

CHM 305: ENVIRONMENTAL CHEMISTRY (PART A)

(DEPT. OF CHEMISTRY FUNAAB)

CONTENTS

- A
 - Concepts of elementary cycles
 - Characteristics of the atmosphere
 - Sources, types and effects of environmental pollution
 - Composition of domestic wastes

- B
 - Water chemistry, water treatment
 - Global warming and its effect
 - Ozone layer and its functions;
 - Depletion of ozone layer and its implications

Introduction

- **Environmental science** is the study of the earth, air, water and living environment and the effect of technology on it. It comprises the physics, chemistry and biology of the environment.
- **Technology** involves the use of machines and automation. This brings a lot of changes which usually affect the environment adversely. Environmental science seeks to minimize the damage and instead, allow technology to serve the environment i.e. make the environment safe for its inhabitants.
- **Environmental chemistry** is the discipline that concerns itself with how chemicals are formed, how they are introduced into the environment, how they change after being introduced, the extent to which they enter and where they end up in organisms and other receptors, and the effects they have (usually the damage they do) once they get there.

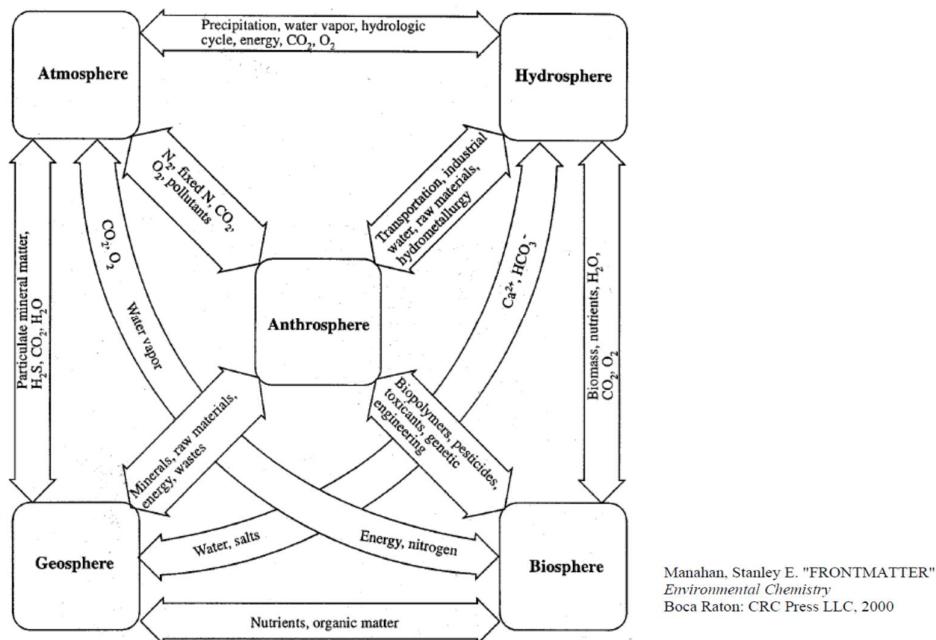
MATTER AND CYCLES OF MATTER

Cycles of matter often based on elemental cycles, are of utmost importance in the environment. Global geochemical cycles can be regarded from the viewpoint of various reservoirs, such as oceans, sediments, and the atmosphere, connected by conduits through which matter moves continuously. *The movement of a specific kind of matter between two particular reservoirs may be reversible or irreversible.*

The fluxes of movement for specific kinds of matter vary greatly as do the contents of such matter in a specified reservoir. Cycles of matter would occur even in the absence of life on Earth but are strongly influenced by life forms, particularly plants and microorganisms. Organisms participate in **biogeochemical cycles**, which describe the strong interactions among living organisms and the various spheres of the abiotic environment that involve biological, chemical, and geological processes and phenomena.

As part of the carbon cycle, atmospheric carbon in CO_2 is fixed as biomass; as part of the nitrogen cycle, atmospheric N_2 is fixed in organic matter. The reverse of these kinds of processes is **mineralization**, in which biologically bound elements are returned to inorganic states. Biogeochemical cycles are ultimately powered by solar energy, which is fine-tuned and directed by energy expended by organisms.

The Figure below shows a general cycle with all five spheres or reservoirs in which matter may be contained. Human activities now have such a strong influence on materials cycles that it is useful to refer to the “anthrosphere” along with the other environmental “spheres” as a reservoir of materials. Using this Figure as a model, it is possible to arrive at any of the known elemental cycles. Some of the numerous possibilities for materials exchange are summarized in the Table below.



General cycle showing interchange of matter among the atmosphere, biosphere, anthrosphere, geosphere, and hydrosphere.

Note:

The **atmosphere** is the thin layer of gases that cover Earth's surface. In addition to its role as a reservoir of gases, the atmosphere moderates Earth's temperature, absorbs energy and

damaging ultraviolet radiation from the sun, transports energy away from equatorial regions, and serves as a pathway for vapor-phase movement of water in the hydrologic cycle.

The **hydrosphere** contains Earth's water. Over 97% of Earth's water is in oceans, and most of the remaining fresh water is in the form of ice. Therefore, only a relatively small percentage of the total water on Earth is actually involved with terrestrial, atmospheric, and biological processes.

The **geosphere** consists of the solid earth, including soil, which supports most plant life. The part of the geosphere that is directly involved with environmental processes through contact with the atmosphere,

All living entities on Earth compose the **biosphere**. Living organisms and the aspects of the environment pertaining directly to them are called **biotic**, and other portions of the environment are **abiotic**.

The **anthrosphere** is that part of the environment that is made or modified by human for use in human activities. As human technology becomes more evolved, so do the impacts of human activities on the environment.

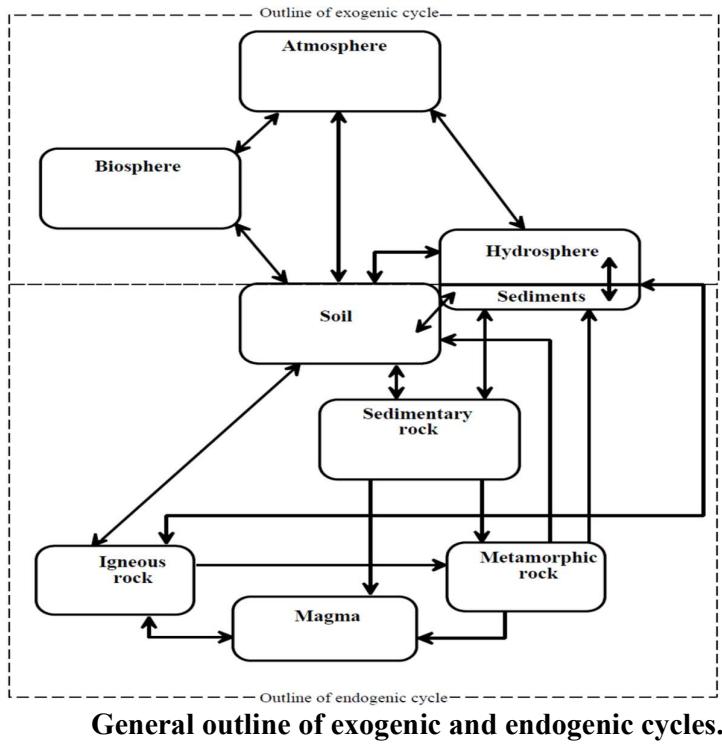
Interchange of Materials among the Possible Spheres of the Environment

From	Atmosphere	Hydrosphere	Biosphere	Geosphere	Anthrosphere
To					
Atmosphere	—	H ₂ O	O ₂	H ₂ S, particles	SO ₂ , CO ₂
Hydrosphere	H ₂ O	—	{CH ₂ O}	Mineral solutes	Water pollutants
Biosphere	O ₂ , CO ₂	H ₂ O	—	Mineral nutrients	Fertilizers
Geosphere	H ₂ O	H ₂ O	Organic matter	—	Hazardous wastes
Anthrosphere	O ₂ , N ₂	H ₂ O	Food	Minerals	—

Endogenic and Exogenic Cycles

Materials cycles may be divided broadly between **endogenic cycles**, which predominantly involve subsurface rocks of various kinds, and **exogenic cycles**, which occur largely on Earth's surface and usually have an atmospheric component. These two kinds of cycles are broadly outlined in the Figure below.

In general, sediment and soil can be viewed as being shared between the two cycles and constitute the predominant interface between them. Most biogeochemical cycles can be described as **elemental cycles** involving **nutrient elements** such as carbon, nitrogen, oxygen, phosphorus, and sulfur. Many are exogenic cycles in which the element in question spends part of the cycle in the atmosphere—O₂ for oxygen, N₂ for nitrogen, CO₂ for carbon. Others, notably the phosphorus cycle, do not have a gaseous component and are endogenic cycles. All sedimentary cycles involve **salt solutions** or **soil solutions** that contain dissolved substances leached from weathered minerals; these substances may be deposited as mineral formations, or they may be taken up by organisms as nutrients.



General outline of exogenic and endogenic cycles.

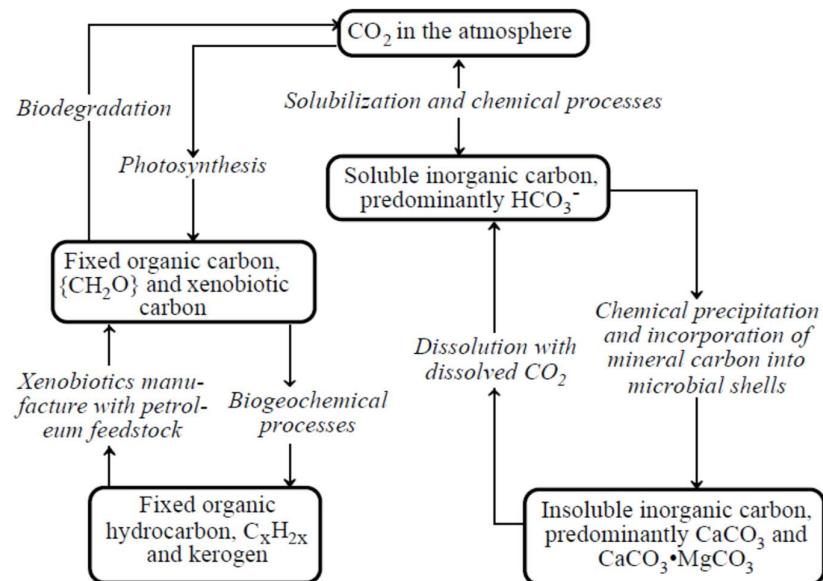
Carbon Cycle

Carbon is circulated through the **carbon cycle** shown in the Figure below. This cycle shows that carbon may be present as gaseous atmospheric CO_2 , constituting a relatively small but highly significant portion of global carbon. Some of the carbon is dissolved in surface water and groundwater as HCO_3^- or molecular $\text{CO}_2(aq)$. A very large amount of carbon is present in minerals, particularly calcium and magnesium carbonates such as CaCO_3 . Photosynthesis fixes inorganic C as biological carbon, represented as $\{\text{CH}_2\text{O}\}$, which is a constituent of all life molecules. Another fraction of carbon is fixed as petroleum and natural gas, with a much larger amount as hydrocarbonaceous kerogen (the organic matter in oil shale), coal, and lignite, represented as $\text{C}_x\text{H}_2\text{x}$. Manufacturing processes are used to convert hydrocarbons to xenobiotic compounds with functional groups containing halogens, oxygen, nitrogen, phosphorus, or sulfur. Though a very small amount of total environmental carbon, these compounds are particularly significant because of their toxicological chemical effects.

An important aspect of the carbon cycle is that it is the cycle by which solar energy is transferred to biological systems and ultimately to the geosphere and anthrosphere as fossil carbon and fossil fuels. Organic, or biological, carbon, $\{\text{CH}_2\text{O}\}$, is contained in energy-rich molecules that can react biochemically with molecular oxygen, O_2 , to regenerate carbon dioxide and produce energy. This can occur biochemically in an organism through aerobic respiration or it may occur as combustion, such as when wood or fossil fuels are burned.

Microorganisms are strongly involved in the carbon cycle, mediating crucial biochemical reactions discussed later in this section. **Photosynthetic algae are the predominant carbon-fixing agents in water;** as they consume CO_2 to produce biomass, the pH of the water is raised enabling precipitation of CaCO_3 and $\text{CaCO}_3 \cdot \text{MgCO}_3$. Organic carbon fixed by microorganisms is transformed by biogeochemical processes to fossil petroleum, kerogen, coal, and lignite. Microorganisms degrade organic carbon from biomass, petroleum, and xenobiotic sources, ultimately returning it to the atmosphere as CO_2 . Hydrocarbons such as those in crude oil and some synthetic hydrocarbons are degraded by microorganisms. This is an important mechanism for eliminating pollutant hydrocarbons, such as those that are accidentally spilled

on soil or in water. Biodegradation can also be used to treat carbon-containing compounds in hazardous wastes.



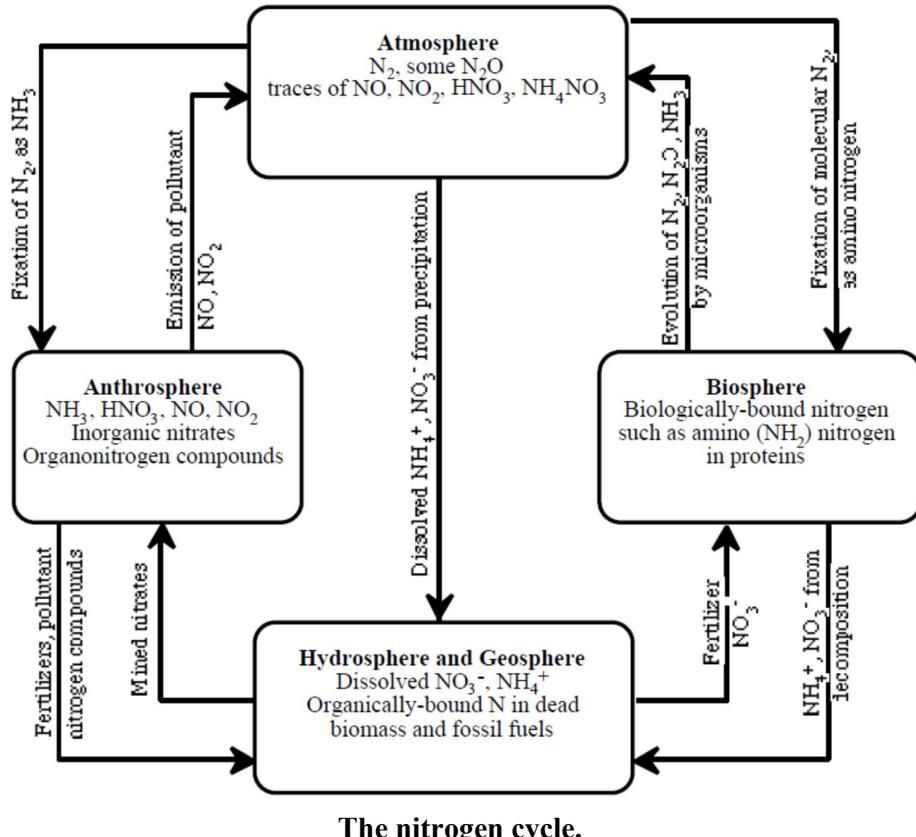
The Carbon Cycle

Mineral carbon is held in a reservoir of limestone, CaCO_3 , from which it may be leached into a mineral solution as dissolved hydrogen carbonate ion, HCO_3^- , formed when dissolved $\text{CO}_2(aq)$ reacts with CaCO_3 . In the atmosphere carbon is present as carbon dioxide, CO_2 . **Atmospheric carbon dioxide is fixed as organic matter by photosynthesis, and organic carbon is released as CO₂ by microbial decay of organic matter.**

The Nitrogen Cycle

As shown in the Figure below, nitrogen occurs prominently in all the spheres of the environment. The atmosphere is 78% elemental nitrogen, N_2 , by volume and comprises an inexhaustible reservoir of this essential element. Nitrogen, though constituting much less of biomass than carbon or oxygen, is an essential constituent of proteins. The N_2 molecule is very stable so that breaking it down into atoms that can be incorporated with inorganic and organic chemical forms of nitrogen is the limiting step in the nitrogen cycle. This does occur by highly energetic processes in lightning discharges that produce nitrogen oxides. Elemental nitrogen is also incorporated into chemically bound forms, or **fixed** by biochemical processes mediated by microorganisms. The biological nitrogen is mineralized to the inorganic form during the decay of biomass. Large quantities of nitrogen are fixed synthetically under high temperature and high pressure conditions according to the following overall reaction:

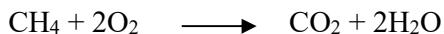
The production of gaseous N_2 and N_2O by microorganisms and the evolution of these gases to the atmosphere completes the nitrogen cycle through a process called **denitrification**.



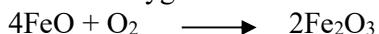
The nitrogen cycle.

The Oxygen Cycle

The **oxygen cycle** involves the interchange of oxygen between the elemental form of gaseous O_2 , contained in a huge reservoir in the atmosphere, and chemically bound O in CO_2 , H_2O , and organic matter. It is strongly tied with other elemental cycles, particularly the carbon cycle. Elemental oxygen becomes chemically bound by various energy yielding processes, particularly combustion and metabolic processes in organisms. It is released in photosynthesis. This element readily combines with and oxidizes other species such as carbon in aerobic respiration or carbon and hydrogen in the combustion of hydrogen in the combustion of fossil fuels such as methane:

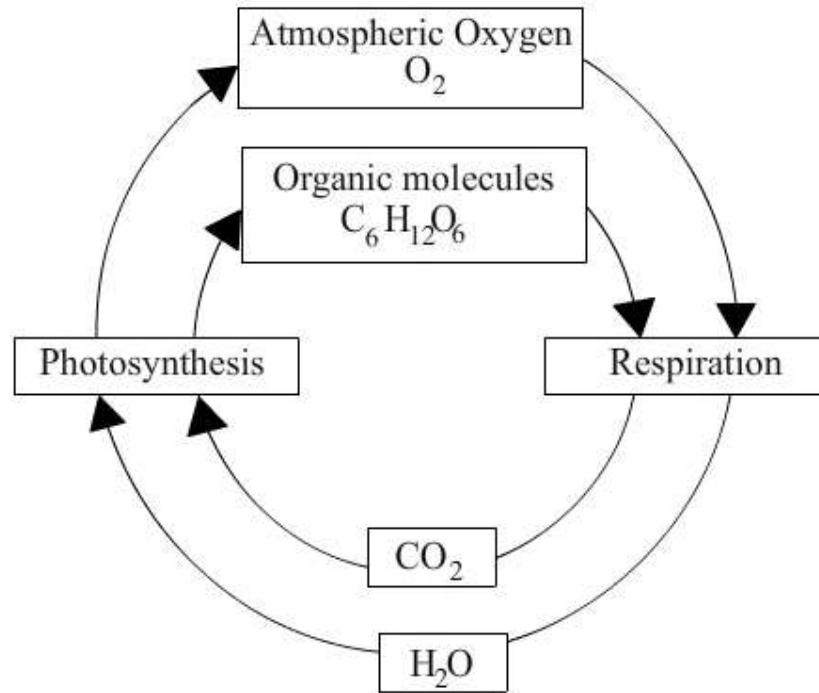


Elemental oxygen also oxidizes inorganic substances such as iron(II) in minerals:



A particularly important aspect of the oxygen cycle is stratospheric ozone, O_3 . A relatively small concentration of ozone in the stratosphere, more than 10 kilometers high in the atmosphere, filters out ultraviolet radiation in the wavelength range of 220-330 nm, thus protecting life on Earth from the highly damaging effects of this radiation. The oxygen cycle is completed by the return of elemental O_2 to the atmosphere.

The only significant way in which this is done is through photosynthesis mediated by plants.

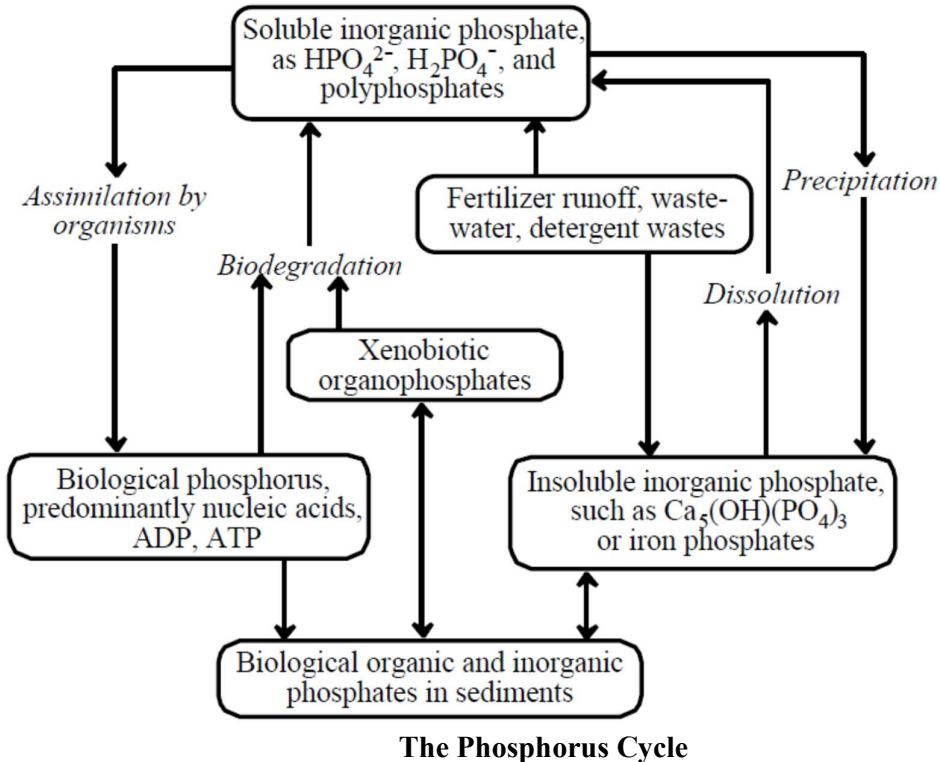


The Oxygen Cycle

(https://www.smartlearning.in/Virtual/CommunityQuestions/Answers//83476_A.jpeg)

The Phosphorus Cycle

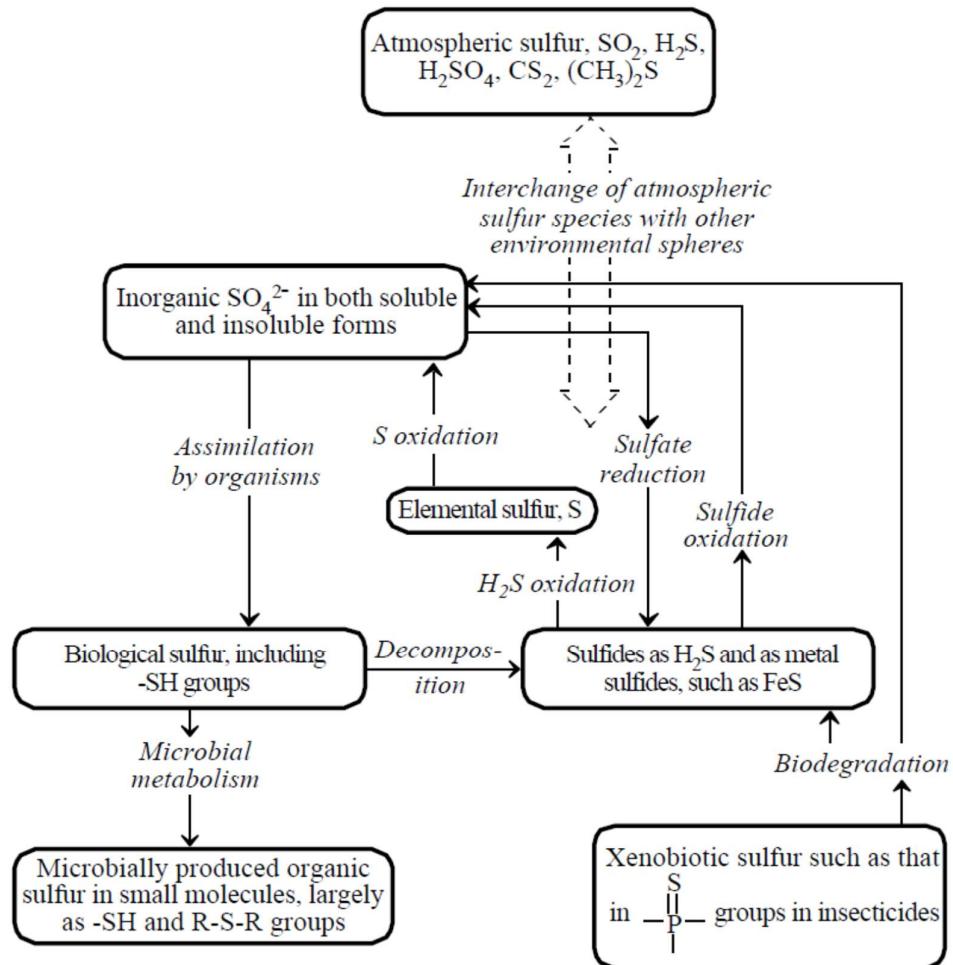
The phosphorus cycle, is crucial because phosphorus is usually the limiting nutrient in ecosystems. There are no common stable gaseous forms of phosphorus, so the phosphorus cycle is endogenic. In the geosphere, phosphorus is held largely in poorly soluble minerals, such as hydroxyapatite a calcium salt, deposits of which constitute the major reservoir of environmental phosphate. Soluble phosphorus from phosphate minerals and other sources such as fertilizers is taken up by plants and incorporated into nucleic acids which make up the genetic material of organisms. Mineralization of biomass by microbial decay returns phosphorus to the salt solution from which it may precipitate as mineral matter. The anthrosphere is an important reservoir of phosphorus in the environment. Large quantities of phosphates are extracted from phosphate minerals for fertilizer, industrial chemicals, and food additives. Phosphorus is a constituent of some extremely toxic compounds, especially organophosphate insecticides and military poison nerve gases.



The Phosphorus Cycle

The Sulfur Cycle

The sulfur cycle, is relatively complex in that it involves several gaseous species, poorly soluble minerals, and several species in solution. It is tied with the oxygen cycle in that sulfur combines with oxygen to form gaseous sulfur dioxide, SO_2 , an atmospheric pollutant, and soluble sulfate ion, SO_4^{2-} . Among the significant species involved in the sulfur cycle are gaseous hydrogen sulfide, H_2S ; mineral sulfides, such as PbS , sulfuric acid, H_2SO_4 , the main constituent of acid rain; and biologically bound sulfur in sulfur-containing proteins. Insofar as pollution is concerned, the most significant part of the sulfur cycle is the presence of pollutant SO_2 gas and H_2SO_4 in the atmosphere. The former is a somewhat toxic gaseous air pollutant evolved in the combustion of sulfur-containing fossil fuels. The major detrimental effect of sulfur dioxide in the atmosphere is its tendency to oxidize in the atmosphere to produce sulfuric acid. This species is responsible for acidic precipitation, “acid rain,” discussed as a major atmospheric pollutant.



The Sulfur Cycle

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CHARACTERISTICS OF THE ATMOSPHERE

The **atmosphere of Earth** is a layer of gases surrounding the planet Earth that is retained by Earth's gravity. **Atmospheric science** deals with the movement of air masses in the atmosphere, atmospheric heat balance, and atmospheric chemical composition and reactions. In order to understand atmospheric chemistry and air pollution, it is important to have an overall appreciation of the atmosphere, its composition, and physical characteristics.

Importance of the Atmosphere

- The atmosphere is a protective blanket that nurtures life on the Earth and protects it from the hostile environment of outer space.
- The atmosphere is the source of carbon dioxide for plant photosynthesis and of oxygen for respiration.
- It provides the nitrogen that nitrogen-fixing bacteria and ammonia-manufacturing plants use to produce chemically bound nitrogen, an essential component of life molecules.
- As a basic part of the hydrologic cycle, the atmosphere transports water from the oceans to land, thus acting as the condenser in a vast solar-powered still.
- Unfortunately, the atmosphere also has been used as a dumping ground for many pollutant materials—ranging from sulfur dioxide to refrigerant Freon—a practice that causes damage to vegetation and materials, shortens human life, and alters the characteristics of the atmosphere itself.

Physical Characteristics of the Atmosphere

Atmospheric Composition

Dry air within several kilometers of ground level consists of

Two major components

- Nitrogen, 78.08 % (by volume)
- Oxygen, 20.95 %

Two minor components

- Argon, 0.934 %
- Carbon dioxide, 0.036 %

In addition to argon, four more **noble gases**,

- Neon, 1.818×10^{-3} %
- Helium, 5.24×10^{-4} %
- Krypton, 1.14×10^{-4} %
- Xenon, 8.7×10^{-6} %

Trace gases (see table below)

Atmospheric air may contain 0.1–5 % water by volume, with a normal range of 1–3 %.

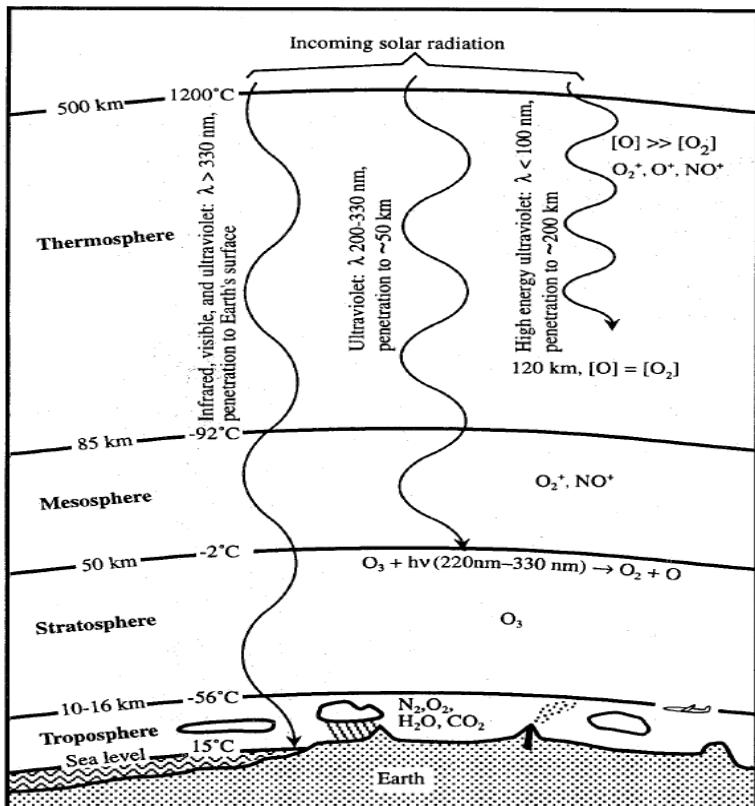
Atmospheric Trace Gases in Dry Air near Ground Level

Gas or species	Volume percent ¹	Major sources	Process for removal from the atmosphere
CH ₄	1.6×10^{-4}	Biogenic ²	Photochemical ³
CO	$\sim 1.2 \times 10^{-5}$	Photochemical, anthropogenic ⁴	Photochemical
N ₂ O	3×10^{-5}	Biogenic	Photochemical
NO _x ⁵	10^{-10} – 10^{-6}	Photochemical, lightning, anthropogenic	Photochemical
HNO ₃	10^{-9} – 10^{-7}	Photochemical	Washed out by precipitation
NH ₃	10^{-8} – 10^{-7}	Biogenic	Photochemical, washed out by precipitation
H ₂	5×10^{-5}	Biogenic, photochemical	Photochemical
H ₂ O ₂	10^{-8} – 10^{-6}	Photochemical	Washed out by precipitation
HO· ⁶	10^{-13} – 10^{-10}	Photochemical	Photochemical
HO ₂ · ⁶	10^{-11} – 10^{-9}	Photochemical	Photochemical
H ₂ CO	10^{-8} – 10^{-7}	Photochemical	Photochemical
CS ₂	10^{-9} – 10^{-8}	Anthropogenic, biogenic	Photochemical
OCS	10^{-8}	Anthropogenic, biogenic, photochemical	Photochemical
SO ₂	$\sim 2 \times 10^{-8}$	Anthropogenic, photochemical, volcanic	Photochemical
I ₂	0-trace	—	—
CCl ₂ F ₂ ⁷	2.8×10^{-5}	Anthropogenic	Photochemical
H ₃ CCCCl ₃ ⁸	$\sim 1 \times 10^{-8}$	Anthropogenic	Photochemical

Stratification of the Atmosphere

The atmosphere is stratified on the basis of the temperature/density relationships resulting from interactions between physical and photochemical (light-induced chemical phenomena) processes in air.

1. The **troposphere**: This is lowest layer of the atmosphere extending from sea level to an altitude of 10–16 km. It is characterized by a generally homogeneous composition of major gases other than water and decreasing temperature with increasing altitude from the heat-radiating surface of the earth. The upper limit of the troposphere, which has a temperature minimum of about -56°C, varies in altitude by a kilometer or more with atmospheric temperature, underlying terrestrial surface, and time. The homogeneous composition of the troposphere results from constant mixing of circulating air masses. However, the water vapor content of the troposphere is extremely variable because of cloud formation, precipitation, and evaporation of water from terrestrial water bodies. The very cold temperature of the **tropopause** layer at the top of the troposphere serves as a barrier that causes water vapor to condense to ice so that it cannot reach altitudes at which it would photodissociate through the action of intense high-energy ultraviolet radiation. If this happened, the hydrogen produced would escape the earth's atmosphere and be lost. (Much of the hydrogen and helium gases originally present in the earth's atmosphere were lost by this process.)
2. The **stratosphere**: This is the atmospheric layer directly above the troposphere in which the temperature rises to a maximum of about -2 °C with increasing altitude. This phenomenon is due to the presence of ozone, O₃, which can reach a level of around 10 ppm by volume in the mid-range of the stratosphere. The heating effect is caused by the absorption of ultraviolet radiation energy by ozone.
3. The **mesosphere**: This is the atmospheric layer immediately above the stratosphere. high levels of radiation-absorbing species are absent in the **mesosphere** causing further temperature decrease to about -92°C at an altitude around 85 km. The upper regions of the mesosphere and higher defined region, called the exosphere, from which molecules and ions can completely escape the atmosphere.
4. The **thermosphere**: Extending to the far outer reaches of the atmosphere is the **thermosphere**, in which the highly rarified gas reaches temperatures as high as 1200°C by the absorption of very energetic radiation of wavelengths less than approximately 200 nm by gas species in this region.



Major regions of the atmosphere

Atmospheric Chemical Processes

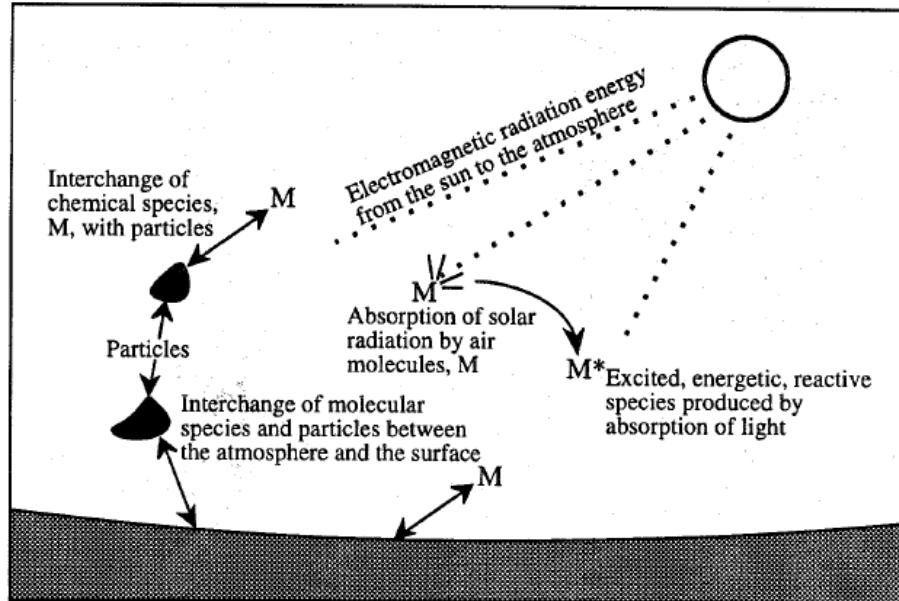
Atmospheric chemistry involves the unpolluted atmosphere, highly polluted atmospheres, and a wide range of gradations in between. The same general phenomena govern all and produce one huge atmospheric cycle in which there are numerous subcycles.

Gaseous atmospheric chemical species fall into the following somewhat arbitrary and overlapping classifications:

- Inorganic oxides (CO, CO₂, NO₂, SO₂),
- Oxidants (O₃, H₂O₂, HO• radical, HO₂• radical, ROO• radicals, NO₃),
- Reductants (CO, SO₂, H₂S),
- Organics (also reductants; in the unpolluted atmosphere, CH₄ is the predominant organic species, whereas alkanes, alkenes, and aryl compounds are common around sources of organic pollution),
- Oxidized organic species (carbonyls, organic nitrates),
- Photochemically active species (NO₂, formaldehyde),
- Acids (H₂SO₄),
- Bases (NH₃),
- Salts (NH₄HSO₄),
- Unstable reactive species (electronically excited NO₂, HO• radical).

Two constituents of utmost importance in atmospheric chemistry are:

- Radiant energy from the sun, predominantly in the ultraviolet region of the spectrum: It provides a way to pump a high level of energy into a single gas molecule to start a series of atmospheric chemical reactions
- The hydroxyl radical, HO•, the most important reactive intermediate and “currency” of daytime atmospheric chemical phenomena; NO₃ radicals are important intermediates in nighttime atmospheric chemistry.



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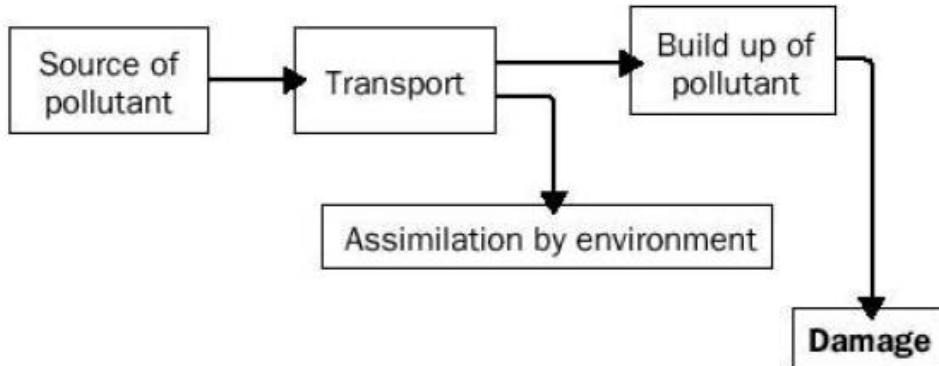
SOURCES, TYPES AND EFFECTS OF ENVIRONMENTAL POLLUTION

POLLUTANTS

A substance becomes a **pollutant** when it is present in a concentration that is high enough for it to have a harmful effect on the natural environment. Often, only highly toxic substances are thought of as pollutants, but even substances that are normally considered harmless may pollute if they are present in high enough concentrations and in the *wrong place at the wrong time*. For example, nitrate is added to soil in order to increase plant growth, but an excessive concentration of nitrate present in drinking water can be toxic, especially to young children.

A **contaminant** is a substance that is present in greater concentration than its natural concentration as a result of human activities (causes deviation from normal composition of an environment, it is not a pollutant unless has some detrimental effect). The toxic or harmful effects from contamination may become apparent at a later date.

Pollution originates from a source. The pollutant is then transported by air, water or dumped on land by man. Some of the pollutant may be absorbed (assimilated) or chemically changed by the environment; the rest builds up to a concentration that enables it to damage organisms or buildings, or to upset the balance of environmental processes.



An environmental pollution model

Three main types of environmental pollution are:

1. Air pollution
2. Water pollution
3. Land pollution

1. AIR POLLUTION

Air pollution is the unwanted change in the quality of the earth's atmosphere caused by the emission of gases and of particulates [which are small particles of solid matters or droplets of liquids].

Air pollutants come mainly from the internal combustion engines of automobiles and other vehicles used for transportation, from electric power generating plants and stationary combustion sources. Other sources are industries and from incineration of refuse.

Five main classes of air pollutants are.

1. Carbon monoxide(CO);
Sources: Incomplete combustion of carbon and automobile emission(that is combustion chambers of motor vehicles)
2. Hydrocarbons[e.g. PAHs, PCBs, CFC or Volatile organic compounds(VOC)]
Sources: Incomplete combustion of fossil fuels, petroleum industries, automobile emission.
3. Nitrogen oxides(NO_x) e.g. Nitrogen dioxide + Nitric oxide)
Source: gas flaring industries, petroleum industries, automobile emission
4. Sulphur dioxide: (SO_2)
Sources: Power stations(epically those that burn coal), smelting sulphur ore industries(where metals like copper, zinc are produced), petroleum industries etc.
5. Suspended particulate matters (SPM)e.g. smoke, dust.
Sources: cement factories

Effects of Air Pollutions;

1. Effects on Man:

It causes respiratory diseases asthma, bronchitis. Also, allergies especially in children. It increases death rate and incurable diseases like cancer and heart diseases. It also causes eye irritation and visibility degradation which can cause accidents.

2. Effects on Vegetations:

Air pollutants destroy plants. Sulphur fumes destroyed acres of timberland at Tenn., America. Air pollutants which cause smog have been known to contribute to a slow decline of citrus groves.

3. Effects on Properties/ Materials:

Air Pollutants are damaging to wide variety of materials. Steel corrodes 2-4 times faster in urban and industrial areas than in rural areas. These pollutants are also known to accelerate the weathering of stone and masonry surfaces of building throughout the world; damage of textiles, discolour of dyes and accelerates the cracking of rubber products.

4. Effects on Weather

a. Photochemical smog

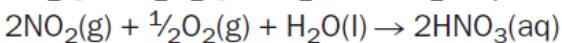
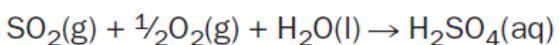
Exhaust gases are involved in the formation of photochemical smog. Here, strong sunlight interacts with pollutant gases from millions of automobiles, causing a complex series of photochemical reactions which produce a choking mixture of ozone, NO_x and other gases. Major effect is irritation, reduced visibility.

b. Greenhouse Effect [Global warming]

This is the apparent rise in global average temperature attributed principally to the build up of carbon IV oxide and other trace gases. These gases trap the infrared radiation emitted by the sun and earth leading to rise in temperature. The depletion of ozone layer[which absorbs high energy radiation from the sun and prevents them from harming life on earth) by some gases in the stratosphere[e.g. NO_x, CFCs] also leads to green effect by permitting radiation of very short wavelength to reach the earth.

c. Unpredictable Weather: Storms, cyclones, tsunamis etc

d. Acid rain: Acid depositions is sometimes referred to as acid rain describe all the different ways in which acid materials get deposited on the earth including rain, snow, mist, sleet and solid particles that are abnormally acidic.



2. WATER POLLUTION

The quality of drinking water is very important to human welfare. However, pollution of water results from various sources with serious health effects. Some water pollution sources are:

1. Heavy metals

Metals such as Cd, Pb and Hg may be present in industrial or mining waste. These metals can prove poisonous to humans – cadmium and mercury can cause kidney damage, and lead poisoning can cause damage to the kidneys, liver, brain and central nervous system. All of these metals are cumulative poisons – the body does not excrete them and their concentration builds up.

2. Detergents and fertilizers

These may contain phosphates as additives. The addition of phosphorus to water, in the form of the phosphate anion PO₄³⁻, encourages the formation of algae which reduces the dissolved

oxygen concentration of the water. This process is known as eutrophication and threatens the development of higher life forms, such as fish.

3. Acid-polluted water ($\text{pH} < 3$)

This is deadly to most forms of aquatic life. Water downstream from a mine may be contaminated by acid mine drainage, the result of microbial oxidation of discarded waste material at the mine site. Acid mine water principally contains sulfuric acid produced by the oxidation of iron pyrites (FeS_2). Industrial wastes and acid rain may also contribute to the acidity of natural waters.

4. PCBs (polychlorinated biphenyls)

Peak production of these chemicals occurred in the 1970s. They have high stabilities and this led to their being used in many applications, for example as fluids in transformers and capacitors. Although their manufacture has been stopped, PCBs are resistant to oxidation when released into the environment and so persist for a long time and can cause skin disorders in humans. They may be carcinogenic to humans.

The maximum recommended levels of impurities for drinking water, set by the EU, are as follows

Impurity	Concentration/ppm or mg dm^{-3}
Zn	5
Fe	0.2
Mn	0.05
Cu	3
Cd	0.005
Al	0.2

3. LAND POLLUTION

Land pollution involves disposal of hazardous waste on, or within a hole in, the ground. Problems associated with pollution include – volatile waste may lead to unpleasant odours, and the decomposition of garbage may release methane and other gases for many years. Also, rain may dissolve (leach) buried toxic material – the resulting solution can contaminate drinking water supplies via underground water courses.

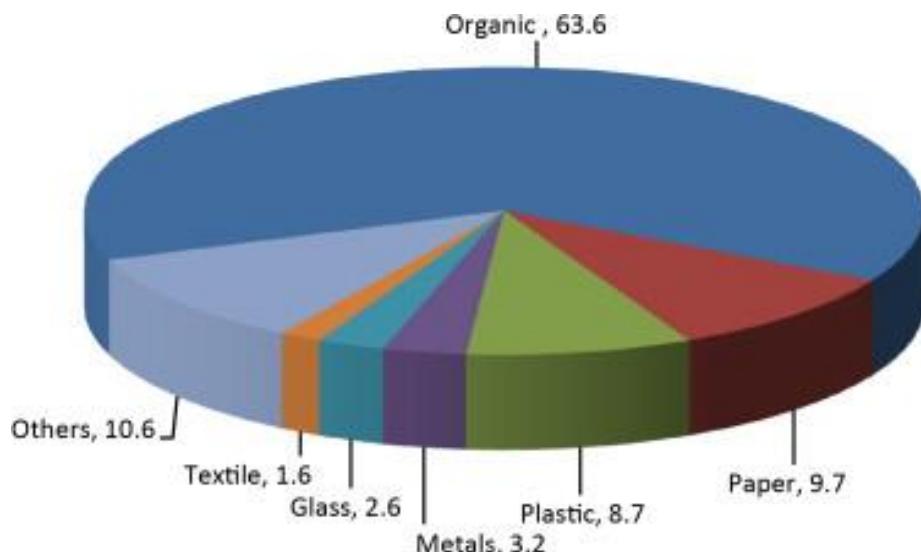
Problems associated with pollution include:

- Volatile waste may lead to unpleasant odours
- The decomposition of garbage may release methane and other gases for many years.
- Also, rain may dissolve (leach) buried toxic material – the resulting solution can contaminate drinking water supplies via underground water courses.

COMPOSITION OF DOMESTIC WASTES

Domestic refers to the home/ household. Household solid waste is highly heterogeneous and is widely dependent on the socioeconomic status of the households. Households waste consisted of 63.6% organic waste, 9.7% paper, 8.7% plastics, 3.2% metal, 2.6% glass, 1.6% textile and 10.6% others (unclassified) and the bulk density was 240 kg/m^3 .

The evaluation of relationship between income and daily per capita household waste generation showed a positive relationship.



Survey of household waste composition and quantities in Abuja, Nigeria
<https://doi.org/10.1016/j.resconrec.2013.05.011>.

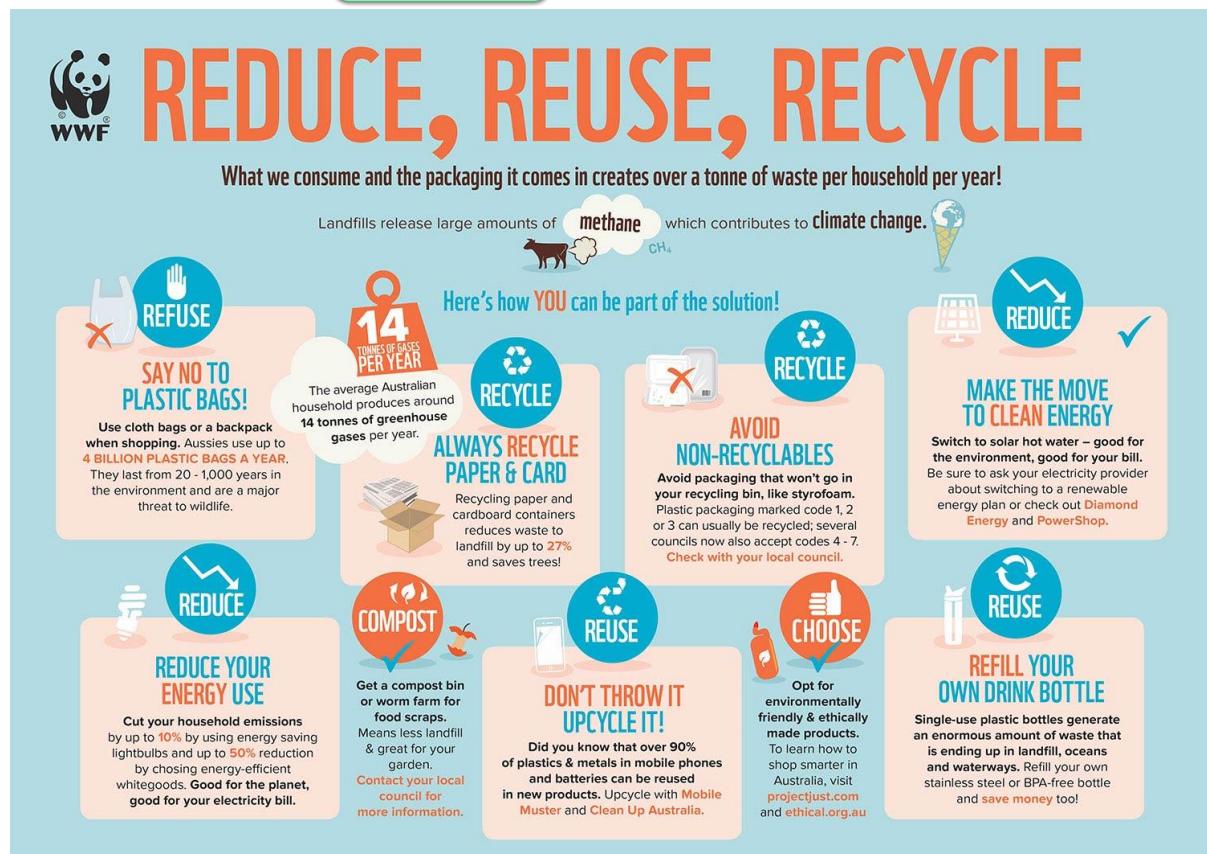
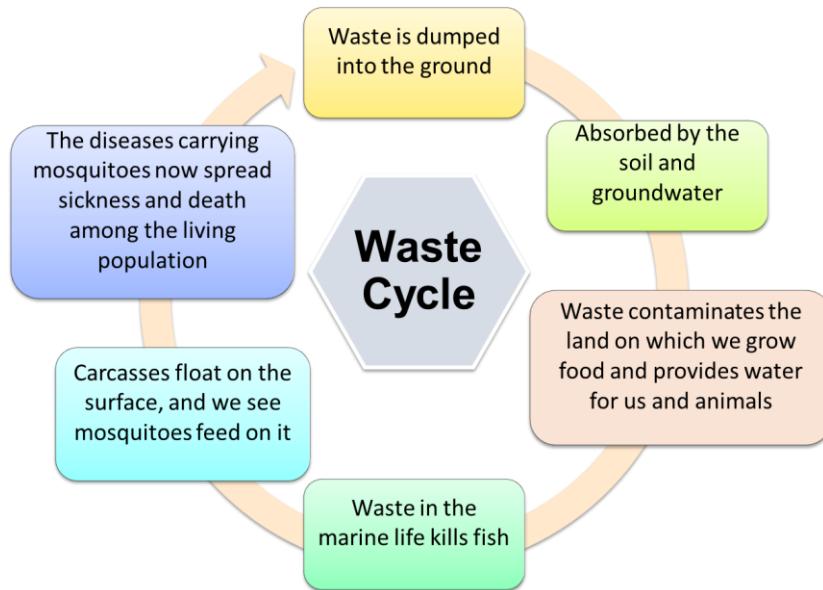
Domestic wastes can be classified based on their state;

- ❖ Solids: glass, paper etc
- ❖ Liquids: used water containing soap/detergents from washings/laundry, improperly channelled toilet wastes etc
- ❖ Gases: Burning of items like wood for cooking, cooking gases etc

Improper disposal or channelling of domestic wastes results in gross pollutants in all three spheres: air, land and water.



This leads to a vicious cycle which feeds itself;



<https://www.wwf.org.au/Images/UserUploadedImages/408/infographic-reduce-reuse-recycle.jpg>

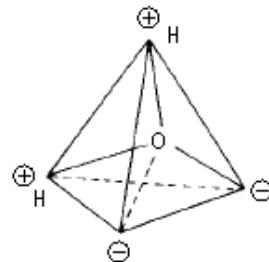
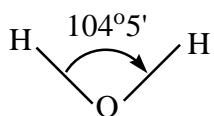


WATER CHEMISTRY

Water is the most abundant molecule on the Earth's surface and one of the most important molecules to study in chemistry. Water plays an important role as a chemical substance. Its many important functions include being a good solvent for dissolving many solids, serving as an excellent coolant both mechanically and biologically, and acting as a reactant in many chemical reactions. Blood, sweat and tears; are all solutions of water.

1. Molecular structure of water

Each molecule of water, H_2O or HOH , consists of two atoms of hydrogen bonded to one atom of oxygen. The molar mass of water is 18.01528g/mol. Its density is 1000kg/m^3 (liquid) or 917kg/mol (at 4°C –solid). The atomic distance between the H and O is 0.96 \AA , and the angle of H-O-H is $104^\circ 5'$.



A water molecule has four electrical charges of two positive and

two negative ones. As the four electrical charges occupy symmetrical positions, a water molecule behaves like a bar magnet, that is it has the dipole moment. The hydrogen bond is a kind of atomic bond which a hydrogen atom interposes, like $\text{O}-\text{H}\cdots\text{O}$, $\text{O}-\text{H}\cdots\text{N}$, $\text{N}-\text{H}\cdots\text{O}$ and so on. Thus a water molecule combines the other water molecules, alcohols, amino acids, etc. These dipole moment and hydrogen bond of water give very unique properties to water comparing with the other organic and inorganic substances

2 Water as a solvent

Compared with organic solvents, water easily dissolves several substances. This is due to the strong dipole moment of water. Most electrolytes dissociate in water, and dissolves into ions. Water can also dissolve organic substances such as sugars and alcohols, as a result of its special structure and hydrogen bonding forces.

4 Basic properties of Water

Some of the basic properties of water are enumerated below:

- ✓ melting point: 0°C , 32°F (273.15 K).
- ✓ boiling point: 100°C , 212°F (373.15 K)
- ✓ acidity (pKa): 15.74

- ✓ refractive index: (nD) 1.3330
- ✓ viscosity: 0.001 Pa s at 20 °C
- ✓ crystal structure: hexagonal
- ✓ molecular shape: bent
- ✓ Pure liquid water at room temperature is odourless, tasteless and nearly colourless. Water has a faint blue colour, which becomes more apparent in large volumes of water.
- ✓ Water has the second highest specific enthalpy of fusion of all substance (after ammonia). The specific enthalpy of fusion of water is 333.55 kJ·kg⁻¹ at 0 °C.
- ✓ Water has the second highest specific heat capacity of all known substances. (Ammonia has the highest specific heat.) Water also has a high heat of vaporization (40.65 kJ·mol⁻¹). The high specific heat and heat of vaporization result from the high degree of hydrogen bonding between water molecules. One consequence of this is that water is not subject to rapid temperature fluctuations. On Earth, this helps to prevent dramatic climate changes.

5. Amount of Water

The total amount of water present in the earth crust is about 1.4 billion km³. This tremendous amount of water is present in different types and forms as shown in Table 1 below. About 96.5% of the water is seawater and fresh water occupies around 2.5%. Around two-third of fresh water is icebergs and glaciers. Available fresh water for our daily life, industries and so on is about 0.8% of the total amount of water, and this frees water body includes ground water, river water and lake water.

6. Chemistry of fresh water

Water is essential for all life on Earth. As the Earth's population continues to increase rapidly, the growing human need for freshwater (e.g. for drinking, cooking, washing, carrying wastes, cooling machines, irrigating crops, receiving sewage and agricultural runoff, recreation, and industrial purposes) is leading to a global water resources crisis. The average annual water withdrawal for use by humans is currently about 4000 km³, of which 69% is used by agriculture, 21% by industry/power, and 10% for domestic purposes. Figures vary widely between continents and countries. On a per capita basis, North America withdraws seven times as much freshwater as Africa. The USA withdraws almost 20% of its renewable freshwater resources each year, in comparison with 7% for the UK, 22% for China, 33% for Poland, 51% for India, and 76% for Bangladesh. In Africa, most of the pollution associated with fresh water is due to ignorance and poverty.

Table 1: Amount of water

Type/Kind of water	Amount (10 ⁶ km ³)	Distribution ratio (%)
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Seawater	1,366	96.53
Fresh water	35.03	2.53
<i>(Icebergs and glaciers)</i>	<i>(24.06)</i>	<i>(68.7)</i>
<i>(Groundwater and soil moisture)</i>	<i>(10.58)</i>	<i>(31.0)</i>
<i>(Air moisture)</i>	<i>(0.01)</i>	<i>(0.03)</i>
<i>(Lake and marshes)</i>	<i>(0.108)</i>	<i>(0.29)</i>
<i>(Rivers)</i>	<i>(0.002)</i>	<i>(0.006)</i>
Others	12.59	0.94

Many developing countries are using up to 40% of their renewable freshwater for irrigation. As a consequence of population growth, pollution and climate change, the average supply of water per person is likely to drop by one-third over the next two decades, with a global supply crisis projected to occur between 2025 and 2050, although much earlier for some individual countries.

The quality of freshwater is also of concern. The effects of contaminants or pollutants on freshwater depend upon their chemical, physical, and biological properties, their concentrations and duration of exposure. Aquatic life may be affected indirectly (e.g. through depletion of oxygen caused by biodegradation of organic matter) or directly, through exposure to toxic or carcinogenic chemicals, some of which may accumulate in organisms. The toxicity of many heavy metals to fish is also inversely related to water hardness, with Ca competing with free metal ions for binding sites in biological systems.

A further demonstration of the importance of fundamental properties of both pollutants and water bodies is provided by the behaviour of chemicals upon reaching a groundwater aquifer. Soluble chemicals, such as nitrate, move in the same direction as groundwater flow. A poorly soluble liquid which is less dense than water, such as petrol, spreads out over the surface of the water table and flows in the direction of the groundwater. Poorly soluble liquids which are denser than water, such as various chlorinated solvents, sink below the water table and may flow separately along low permeability layers encountered at depth in the aquifer and not necessarily in the same direction as that of the overlying groundwater.

Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD)

Biological oxygen demand (BOD) refers to the amount of oxygen consumed when the organic matter in a given volume of water is biodegraded. BOD is an indicator of the *potential* for a water body to become depleted in oxygen and possibly become anaerobic because of biodegradation.

BOD measurements do not take into account re-oxygenation of water by naturally occurring diffusion from the atmosphere or mechanical aeration. Water with a high BOD and a microbial population can become depleted in oxygen and may not support aquatic life, unless there is a means for rapidly replenishing dissolved oxygen.

Chemical oxygen demand (COD) refers to the amount of oxygen consumed when the organic matter in a given volume of water is chemically oxidized to CO₂ and H₂O by a strong chemical oxidant, such as permanganate or dichromate. COD is sometimes used as a measure of general pollution. For example, in an industrial area built on fill dirt, COD in the groundwater might be used as an indicator of organic materials leached from the fill material. Leachate from landfills often has high levels of COD.

BOD is a subset of COD. The COD analysis oxidizes organic matter that is both chemically and biologically oxidizable. If a reliable correlation between COD and BOD can be established at a particular site, the simpler COD test may be used in place of the more complicated BOD analysis.

WATER QUALITY

Practical evaluation of water quality depends on how the water is used, as well as its chemical makeup. The quality of water in a stream might be considered good if the water is used for irrigation but poor if it is used as a drinking water supply. To determine water quality, one must first identify the ways in which the water will be used and only then determine appropriate numerical standards for important parameters of the water that will support and protect the designated water use.

The quality of water is not judged by its purity but rather by its suitability for the different uses intended for it. The water contaminant nitrate (NO₃⁻) illustrates this point. In drinking water supplies, nitrate concentrations greater than 10 mg/L are considered a potential health hazard, particularly to young children. On the other hand, nitrate is a beneficial plant nutrient in agricultural water and is added as a fertilizer. Water containing more than 10 mg/L of nitrate is of poor quality if it is used for potable water but may be of good quality for agricultural use. Thus, water uses must be identified before water quality can be judged.

The following preliminary steps, taken by a state or federal agency, are a common approach to evaluating water quality:

1. Define the basic purposes for which natural waters will potentially be used (water supply, aquatic life, recreation, agriculture, etc.). These will be the categories used for classifying existing bodies of water.
2. Set numerical water quality standards for physical and chemical characteristics that will support and protect the different water use categories.
3. Compare the water quality standards with field measurements of existing bodies of water, then assign appropriate use classifications to the water bodies according to whether their present or potential quality is suitable for the assigned water uses.

After a body of water is classified for one or more uses, compile an appropriate set of numerical standards to protect its assigned use classifications. Where different assigned classifications have different standards for the same parameter, the more stringent standard applies. It is clear that measuring the chemical composition of a water sample collected in the field is just one step in determining water quality. The sample data must then be compared with the standards assigned to that water body. If no standards are exceeded, the water quality is defined as good within its classified uses. As new information is collected about environmental and health effects of individual water constituents, it may be necessary to revise the standards for different water uses.

Federal and state regulations require that water quality standards be reviewed periodically and modified when appropriate. Typical water use classifications includes: recreational, aquatic life, Agriculture, Domestic water supply, wetland, groundwater, etc.

DOMESTIC AND INDUSTRIAL EFFLUENTS

Domestic and industrial effluents are liquid waste discharged from a municipal waste, sewage system, factory, nuclear power station, or other industrial plant. When insoluble particles, soluble salts, sewage (waste water), garbage, low level of radioactive substances, industrial wastes, algae, bacteria, etc. go into the water, water gets polluted. A lot of industrial wastes are generated by industrial processes which are invariably disposed to the environment. These do result into pollution when the assimilative capacity of the environment is exceeded.

Pollution is defined as the introduction to the environment by man, directly or indirectly of substance or energy into the environment resulting in deleterious effects to living resources and ecological systems and damage to structure, amenity or interference with the use of the environment.

Industrial waste encompasses a wide range of materials of varying environmental toxicity. This includes general rubbish, food wastes, acids and alkali, oils, solvents, resins, paints and sludge. About 8-9% of the total waste generated by industry is classified as ‘hazardous’ wastes because they contain substance that are toxic to humans, plants or animals, are corrosive, flammable or explosive or have high chemical reactivity. Hazardous wastes arise from the use of pesticides, chemicals, from wood treatments, oils, solvents, and batteries discarded.

SOURCES OF WATER IMPURITIES

A water impurity is any substance other than water (H_2O) that is found in the water sample. Thus, calcium carbonate ($CaCO_3$) is a water impurity even though it is not considered hazardous and is not regulated. Impurities can be divided into two classes:

- (1) unregulated impurities not considered harmful,
- (2) regulated impurities (pollutants) considered harmful.

In water quality analysis, unregulated as well as regulated impurities are measured. For example, hardness is a water quality parameter that results mainly from the presence of dissolved calcium and magnesium ions, which are unregulated impurities. However, high hardness levels can partially mitigate the toxicity of many dissolved metals to aquatic life. Hence, it is important to measure water hardness in order to evaluate the hazards of dissolved metals.

Data concerning unregulated impurities are also helpful for anticipating certain non-health related potential problems, such as pipe and boiler deposits, corrosivity, and low soil permeability. Unregulated impurities can also help to identify the recharge sources of wells and springs, learn about the mineral formations through which surface water or groundwaters pass, and age-date water samples.

Natural Sources

Snow and rain water contain dissolved and particulate minerals collected from atmospheric particulate matter, and small amounts of gases dissolved from atmospheric gases. Snow and rain have virtually no bacterial content until they reach the surface of the earth. After precipitation reaches the surface of the earth and flows over and through the soil, there are innumerable opportunities for the introduction of mineral, organic, and biological substances.

Water can dissolve at least a little of nearly anything it contacts. Because of its relatively high density, water can also carry suspended solids. Even under pristine conditions, surface and ground waters will usually contain various dissolved and suspended chemical substances.

Human caused sources

Many human activities cause additional possibilities for water contamination. Some important sources are:

- Construction and mining where freshly exposed soils and minerals can contact flowing water
- Industrial waste discharges and spills
- Petroleum discharges from leaking storage tanks, pipelines, tankers, and trucks
- Agricultural applications of chemical fertilizers, herbicides, and pesticides

- Urban storm water runoff, which contains all the debris of a city, including spilled fuels, animal feces, dissolved metals, organic scraps, road salt, tire and brake particles, construction rubble, etc.
- Effluents from industries and waste treatment plants.
- Leachate from landfills, septic tanks, treatment lagoons, and mine tailings
- Fallout from atmospheric pollution

The environmental professional must remain alert to the possibility that natural impurity sources may be contributing to problems that at first appear to be solely the result of human-caused sources. Whenever possible, one should obtain background measurements that demonstrate what impurities are present in the absence of known human-caused contaminant sources. For instance, groundwater in an area impacted by mining often contains relatively high concentrations of dissolved metals.

Before any remediation programs are initiated, it is important to determine what the groundwater quality would have been if the mines had not been there. This generally requires finding a location upgradient of the area influenced by mining, where the groundwater encounters subsurface mineral structures similar to those in the mined area.

CAUSES OF INDUSTRIAL POLLUTION

- 1) *Technical:* Many industries use outdated manufacturing processes, obsolete equipment and technologies, failure (such as oil spillage), pipeline leakage or corrosion, leaking underground storage; any of these may lead to water pollution.
- 2) *Types of energy source:* The energy source is usually a major investment in industries. If this is unreliable, and obsolete, a serious air, noise pollution, and water pollution.
- 3) *Economical causes:* Lack of adequate financial resources may inhibit implementation of abatement technology or upgrading of old plants or ineffective environmental controls.
- 4) *Social causes:* This may be due to ignorance, low environmental awareness, sabotage and vandalisation of pipelines.
- 5) *Regulatory/Environmental failures:* this arise when the environmental protection agencies are weak or they allow culprit to pay pittance compensation for environmental damage.
- 6) *Racism:* This occurs from trans-boundary movement of hazardous wastes from one country to the other. Example is the 1988 illegal dumping of toxic wastes from Italy to Koko port in Delta State, Nigeria.
- 7) *Profit/Attitudinal perception:* Many industries perceive investment made on pollution abatement and control as reducing profit.

SOURCE AND HARMFUL EFFECTS OF DOMESTIC & INDUSTRIAL EFFLUENTS

1. Industrial wastes and organic sewage wastes: The wastes discharged by industries are called industrial wastes. These wastes contain compounds of metals (e.g. Hg, Cd, Pb, etc.), organic compounds, alkalies, phenols, etc. which make water polluted.

The sewage is the dirty water which contains human and animal excretions (e.g., urine and faeces). The discharge of large quantities of sewage into rivers and lakes also causes water pollution. This sewage is produced by the everyday human activities like bathing, washing clothes and excreting the urine and faeces.

Some of the effects of industrial and domestic wastes effluents are:

- a) The sewage contain organic compounds. These organic compounds act as food for bacteria present in water of lakes and rivers and hence the population of bacteria in water is rapidly increased. This bacteria oxidizes nitrogen and phosphorous present in organic compounds of the sewage to nitrates and phosphates. This oxidation process consumes a large quantity of O₂ gas dissolved in river water. The loss of dissolved O₂ from the river water causes the death of fish and other aquatic living beings.
- b) These wastes produce scum and sludge in water.
- c) These wastes change the colour of water and produce foul smell.
- d) The metallic elements present in the industrial wastes make water polluted. These metals affect adversely human beings, plants aquatic life. Such metals include Pb, Hg and Cd. Also, Zn, Cr, As, Be, B, Mn, Ni, V, and Se, have adverse effect on humans and animals.

2. Organic compounds: These includes synthetic detergents, herbicides, pesticides, oil and decomposition products. Their effects are given below:

- a) *Detergents:* Detergents are surfactants (i.e. surface active agents) and builders. Surfactants are organic compounds having polar or hydrophilic groups such as -COOH, -SO₃H₂, NH₄⁺ or non-polar or lyophilic groups soluble in water. Surfactants have the following properties and hence cause water pollution.
 - i) *Bio-micro-organisms* (i.e. bacteria present in the water of lakes or rivers) are not able to biodegrade the surfactants, i.e. surfactants are not decomposed (digested) by the bio-micro-organisms and hence large volumes of detergent foams are collected in the lakes and rivers. These foams make water polluted.
 - ii) *Surfactants* form a sort of envelope around the organic substances (e.g. phenol). The formation of an envelope results in that these substances do not undergo oxidative degradation during the treatment of municipal waste water. Thus, the removal of organic substances from the waste water by the usual treatment methods becomes a problem.
 - iii) *Builders* are generally sodium salts of phosphoric acid, carbonic acid, sulphuric acid, etc. The builders form stable soluble complexes with hardness-producing ions such as Ca²⁺ and Mg²⁺. These complexes act as plant nutrients and cause a rapid growth of algae and weeds in water.

The growth of these plants appears as a green sludge on the surface of the water. These plants bring about de-oxygenation of water and hence aquatic animals die.

iv) **Pesticides:** The pesticides (e.g. DDT, endrin, dieldrin, polychlorinated diphenyls etc.) are both toxic and persistent. Analysis of polluted water has shown that it contains pesticides which are toxic to fish. Endrin, even in traces is reported to be toxic for catfish and other varieties of fish. D.D.T. affects the central nervous system of fish and toxaphene has been reported to cause bone degeneration in fish.

3. Chemical fertilizers: plant nutrients. Nitrate/phosphate salts are generally used as fertilizers, to increase the yield of the crops. When these fertilizers are used in excess, some of their unused quantity is washed away from the agriculture lands into the ponds, lakes rivers with rain water and thus pollute the water. This water is polluted, since it contains unused nitrate/phosphatic fertilizers which, when washed away into the lakes and rivers with rain water, make the water polluted.

4. Disease producing micro-organisms: If the residents of a municipality are suffering from diseases like dysentery, typhoid, cholera, etc., the faeces and urine discharged by such patients contain micro-organisms which are transmitted through water supplies and thus produce disease in other living beings.

5. Petroleum oil: If large quantity of crude petroleum oil is spilled accidentally or intentionally into the sea-water from the tankers (ships) or during the drilling and shipping operations, this oil pollutes sea water.

WATER TREATMENT

The treatment of water can be divided into three major categories:

- Purification for domestic use
- Treatment for specialized industrial applications
- Treatment of wastewater to make it acceptable for release or reuse

The type and degree of treatment are strongly dependent upon the source and intended use of the water. Water for domestic use must be thoroughly disinfected to eliminate disease-causing microorganisms, but may contain appreciable levels of dissolved calcium and magnesium (hardness). Water to be used in boilers may contain bacteria but must be quite soft to prevent scale formation. Wastewater being discharged into a large river may require less rigorous treatment than water to be reused in an arid region. As world demand for limited water resources grows, more sophisticated and extensive means will have to be employed to treat water

MUNICIPAL WATER TREATMENT

The modern water treatment plant is often called upon to perform wonders with the water fed to it. The clear, safe, even tasteful water that comes from a faucet may have started as a murky liquid pumped from a polluted river laden with mud and swarming with bacteria. Or, its source may have been well water, much too hard for domestic use and containing high levels of stain-producing dissolved iron and manganese. The water treatment plant operator's job is to make sure that the water plant product presents no hazards to the consumer.

A schematic diagram of a typical municipal water treatment plant is shown in Figure 1. This particular facility treats water containing excessive hardness and a high level of iron. The raw water taken from wells first goes to an aerator. Contact of the water with air removes volatile solutes such as hydrogen sulfide, carbon dioxide, methane, and volatile odorous substances such as methane thiol (CH_3SH) and bacterial metabolites. Contact with oxygen also aids iron removal by oxidizing soluble iron(II) to insoluble iron(III). The addition of lime as CaO or $\text{Ca}(\text{OH})_2$ after aeration raises the pH and results in the formation of precipitates containing the hardness ions Ca^{2+} and Mg^{2+} . These precipitates settle from the water in a primary basin. Much of the solid material remains in suspension and requires the addition of coagulants (such as iron(III) and aluminum sulfates, which form gelatinous metal hydroxides) to settle the colloidal particles. Activated silica or synthetic polyelectrolytes may also be added to stimulate coagulation or flocculation. The settling occurs in a secondary basin after the addition of carbon dioxide to lower the pH. Sludge from both the primary and secondary basins is pumped to a sludge lagoon. The water is finally chlorinated, filtered, and pumped to the city water mains.

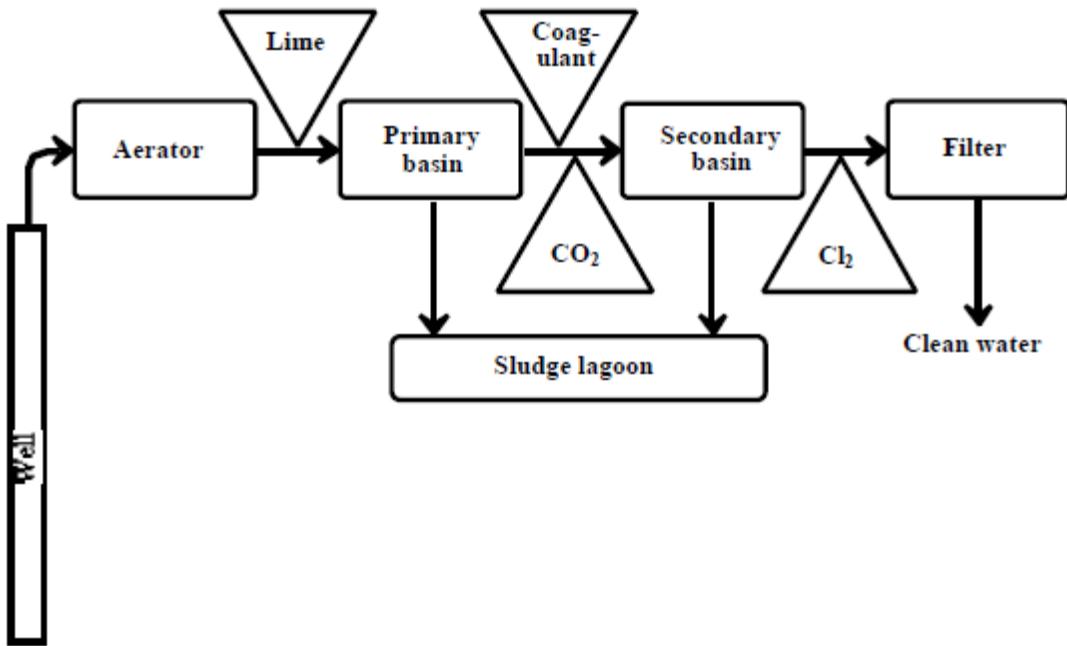


Figure 1: Schematic diagram of municipal water treatment plant.

TREATMENT OF WATER FOR INDUSTRIAL USE

Water is widely used in various process applications in industry. Other major industrial uses are boiler feedwater and cooling water. The kind and degree of treatment of water in these applications depends upon the end use. As examples, although cooling water may require only minimal treatment, removal of corrosive substances and scale-forming solutes is essential for boiler feedwater, and water used in food processing must be free of pathogens and toxic substances. Improper treatment of water for industrial use can cause problems such as corrosion, scale formation, reduced heat transfer in heat exchangers, reduced water flow, and product contamination.

These effects may cause reduced equipment performance or equipment failure, increased energy costs due to inefficient heat utilization or cooling, increased costs for pumping water, and product deterioration. Obviously, the effective treatment of water at minimum cost for industrial use is a very important area of water treatment.

Numerous factors must be taken into consideration in designing and operating an industrial water treatment facility. These include the following:

- Water requirement
- Quantity and quality of available water sources
- Sequential use of water (successive uses for applications requiring progressively lower water quality)
- Water recycle

- Discharge standards

External treatment, usually applied to the plant's entire water supply, uses processes such as aeration, filtration, and clarification to remove material that might cause problems from water. Such substances include suspended or dissolved solids, hardness, and dissolved gases. Following this basic treatment, the water can be divided into different streams, some to be used without further treatment, and the rest to be treated for specific applications.

Internal treatment is designed to modify the properties of water for specific applications. Examples of internal treatment include the following:

- a) Reaction of dissolved oxygen with hydrazine or sulfite
- b) Addition of chelating agents to react with dissolved Ca^{2+} and prevent formation of calcium deposits
- c) Addition of precipitants, such as phosphate used for calcium removal
- d) Treatment with dispersants to inhibit scale
- e) Addition of inhibitors to prevent corrosion
- f) Adjustment of pH
- g) Disinfection for food processing uses or to prevent bacterial growth in cooling water

SEWAGE TREATMENT

Typical municipal sewage contains oxygen-demanding materials, sediments, grease, oil, scum, pathogenic bacteria, viruses, salts, algal nutrients, pesticides, refractory organic compounds, heavy metals, and an astonishing variety of flotsam ranging from children's socks to sponges. It is the job of the waste-treatment plant to remove as much of this material as possible.

Several characteristics are used to describe sewage. These include turbidity (international turbidity units), suspended solids (ppm), total dissolved solids (ppm), acidity (H^+ ion concentration or pH), and dissolved oxygen (in ppm O_2). Biochemical oxygen demand is used as a measure of oxygen-demanding substances. Current processes for the treatment of wastewater can be divided into three main categories of:

primary treatment secondary treatment tertiary treatment.

Primary Waste Treatment

Primary treatment of wastewater consists of the removal of insoluble matter such as grit, grease, and scum from water. The first step in primary treatment normally is screening. Screening removes or reduces the size of trash and large solids that get into the sewage system. These solids are collected on screens and scraped off for subsequent disposal. Most screens are

cleaned with power rakes. Comminuting devices shred and grind solids in the sewage. Particle size can be reduced to the extent that the particles can be returned to the sewage flow.

Grit in wastewater consists of such materials as sand and coffee grounds that do not biodegrade well and generally have a high settling velocity. **Grit removal** is practiced to prevent its accumulation in other parts of the treatment system, to reduce clogging of pipes and other parts, and to protect moving parts from abrasion and wear. Grit normally is allowed to settle in a tank under conditions of low flow velocity, and it is then scraped mechanically from the bottom of the tank.

Primary sedimentation removes both settleable and floatable solids. During primary sedimentation there is a tendency for flocculent particles to aggregate for better settling, a process that may be aided by the addition of chemicals. The material that floats in the primary settling basin is known collectively as grease. In addition to fatty substances, the grease consists of oils, waxes, free fatty acids, and insoluble soaps containing calcium and magnesium. Normally, some of the grease settles with the sludge and some floats to the surface, where it can be removed by a skimming device.

Secondary Waste Treatment by Biological Processes

The most obvious harmful effect of biodegradable organic matter in wastewater is BOD, consisting of a biochemical oxygen demand for dissolved oxygen by microorganism-mediated degradation of the organic matter. Secondary wastewater treatment is designed to remove BOD, usually by taking advantage of the same kind of biological processes that would otherwise consume oxygen in water receiving the wastewater. Secondary treatment by biological processes takes many forms but consists basically of the action of microorganisms provided with added oxygen degrading organic material in solution or in suspension until the BOD of the waste has been reduced to acceptable levels. The waste is oxidized biologically under conditions controlled for optimum bacterial growth, and at a site where this growth does not influence the environment.

One of the simplest biological waste treatment processes is the trickling filter in which wastewater is sprayed over rocks or other solid support material covered with microorganisms. The structure of the trickling filter is such that contact of the wastewater with air is allowed and degradation of organic matter occurs by the action of the microorganisms.

Tertiary Waste Treatment

Unpleasant as the thought may be, many people drink used water—water that has been discharged from a municipal sewage treatment plant or from some industrial process. This raises serious questions about the presence of pathogenic organisms or toxic substances in such water. Because of high population density and heavy industrial development, the problem is especially acute in Europe where some municipalities process 50% or more of their water from “used”

sources. Obviously, there is a great need to treat wastewater in a manner that makes it amenable to reuse. This requires treatment beyond the secondary processes.

Tertiary waste treatment (sometimes called advanced waste treatment) is a term used to describe a variety of processes performed on the effluent from secondary waste treatment. The contaminants removed by tertiary waste treatment fall into the general categories of (1) suspended solids, (2) dissolved organic compounds, and (3) dissolved inorganic materials, including the important class of algal nutrients. Each of these categories presents its own problems with regard to water quality. Suspended solids are primarily responsible for residual biological oxygen demand in secondary sewage effluent waters. The dissolved organics are the most hazardous from the standpoint of potential toxicity. The major problem with dissolved inorganic materials is that presented by algal nutrients, primarily nitrates and phosphates. In addition, potentially hazardous toxic metals may be found among the dissolved inorganics.

In addition to these chemical contaminants, secondary sewage effluent often contains a number of disease-causing microorganisms, requiring disinfection in cases where humans may later come into contact with the water. Among the bacteria that may be found in secondary sewage effluent are organisms causing tuberculosis, dysenteric bacteria (*Bacillus dysenteriae*, *Shigella dysenteriae*, *Shigella paradyserteriae*, *Proteus vulgaris*), cholera bacteria (*Vibrio cholerae*), bacteria causing mud fever (*Leptospira icterohemorrhagiae*), and bacteria causing typhoid fever (*Salmonella typhosa*, *Salmonella paratyphi*). In addition, viruses causing diarrhea, eye infections, infectious hepatitis, and polio may be encountered. Ingestion of sewage still causes disease, even in more developed nations.

Physical-Chemical Treatment of Municipal Wastewater

Complete physical-chemical wastewater treatment systems offer both advantages and disadvantages relative to biological treatment systems. The capital costs of physical-chemical facilities can be less than those of biological treatment facilities, and they usually require less land. They are better able to cope with toxic materials and overloads. However, they require careful operator control and consume relatively large amounts of energy.

Basically, a physical-chemical treatment process involves:

- a) Removal of scum and solid objects
- b) Clarification, generally with addition of a coagulant, and frequently with the addition of other chemicals (such as lime for phosphorus removal)
- c) Filtration to remove filterable solids
- d) Activated carbon adsorption
- e) Disinfection

INDUSTRIAL WASTEWATER TREATMENT

Before treatment, industrial wastewater should be characterized fully and the biodegradability of wastewater constituents determined. One of two major ways of removing organic wastes is biological treatment by an activated sludge or related process). It may be necessary to acclimate microorganisms to the degradation of constituents that are not normally biodegradable. Consideration needs to be given to possible hazards of biotreatment sludges, such as those containing excessive levels of heavy metal ions. The other major process for the removal of organics from wastewater is sorption by activated carbon, usually in columns of granular activated carbon.

Activated carbon and biological treatment can be combined with the use of powdered activated carbon in the activated sludge process. The powdered activated carbon sorbs some constituents that may be toxic to microorganisms and is collected with the sludge. A major consideration with the use of activated carbon to treat wastewater is the hazard that spent activated carbon may present from the wastes it retains. These hazards may include those of toxicity or reactivity, such as those posed by wastes from the manufacture of explosives sorbed to activated carbon. Regeneration of the carbon is expensive and can be hazardous in some cases.

Wastewater can be treated by a variety of chemical processes, including acid/base neutralization, precipitation, and oxidation/reduction. Sometimes these steps must precede biological treatment; for example, acidic or alkaline wastewater must be neutralized in order for microorganisms to thrive in it. Cyanide in the wastewater may be oxidized with chlorine and organics with ozone, hydrogen peroxide promoted with ultraviolet radiation, or dissolved oxygen at high temperatures and pressures. Heavy metals may be precipitated with base, carbonate, or sulfide.

Wastewater can be treated by several physical processes. In some cases, simple density separation and sedimentation can be used to remove water-immiscible liquids and solids. Filtration is frequently required, and flotation by gas bubbles generated on particle surfaces may be useful. Wastewater solutes can be concentrated by evaporation, distillation, and membrane processes, including reverse osmosis, hyperfiltration, and ultrafiltration. Organic constituents can be removed by solvent extraction, air stripping, or steam stripping. Synthetic resins are useful for removing some pollutant solutes from wastewater. Organophilic resins have proven useful for the removal of alcohols; aldehydes; ketones; hydrocarbons; chlorinated alkanes, alkenes, and aryl compounds; esters, including phthalate esters; and pesticides. Cation exchange resins are effective for the removal of heavy metals.

In a nutshell, industrial effluents can be managed through at least four distinct strategies:

- a) Installation of industrial – waste treatment plants operated within the factory.
- b) Discharge of industrial wastes to public systems for treatment
- c) Process modification and changed product formulation to reduce wastes. Example include the development of biodegradable detergents.
- d) Abandonment of a product line or process procedure.

https://youtu.be/d7Ci_EooW-k

Understand Global warming through the above link

THE OZONE LAYER AND THE GREENHOUSE EFFECT

THE OZONE LAYER

- Ozone Layer refers to a region of Earth's stratosphere that absorbs most of the Sun's UV radiation.
- The ozone layer contains less than 10 ppm of ozone, while the average ozone concentration in Earth's atmosphere as a whole is only about 0.3 ppm.

THE OZONE LAYER

- ▶ In 1913, the **ozone layer** was discovered by the French physicists Charles Fabry and Henri Buisson.
- ▶ Also, G. M. B. Dobson developed a simple spectrophotometer that could be used to measure stratospheric ozone from the ground.

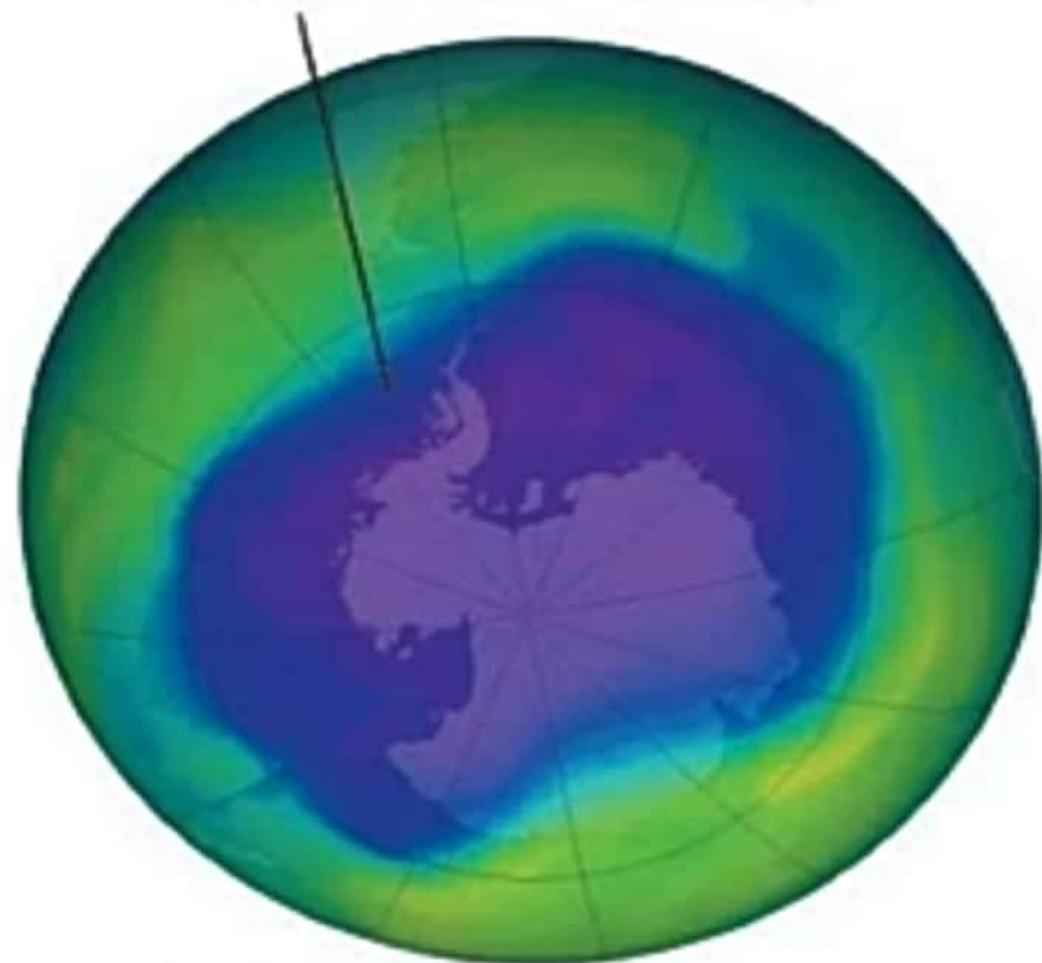
THE OZONE LAYER

- The ozone layer absorbs 97–99% of the Sun's medium-frequency ultraviolet light (from about 200 nm to 315 nm wavelength), which otherwise would potentially damage exposed life forms near the surface.

THE OZONE LAYER

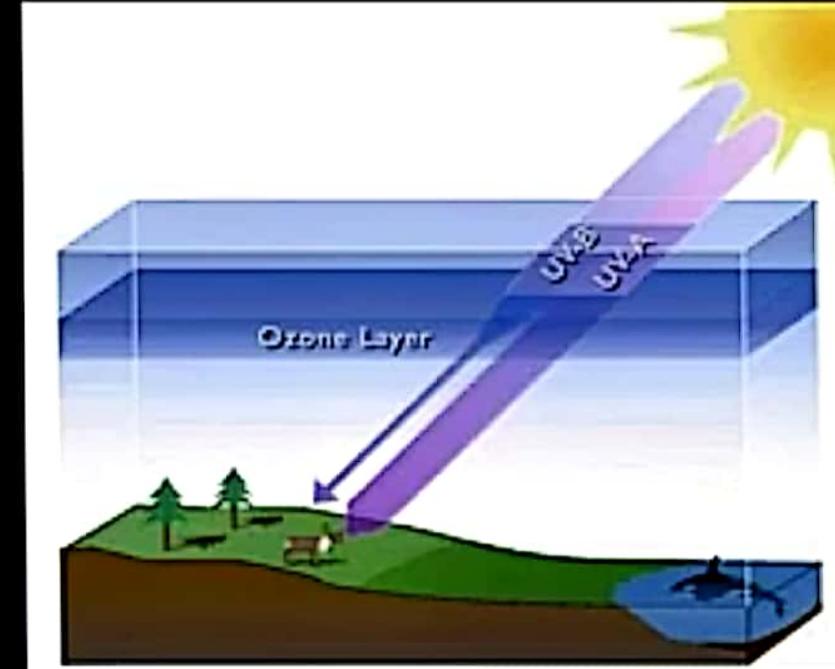
- In the 1970s, scientists noticed that the ozone layer in the stratosphere above Antarctica was thinning.

The largest hole in the ozone layer ever observed.
(September 24, 2006)



CHLOROFLUOROCARBONS

- A group of chemicals called chlorofluorocarbons
- (or CFCs) were once commonly used in air conditioners, in aerosol spray cans, and for cleaning machine parts.



- In the London Agreement of 1991, more than 90 countries banned the production and use of CFCs except for limited medical uses.

CHLOROFLUOROCARBONS



- The ozone layer absorbs the Sun's high-energy ultraviolet (UV) radiation and protects the Earth.

CHLOROFLUOROCARBONS



- In the stratosphere, the CFCs break down and release chlorine. The chlorine reacts with ozone molecules, which normally blocks incoming ultraviolet radiation.

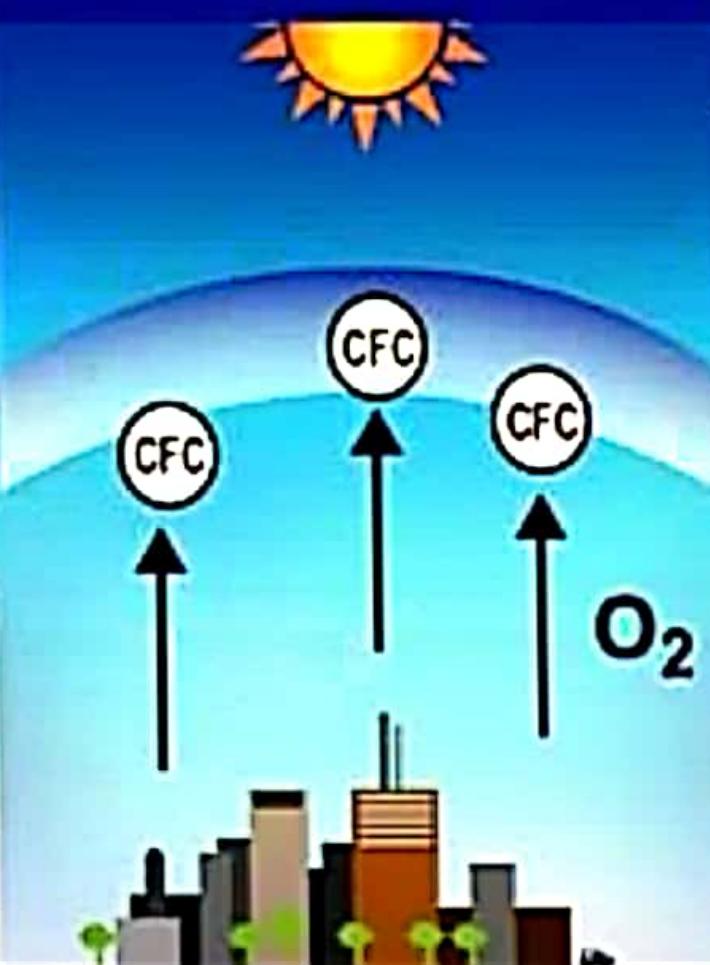


Chlorofluorocarbons (CFCs) and Ozone Depletion

1 The ozone layer protects Earth from ultraviolet light.



2 CFC's reach the stratosphere, destroying ozone.



3 O_2 doesn't block ultra-violet light from the sun.



GREENHOUSE EFFECT

The trapping of heat by gases in the atmosphere.

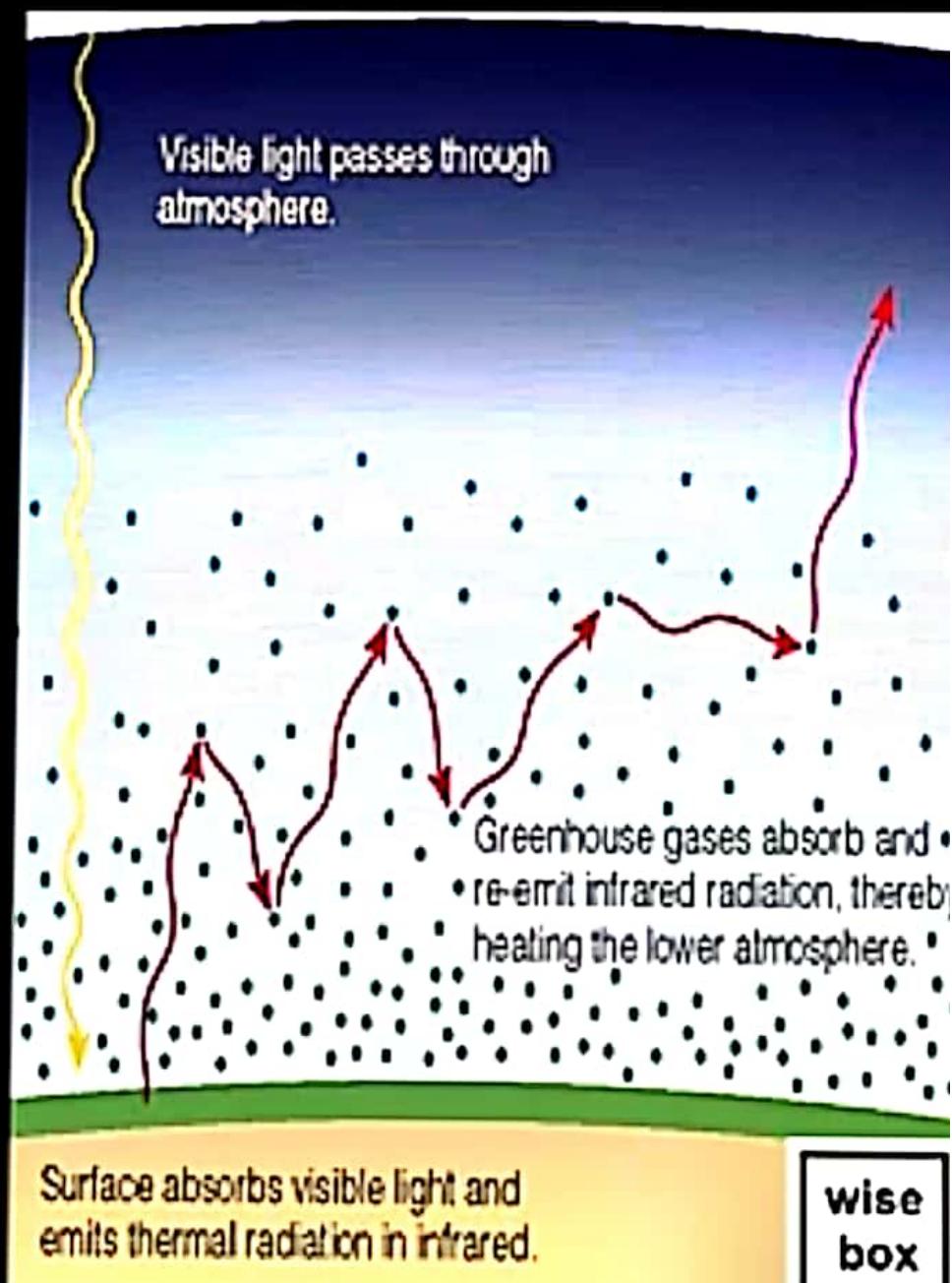
- Naturally occurring greenhouse gases:
 - Water vapor
 - Carbon dioxide
 - Methane
 - Nitrous oxide
 - Ozone

GREENHOUSE EFFECT

- Greenhouse gases that are **not naturally occurring :**
 - *Hydro fluorocarbons (HFCs)*
 - *Per fluorocarbons (PFCs)*
 - *Sulfur hexafluoride (SF₆)*

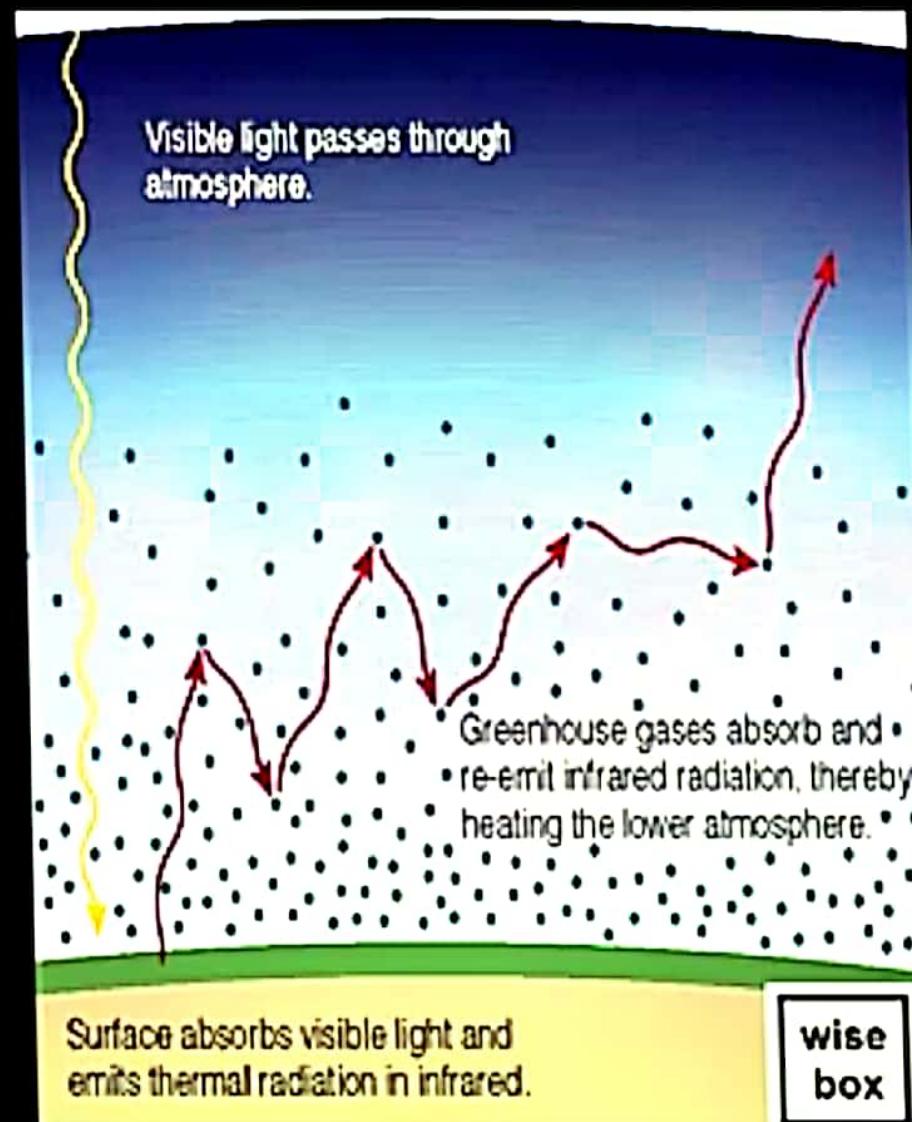
THE GREENHOUSE EFFECT ON EARTH

Earth's atmosphere is slightly warmer than what it should be due to direct solar heating because of a *mild case of greenhouse effect...*



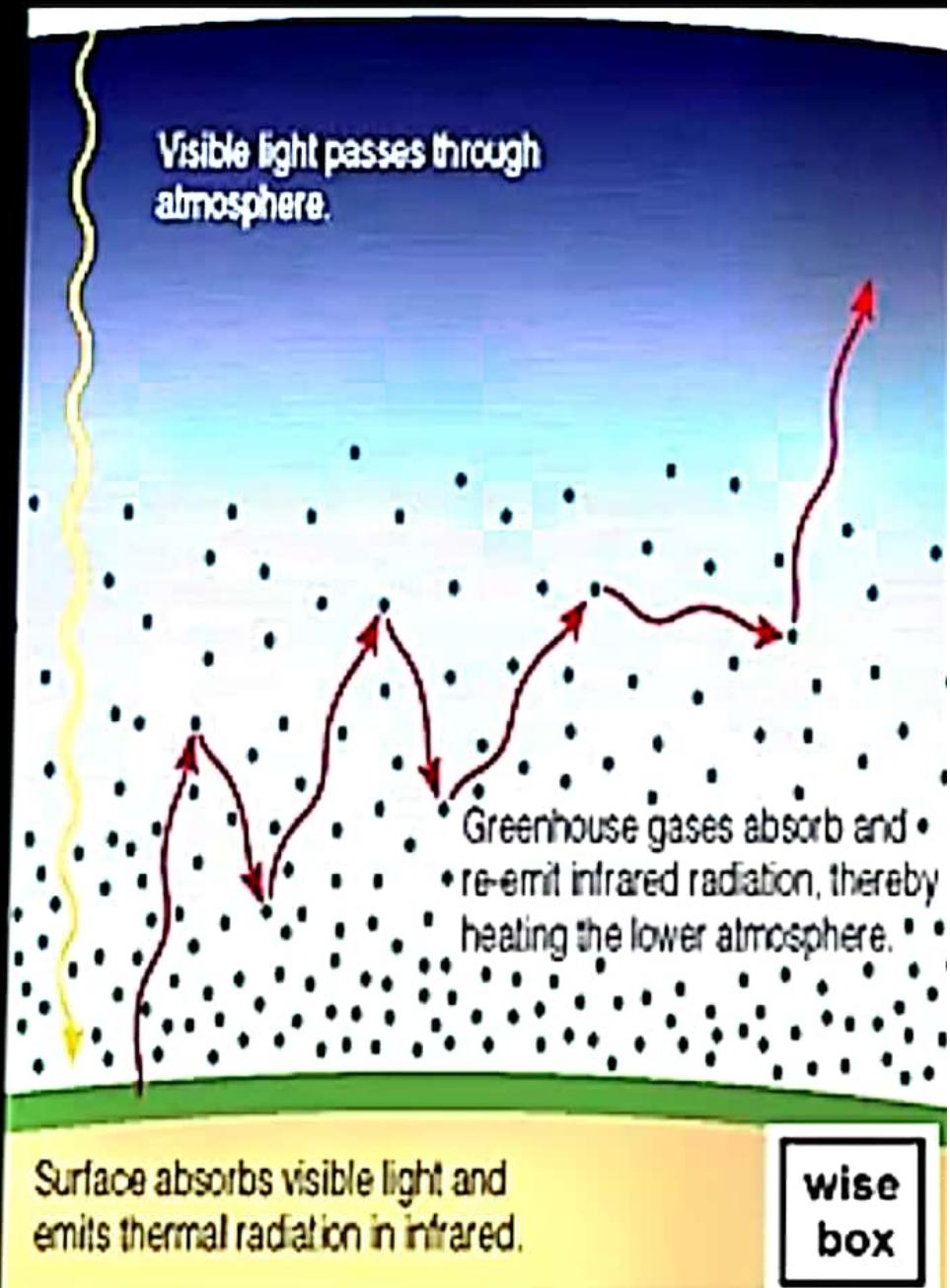
THE GREENHOUSE EFFECT ON EARTH

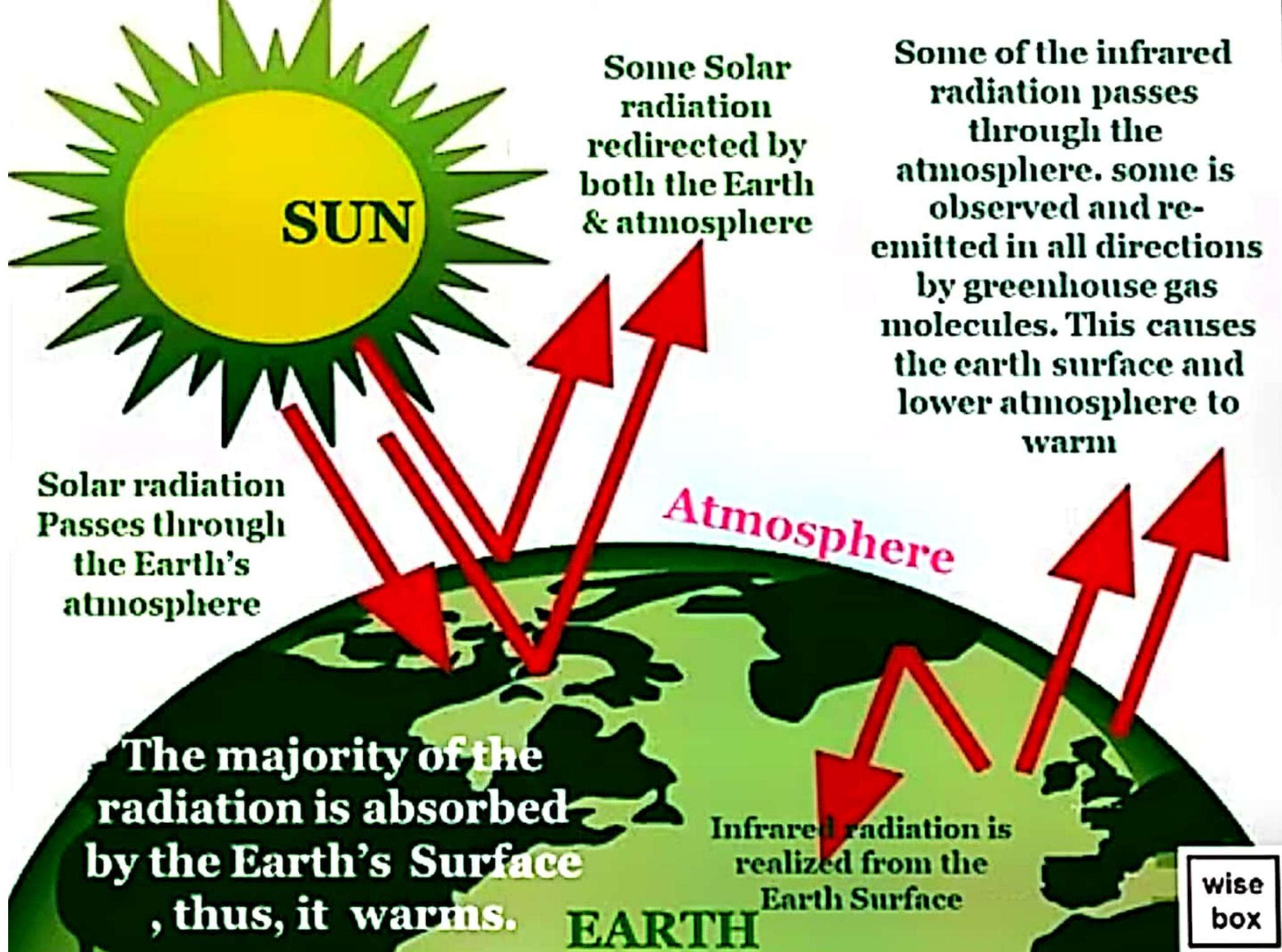
- The ground is heated by visible and (some) infrared light from the Sun.
- The heated surface emits infrared light.

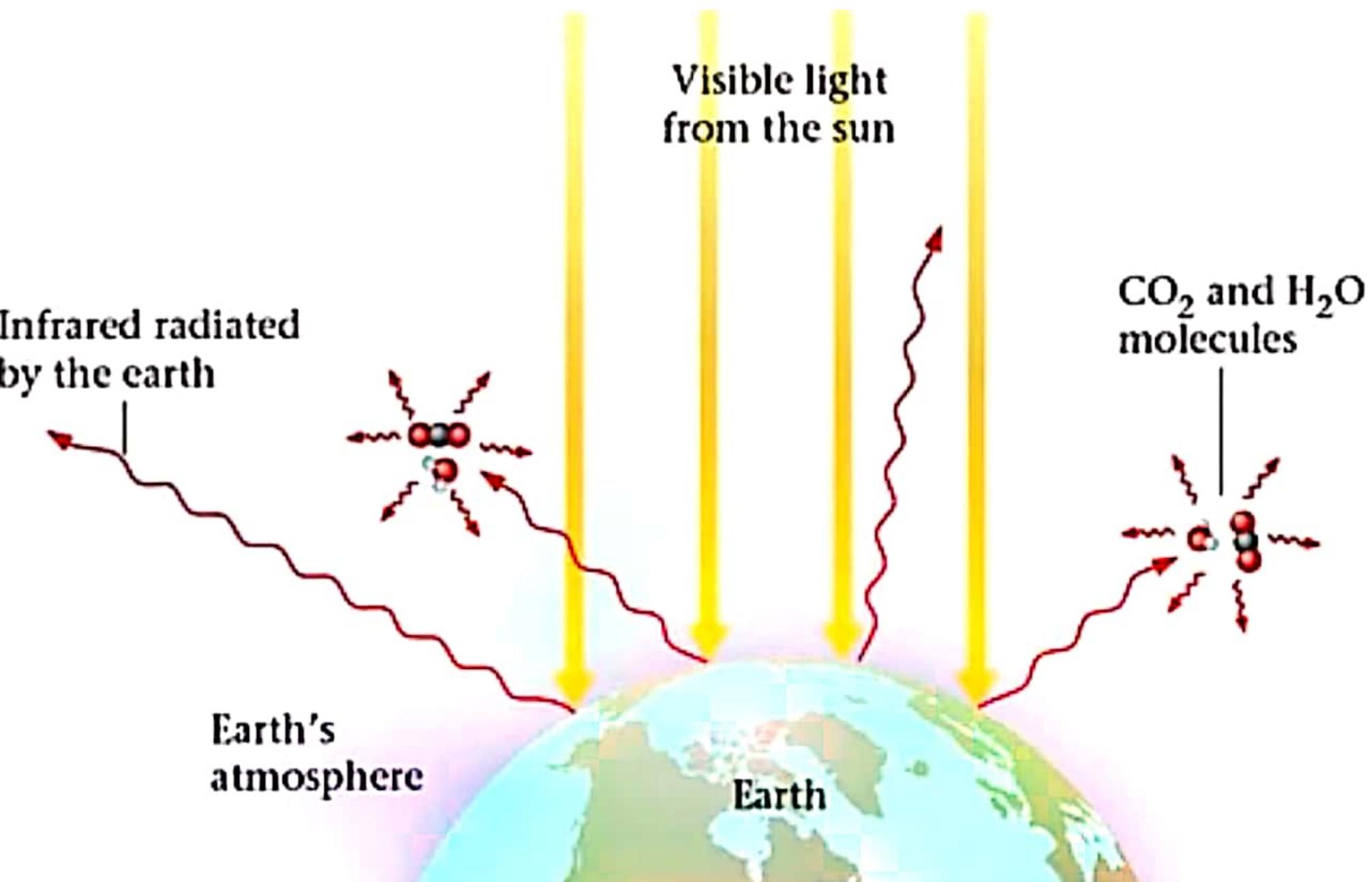


THE GREENHOUSE EFFECT ON EARTH

- The majority of Earth's atmosphere (N_2 and O_2) are not good greenhouse gases.
- The small amount of greenhouse gases (CO_2) traps (absorb and re-emit) the infrared radiation, increasing the temperature of the atmosphere...

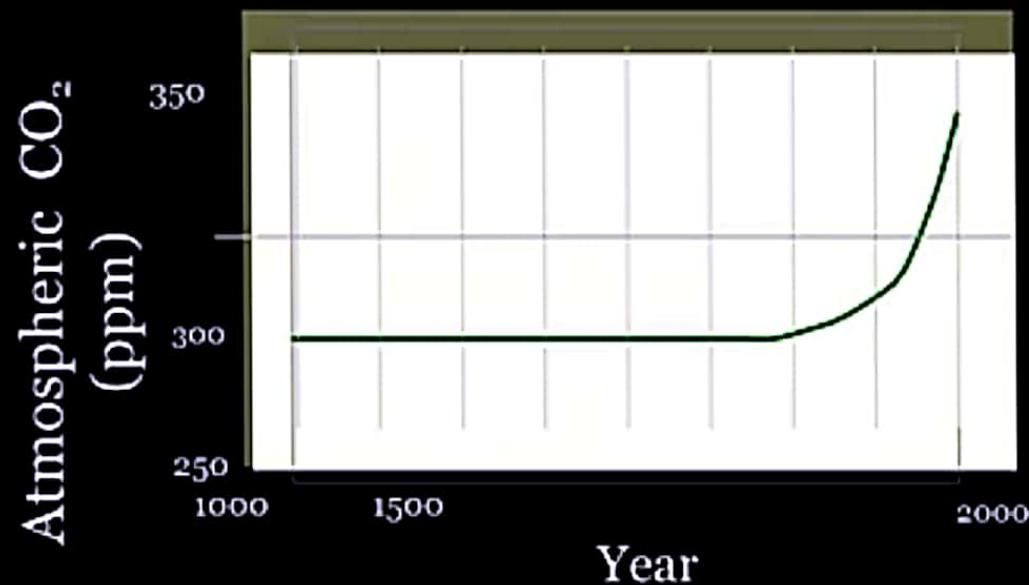






wise
box

GREENHOUSE EFFECT



➤ FACT: 15% increase in [CO₂] in last 100 years



GREENHOUSE EFFECT

➤ Effects:

➤ Global warming

➤ Melt polar ice caps →

flooding at sea level

➤ Warming oceans →

more powerful storms

GREENHOUSE EFFECT

➤ Causes :

- Change from agricultural to industrial lifestyle
- Burning of fossil fuels (petroleum, coal)
- Increase CO₂ emissions (cars, factories etc...)
- Deforestation



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GREENHOUSE EFFECT

How Can We Help ?

- Reduce, Reuse, Recycle....
- Use Less Heat and Air Conditioning...
- Replace Your Light Bulbs.
- Drive Less and Drive Smart.
- Buy Energy-Efficient Products.
- Use the "Off" Switch.
- Plant a Tree.

The
End

