons (HCFCs) Phase-out Management Plan (HPMP). They also agreed to start reducing its consumption and production in 2015. The time of freezing and reducing HCFCs is then known as 2013/2015.

- 💡 To provide funds and help developing countries in this phase out programme, a Multilateral Fund for the Implementation of the Montreal Protocol has been established.

Montreal Protocol: HCFC versus HFC

Please note that Montreal Protocol currently calls for a complete phase-out of HCFCs (Hydrochlorofluorocarbons) by 2030, but does not place any restriction on HFCs (Hydrofluorocarbons). The difference between these two is of Chlorine. Hydrofluorocarbons contain only one or a few fluorine atoms and are the more common type of organofluorine compounds used as refrigerants, their atmospheric concentrations are rapidly increasing, causing international concern about their rising contribution to anthropogenic radiative forcing emissions. All the HCFCs, HFCs & CHCs are now considered to be the Global Warming Potential.

India and Montreal Protocol

India became a party to the Montreal Protocol in 1992 and has been sharing the global concern for phasing out Ozone Depleting Substances. India has emerged as a global leader in promoting smooth transition for phasing out Ozone Depleting Substances (ODS). India is continuing dedicated efforts for generating awareness among all stakeholders on the importance of the Protocol. India has fulfilled all the commitments of the Montreal Protocol and has significantly reduced chlorofluorocarbon production and consumption.

In 2007 India was bestowed with Montreal Protocol Implementers Award. India has achieved 50% reduction target of CFC production from 22558 MT and consumption from 6681MT to 1940 MT as on 1.1.2005. The critical target of 85% reduction of CTC production and consumption also has

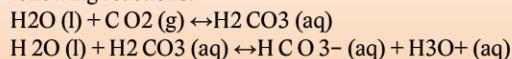
been achieved by 2007. India has been a beneficiary of the Multilateral Fund (MLF) for phase-out of ozone depleting substances such as CFC, CTC, Halon and methyl chloroform.

Chapter 7. Acid Rain

Acid rain refers to the precipitation with elevated levels of hydrogen ions or a low pH. When fossil fuel is burnt, some of the elements within their molecules combine with oxygen and form oxides. The oxide produced in a large quantity is carbon dioxide, followed by smaller quantities of Sulfur Oxides and Nitrogen Oxides. All of these oxides form the acidic solution when they dissolve in water. Out of these oxides, the Nitrogen oxides can also be produced naturally by lightning strikes. Similarly, the Sulfur Dioxide can also be produced by the volcanic eruptions. *But these natural phenomena did not contribute the acidic rains as compared to the anthropogenic activities.* The Acid Rains have been seen in many parts of the world more prominently since 1970s. In some parts of the world the Acid Rains with as low as 1.5pH has been witnessed.

Normal pH of Rainwater

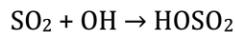
The pH of the pure water vapor in clouds is 7.0 but, even in unpolluted air, there is some carbon dioxide present, and this dissolves in rain drops to produce rain with ph of about 5.6 rains. So the rain is slightly acidic. This is shown by the following reactions:



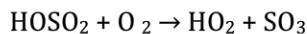
Chemistry of Acid Rains

The three kinds of Oxides matter in the Acid Rains. They are Oxides of Sulphur, Oxides of Nitrogen and Oxides of Hydrogen viz. water and Hydroxyl Radicals.

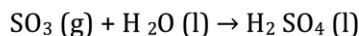
The sulphur dioxide is oxidized by reaction with the hydroxyl radical via an intermolecular reaction shown below:



HOSO_2 is unstable and it reacts with atmospheric Oxygen as follows:



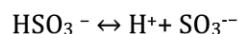
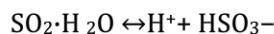
The Sulfur Trioxide SO_3 produced so quickly reacts with the water and forms the Sulphuric acid as follows:



The Nitrogen Dioxide also reacts with the OH to produce the Nitric Acid



The above reactions may take in the cloud drops as follows:



Impacts of Acid Rain

Impact on Biota and Human Life

The Acid Rains show adverse impact on the forests, freshwaters, soil and aquatic life forms. The acid rain eliminates the insect life in the lakes and ponds. It kills the soil organisms and thus changes the soil chemistry.

Impact on Soil Chemistry:

In the soil, there is an adverse impact on the nutrients such as Magnesium. This is because, Calcium and Magnesium are leached away by the Hydronium ion of the acids.

Impact on Buildings:

Acid rain is capable of damaging the buildings and historic monuments which are made up of rocks such as limestone and marble. This is because these rocks contain a large amount of Calcium Carbonate, which reacts with the Sulfuric Acid to create Gypsum. Gypsum flakes off easily. This is shown in the following reaction:



Major sources of stratospheric chlorine

- ✓ As much as 75-85% of the chlorine in the stratosphere comes from human activities. The remaining 15-20% comes almost totally from methyl chloride, most of that from natural sources and burning of biomass.
- ✓ Large, explosive volcanoes also contribute marginally to the same.
- ✓ The major sources of stratospheric chlorine and troposphere chlorine are quite varied (sea-spray, volcanoes, volatile organic compounds and so on). Most of the troposphere chlorine compounds never make it to the stratosphere.
- ✓ They are quickly decomposed by natural oxidants and the chlorine converted to water-soluble species, such as HCl, which get rained out of the atmosphere. Chlorofluorocarbons are very non-reactive in the troposphere, with lifetimes ranging from 50-above 200 years and so they eventually make it up to the stratosphere.

How to control Acid Rain?

The best approach to combat acid rain is to reduce the amount of NO_x and SO₂ being released into the atmosphere. Fitting a catalytic converter to a car can reduce the emission of NO_x by up to 90%, but they are very expensive, and cause more carbon dioxide to be released, which contributes to the greenhouse effect. SO₂ emissions from power stations can be reduced before, during, or after combustion. In addition there are several methods to control SO₂ and NO_x in the environment.

Acid rain may be controlled by

- ✓ When fuel with low sulphur content (such as North Sea gas or oil) is burnt, not much sulphur dioxide will be formed. However, low sulphur fuels are more expensive because they are in greater demand and although high-sulphur fuels can be treated to reduce their sulphur content, it is very expensive
- ✓ The SO₂ created during combustion can be absorbed if an appropriate chemical (such as limestone) is present while the fuel burns.
- ✓ Once the fuel has been burned, the SO₂ can be removed from the exhaust gases. Most systems spray a mixture of limestone and water onto the gases. This mixture reacts with the SO₂ to form gypsum, useful building materials
- ✓ Another option is not to burn fossil fuels, but to use alternative energy sources.
- ✓ All these methods for reducing acid gases are expensive, and have draw-backs, so have been passed to use them. The best way to reduce them is not to use as much energy in the first place. One can save energy by turning off-lights when you leave a room, avoiding short journeys by car, insulating the house properly and using electric and related appliances which use less energy.

Acid Rain Program

Acid Rain Program came into being after the 1990 Clean Air Act, which is a United States federal law enacted by the United States Congress to control air pollution on a national level, came into being. The Acid Rain Programme is being carried out by the United States Environmental Protection Agency, with an objective to reduce overall atmospheric levels of sulfur dioxide and nitrogen oxides, which cause acid rain in US. This programme implements the Emission Trading and targets the Coal Burning Power Plants. By Emission Trading, the programme allows the power plants whereby, each ton of sulfur dioxide emitted, is subject to a mandatory fine of \$2,000.00 for each ton emitted in excess of allowances held.

Convention on Long-Range Transboundary Air Pollution (CLRTAP)

CLRTAP is an international convention on controlling the Air Pollution. The convention came into being in March 1983 and has 51 parties. Since its adoption in 1979, CLRTAP has addressed some of the major environmental problems of the UNECE region (United Nations Economic Commission for Europe). This has been achieved through a process of scientific collaboration and policy negotiation. In this way, since its entry into force in 1983, the Convention has been extended by eight protocols which identify specific obligations or measures to be taken by Parties. The major protocols are **Sulphur Emissions Reduction Protocol** and **Gothenburg protocol**.

Sulphur Emissions Reduction Protocol

Sulphur Emissions Reduction Protocol is a protocol that aims at reducing the emission of Sulphur by at least 30%. It came into force in 1987 and had 22 parties. It was succeeded by another protocol in 1998 which aims to further reduce the Sulphur emissions. The new protocol has 23 parties. India is not a party.

Gothenburg protocol

A Protocol to Abate Acidification, Eutrophication and Ground-level Ozone was adopted by the countries of UNECE in Gothenburg (Sweden) on 30 November 1999.

- ✓ This protocol is also known as Muti-effect protocol.
- ✓ The Protocol sets emission ceilings for 2010 for four pollutants: Sulphur, NOx, VOCs and ammonia.
- ✓ These ceilings were negotiated on the basis of scientific assessments of pollution effects and abatement options.

Parties whose emissions have a more severe environmental or health impact and whose emissions are relatively cheap to reduce will have to make the biggest cuts. It was predicted that the implementation of the Protocol in Europe will reduce sulphur emissions there by at least 63%, NOx emissions by 41%, VOC emissions by 40% and ammonia emissions by 17% compared to levels in 1990. Currently, the protocol is under negotiation for a revised protocol.

Chapter 8. Legislative and Policy Interventions**Air (Prevention and Control of Pollution) Act, 1981**

The Palriment enacted the Air (Prevention and Control of Pollution) Act, 1981 to arrest the deterioration in the air quality.

The notable points from this act are as follows:

- The Act makes provisions for the establishing of **Central Pollution Control Board (CPCB)** at the apex level and State Pollution Control Boards at the state level.
- The CPCB advises the Central Government on any matter concerning the improvement of the quality of the air and prevention, control and abatement of air pollution. It also helps to plan and cause to be executed a nation-wide programme for the prevention, control and abatement of air pollution. It provides technical assistance to and guidance to the State Pollution Control Board. It also lays down the down standards for the quality of air.
- The SPCBs plan a comprehensive programme for prevention, control and abatement of air pollution and to secure the execution thereof. They also advise the State Government on any matter concerning prevention, control and abatement of air pollution.

- Kindly note that according to this act, the "**air pollutant**" means any solid, liquid or gaseous substance (**including noise**) present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment.

What are Air pollution control areas?

- This act provides that the State Government may, after consultation with the State Board, by notification declare any area or areas within the State as air pollution control areas. The state government is also powered to make any alterations in the area pollution control areas such as merging the areas. If the state government, after consultation with the State Board, is of opinion that the use of any fuel or burning of any non-fuel material other than an approved fuel, in any air pollution control area or part thereof, may cause or is likely to cause air pollution, it may, by notification, prohibit the use of such fuel in such area.
- The further provisions of the act say that no person shall, without the previous consent of the State Board, establish or operate any industrial plant in an air pollution control area. Every person to whom consent has been granted by the State Board, shall comply with the conditions and norms prescribed by the board such as prevention and control of the air pollution. Failure to do so brings penalty including jail term of at least 1.5 years.

National Air Quality Monitoring Programme

The Central Pollution Control Board (CPCB) with the help of concerned State Pollution Control Boards (SPCBs) and Pollution Control Committees (PCCs) is monitoring the ambient air quality in the country at 346 stations covering 130 cities and towns. This is done under the National Air Quality Monitoring Programme (NAMP).

- Under this programme, Central Government provides funds through CPCB for National Air Monitoring Programme to various SPCBs and PCCs.

The objectives of the NAMP are to determine the status and trends of ambient air quality; to ascertain whether the prescribed ambient air quality standards are violated; to assess health hazards and damage to materials; to continue the ongoing process of producing periodic evaluation of air pollution situation in urban and industrial areas of the country; to obtain the knowledge and understanding necessary for developing preventive and corrective measures and to understand the natural cleansing processes undergoing in the environment through pollution dilution, dispersion, wind based movement, dry deposition, precipitation and chemical transformation of pollutants generated.

- Under the NAMP, **four air-pollutants viz., SO_x , NO_x , Suspended Particulate Material (SPM) and Respirable Suspended Particulate Matter (RSPM)** have been identified for regular monitoring at all the locations.

Chapter 9. Understanding Bharat Stage Emission Standards

Background of Indian Emission Standards

First Indian emission regulations were **Idle emission limits** which became effective in 1989. In 1991, Idle CO₂ Limits for Gasoline Vehicles and Free Acceleration Smoke for Diesel Vehicles, Mass Emission Norms for Gasoline Vehicles were issued. In the next year, Mass Emission Norms for Diesel Vehicles were formulated in India, which were revised in 1996. In 1998 **Cold Start Norms** were introduced in India. In 2000, India 2000 (Eq. to Euro I) Norms, Modified IDC (Indian Driving Cycle), Bharat Stage II Norms were introduced for Delhi. Since 2000, India has started adopting European emission and fuel regulations for four-wheeled light-duty and for heavy-duty. Indian own emission regulations still apply to two- and three-wheeled vehicles.

The following table shows the reference of BS with Euro standards.

Standard	Reference
India 2000	Euro 1
Bharat Stage II	Euro 2
Bharat Stage III	Euro 3
Bharat Stage IV	Euro 4

Kindly note that Bharat norms were spearheaded initially by judicial activism in India. In 1999, the Supreme Court had ordered that all the vehicles in India should have India 2000 or Euro -1 norms by June 1999. It was also given as a verdict that all cars should have Euro -II by 2000. By that time, the car makers were not ready and that is why the idea was shelved. Then, in 2002, the Mashelkar committee came up with a roadmap so that the emission can be phased in in India. In 2003, the National Auto Fuel policy was announced, a roadmap was created.

How it works?

The evolution of the various stages is coterminous with decreasing amount of pollution a vehicle can cause. For example, the Euro 1 or BS I emits more amount of toxic gases than Euro 2 or BS II. BS-IV is the latest emission norm in India (European and American countries are following Euro 4 now!). The two important toxic polluters are CO and NO_x + Hydrocarbons. The following table shows it.

Norms	CO (g/km)	HC+ NOx(g/km)
India stage 2000 norms	2.72	0.97
Bharat stage-II	2.2	0.5
Bharat Stage-III	2.3	0.35(combined)
Bharat Stage-IV	1.0	0.18(combined)

The above table shows the various norms for passenger cars. For heavy vehicle such as trucks, these norms are bit different and also include the particulate matter.

Emission norms for Heavy diesel vehicles

Norms	CO (g/ kwhr)	HC(g/kwhr)	NOx(g/ kwhr)	PM (g/kwhr)
India stage 2000 norms	4.5	1.1	8.0	0.36
Bharat stage-II	4.0	1.1	7.0	0.15
Bharat Stage-III	2.1	1.6	5.0	0.10

Bharat Stage-IV	1.5	0.96	3.5	0.02
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Similarly, the emission norms for 2/3 petrol vehicles are as follows:

Norms	CO (g/km)	HC+ NOx (g/km)
India stage 2000 norms	2.0	2.0
Bharat stage-II	1.6	1.5
Bharat Stage-III	1.0	1.0

How Bharat Emission norms are different from Euro Norms?

Kindly note that in terms of stringency or emission limits, the Bharat Stage and Euro norms are equivalent. However, India uses Euro standards with only one modification — lower maximum speed of 90 km/h instead of 120 km/h as mandated in the EU norms. This is the maximum speed at which the vehicle is tested. The conditions of the road and general climate of India must have been taken into account while fixing this.

Chapter 10. Water Resources & Water Pollution

Water Availability - River Basins & Ground water

Twelve major river systems drain the Indian subcontinent along with a number of smaller rivers and streams and form a total catchment area of approximately 252.8 Mha. Of the major rivers, the Ganga-Brahmaputra-Meghna system is the biggest, with a combined catchment area of about 110 Mha. which is more than *43 per cent of the catchment area of all the major rivers in the country*.

Over 70 per cent of India's rivers drain in the Bay of Bengal, mostly as a part of the Ganga-Brahmaputra system. The Arabian Sea, on the western side of the country, receives 20 per cent of the total drainage from the Indus system as well as from a number of smaller rivers down the western coast. The remaining ten per cent drain into the interior basins and few natural lakes scattered across the country.

Total replenishable groundwater potential of the country has been estimated by the Ministry of Water Resources as 431 Km³ per year.

Impacts of Water Pollution

- High **Biochemical Oxygen Demand** (BOD), one of the most important indicators of pollution, is observed in polluted sources of water.
- **Faecal Coliform**, another important indicator of pollution in India was found the highest in the Yamuna river in Agra, Nizamuddin, Mazawali and Okhla.

Water Demand

According to the 2006 data of Ministry of Water Resources, Annual Precipitation (including snowfall) per capita is 4000 Cubic meter, out of which average availability is 1869 Cubic meter. *Per Capita Water Availability (2001) in cubic metres is 1820 Cubic meter.*

The Agricultural, industrial and domestic uses are competing more and more for a limited supply.

Agriculture receives the greatest share of the annual water allocation. According to the World Resources Institute (2000), 92 per cent of India's utilizable water is devoted to this sector, mostly in the form of irrigation. In the past several decades, industrial production has increased in India owing to an increasingly open economy and greater emphasis on industrial development and international trade. Hydroelectric generation already accounts for a large percentage of water demand. Demand from the domestic sector has remained low and accounts for only five per cent of the annual freshwater withdrawals in India.

Only 85 per cent of the urban and 79 per cent of the rural population has access to safe drinking water and fewer still have access to adequate sanitation facilities.

Water Pollution

Almost 70 per cent of India's surface water resources and a growing percentage of its groundwater reserves are contaminated by biological, toxic organic and inorganic pollutants. In many cases, these sources have been rendered unsafe for human consumption as well as for other activities such as irrigation and industrial needs. The high incidence of severe contamination near urban areas indicates that the industrial and domestic sector's contribution to water pollution is much higher. Besides rapidly depleting groundwater table, the country faces another major problem on the water front - groundwater contamination - a problem which has affected as many as 19 states, including Delhi. The geogenic contaminants, including salinity, iron, fluoride and arsenic have affected groundwater in over 200 districts spread across 19 states.

Driver of water pollution

Fertilizers

Rapid increase in agro-chemical use in the past five decades, has contributed significantly to the pollution of both surface and groundwater resources. Fertilizers and pesticides enter the water supply through run-offs and leaching into the groundwater table and pose a hazard.

- Some of these substances have been known to **bio-accumulate** in certain organisms, leading to an increased risk of contamination when used for human consumption and a persistence of the chemicals in the environment over long periods of time.
- Water enriched with nutrients leads to **eutrophication**. Decaying organic matter releases odourous gases and partially decomposed matter accumulates on the river or lakebed, thereby limiting water's suitability for human consumption and other uses.
- *High levels of fertilizer use has been associated with increased incidence of eutrophication in rivers and lakes in several of India's most important water bodies.*

Industrial Sector

Though Industrial sector only accounts for three per cent of the annual water withdrawals in India, yet its contribution to water pollution, particularly in urban areas, is considerable. Wastewater generation from this sector has been estimated to be 55,000 million m³ per day, of which 68.5 million m³ are dumped directly into local rivers and streams without prior treatment. The government has called for the establishment of Common Effluent Treatment Plants (CETP) in industrial areas but their implementation has been slow, and most industries either are not connected to CETPs or only partially treat their wastewater before disposal.

Domestic Sector

The domestic sector is responsible for the majority of wastewater generation in India. Combined, the 22 largest cities in the country produce over 7,267 million litres of domestic wastewater per day, of which slightly over 80 per cent is collected for treatment. Inadequate treatment of human and animal wastes also contributes to high incidence of water-related diseases in the country. Till date, only 19.2 per cent of the rural and 70 per cent of the urban inhabitants have access to adequate sanitation facilities.

Chapter 11. Water Pollution: Policy Intervention**National Water Quality Monitoring Programme (NWMP)**

CPCB in collaboration with concerned SPCBs/PCCs established a nationwide network of water quality monitoring comprising 1019 stations in 27 States and 6 Union Territories. Presently the inland water quality-monitoring network is operated under a three-tier programme i.e. Global Environment Monitoring System (GEMS), Monitoring of Indian National Aquatic Resources System (MINARS) and Yamuna Action Plan (YAP). In this programme, Water samples are being analysed for 28 parameters consisting of 9 core parameters, 19 other physico-chemical and bacteriological parameters apart from the field observations. Besides this, 9 trace metals and 22 pesticides are also analysed in selected samples.

National Water Policy 2012

National Water Policy was first adopted in September, 1987. It has been reviewed and updated in 2002 and now there is a draft National Water Policy 2012 around.

In India, water is a state subject. The Government of India had notified a Water policy in 2002 and has now approved the new National Water Policy 2012. *The first notable observation in National Water Policy 2012 is that this policy treats water as economic good.* The Government claims that treating water as an economic good would promote its conservation and efficient use.

Objectives:

- This policy favors privatization of water-delivery services.

- It aims to ensure access to a minimum quantity of potable water for essential health and hygiene to all citizens, available within easy reach of the household
- It aims to curtail subsidy to agricultural electricity users
- It aims for setting up of Water Regulatory Authority
- It aims to keep aside a portion of the river flow to meet the ecological needs and to ensure that the low and high flow releases correspond in time closely to the natural flow regime.
- It aims to give statutory powers to Water Users Associations to maintain the distribution system
- It aims to project benefited families to bear part of the cost of resettlement & rehabilitation of project affected families
- It aims remove the large disparity between stipulations for water supply in urban areas and in rural areas

Important Observations:

- The proposed national water framework law and the law on river basin management would be drafted only after extensive consultations. Some states such as Kerala, Bihar, Punjab and Madhya Pradesh have expressed reservations on some aspects of the policy. They say that the national water framework law encroaching on their powers, some states had reservations on inter-basin transfer of water. There were also demands for speedy resolution of inter-state disputes.
- Recognizes the need to adapt to climate change scenario in planning and implementation of water resources projects.
- Coping strategies for designing and management of water resources structures and review of acceptability criteria has been emphasized. Need and approaches towards enhancing water availability have been stipulated. Direct use of rainfall and avoidance of inadvertent evapo-transpiration have been proposed as the new additional strategies for augmenting utilizable water resources.
- Mapping of the aquifers to know the quantum and quality of ground water resources.
- Water use efficiency and a system to evolve benchmarks for water uses for different purposes, i.e., water footprints, and water auditing should be developed to ensure efficient use of water. Project financing has been suggested as a tool to incentivize efficient & economic use of water.
- Provision of setting up of Water Regulatory Authority and adequate water pricing to incentivize recycle and re-use.
- Water Users Associations should be given statutory powers to collect and retain a portion of water charges, manage the volumetric quantum of water allotted to them and maintain the distribution system in their jurisdiction.

The policy proposes setting aside a suitable fraction of the costs of infrastructure development, which along with collected water charges, may be utilized for repair and maintenance.

Legislation on water

Water in India is governed under three different Acts: the Environmental Protection Act (1986), the River Boards Act (1956) and the Inter-State Water Disputes Act (1956). Other Acts and Regulations affect water resources in different ways by addressing its importance for agriculture, biodiversity and conservation and drinking water. These three Acts, however, have the broadest scope in terms of how they affect all aspects of water management.

River Boards Act

The regulation and development of inter-state rivers and river valleys was to be entrusted to various River Boards when this Act was adopted in 1956. The River Boards were designed to advise the central government on development opportunities, coordinate activities and resolve disputes. Under their mandate, the Boards were required to provide advice to the government on various issues related to rivers. The Indian government has been unable to constitute a River Board since the Act was enacted, almost fifty years ago.

Inter-State Water Disputes (ISWD) Act, 1956

Interstate River Water Disputes Act, 1956 (IRWD Act) was enacted by the parliament of India under Article 262 of Constitution to resolve the water disputes that would arise in the use, control and distribution of an interstate river or river valley.

Water and Constitution of India

Water is a state subject via Entry 17 of State List, thus states are empowered to enact legislation on subject of water. But this entry is subject to the provisions of Entry 56 of Union List. The specific provisions in this regard are as under:

Entry 56. Regulation and development of inter-State rivers and river valleys to the extent to which such regulation and development under the control of the Union is declared by Parliament by law to be expedient in the public interest.

Entry 17. Water that is to say, water supplies, irrigation and canals, drainage and embankments, water storage and water power subject to the provisions of Entry 56 of List - I. At the same time, the Articles 131 and 136 of the Constitution have been used by the States frequently for bringing the matters related to inter-State rivers before the Supreme Court via the Special Leave Petitions. Further, Article 143(1) of the Constitution has been used by the Central Government (via President) for seeking opinion of the Supreme Court on the matters related to inter-State rivers, under the advisory jurisdiction of the Supreme Court.

Article 262 of the Constitution has made the following provisions:

- The power of legislation conferred upon Indian parliament for adjudication of any dispute or complaint with respect to the use, distribution or control of the waters of, or in, any inter-State river or river valley.
- By making a law, the parliament can also provide that neither the Supreme Court nor any other court shall exercise jurisdiction in respect of inter-state water disputes.

Thus, the constitution provides a role to the Central government in adjudicating conflicts surrounding inter-state rivers that arise among the states/regional governments. This Act further has undergone amendments subsequently and its most recent amendment took place in the year 2002.

Scope of the Act:

IRWD Act is applicable **only to interstate rivers / river valleys**. If the action of one state affects the interests of one or more other states, then only water dispute is deemed to have arisen under IRWD Act. The action of the state can be of two types:

- ✓ Actions of a downstream state affecting the interest of an upstream state
- ✓ Actions of an upstream state affecting the interest of a downstream state

Here we note that the action of the downstream state's action can affect the upstream state only when the downstream state is building a dam or barrage near the boundary or a submerging territory of the upstream state. However, the actions of the upstream state can affect the downstream state in many ways, which includes:

- ✓ Consumption and storage of water by upstream state
- ✓ Obstruction in flow of non-flood water by upstream state
- ✓ Alteration in the quality of water due to anthropogenic activities by upstream state

These come under the purview of the legal causes of water dispute to the downstream states.

Creation of the Tribunal:

When the riparian states are not able to reach amicable agreements on their own in sharing of an interstate river waters, section 4 of IRWD Act provides dispute resolution process in the form of Tribunal.

The tribunal such created as a **power of a Civil Court** but its **verdict is equivalent to Supreme Court verdict** when pronounced in the ambit of IRWD Act. When the tribunal final verdict issued based on the deliberations on the draft verdict is accepted by central government and notified in the official gazette, the verdict becomes law and binding on the states for implementation. **But at the same time, you must note that the verdict of the tribunal can be challenged in Supreme court via civil suits.**

The IRWD act was amended in 2002 for the following purposes

- ✓ If there is any Tribunal award which predates 2002, it **can not be altered by new tribunals**
- ✓ If there is any tribunal award which post dates 2002, **can be altered by new tribunals**. The idea is to resolve fresh water disputes which were not addressed by earlier tribunals/agreements as and when they surface.

So far, the awards of four Inter-State Water Tribunals have been notified.

- ✓ **Godavari Water Disputes Tribunal (April 1969)**
- ✓ **Krishna Water Disputes Tribunal (April 1969)**
- ✓ **Narmada Water Disputes Tribunal (October 1969)**
- ✓ **Cauvery Water Disputes Tribunal (June 1990)**

Out of them, the first three tribunal awards were issued before the year 2002 which cannot be altered by the new tribunals. The tribunals formed on sharing water of Ravi & Beas rivers, Vamsadhara River, Mahadayi / Mandovi River and Krishna River-2 are either yet to pronounce the verdicts or the issued verdicts are to be accepted by the Government of India.