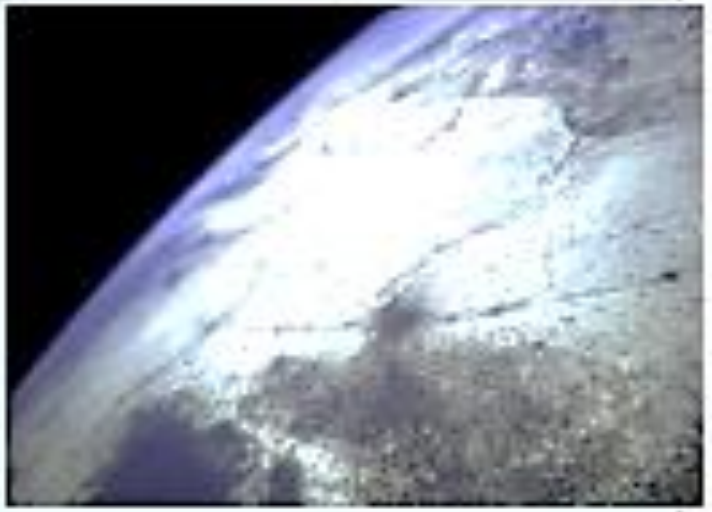
Atmosphere as a Resource

- **Atmospheric Composition**
  - Nitrogen 78.08%
  - Oxygen 20.95%
  - Argon 0.93%
  - Carbon dioxide 0.04%
- **Ecosystem services**
  - Blocks UV radiation
  - Moderates the climate
  - Redistributes water in the hydrologic cycle



Life-Air

Air? Not Ordinary Air!
It is Life-Air from the Skies!

- Without 'Food' but 'Water') human can live for '3 Days'.
- Without 'Water' (and no 'Food') human can live for '1 Day'.
- Without 'Air' (even with 'Food' and 'Water') human can live for '1 Minute'.

Ques: Guess, what is 'Death'?
Ans: No Air for '1 Minute' is called as 'Death'.

Air is so important. Pollution is a serious issue.

Air is Expensive than Blood

Air is what we Breathe every Seconds even during Sleep!

- Air is sucked into lungs every few seconds and the alveolar system of the lungs helps the oxygenation of blood in every drop.
- Heart pumps Blood and Blood carries O_2 (by Hemoglobin) to every part/cell of the body to sustain Life inside.
- 'More O_2' into the body is called 'More Life'.
- Similarly 'Better O_2' into the body is called 'Better Life'.
- But then 'Polluted O_2' into the body is called 'Polluted Life'.

What is air pollution

THE RESULT OF EMISSION INTO THE AIR OF HAZARDOUS SUBSTANCES AT A RATE THAT EXCEEDS THE CAPACITY OF NATURAL PROCESSES IN THE ATMOSPHERE TO CONVERT, DEPOSIT, OR DILUTE THEM...

Factors that affect air pollution

- Emissions (traffic, industrial, domestic)
- Geography (terrain)
- Weather conditions (rain, winds, humidity)
- Season
- Time of day
- Population density
- Indoor vs outdoor

Types of air pollution

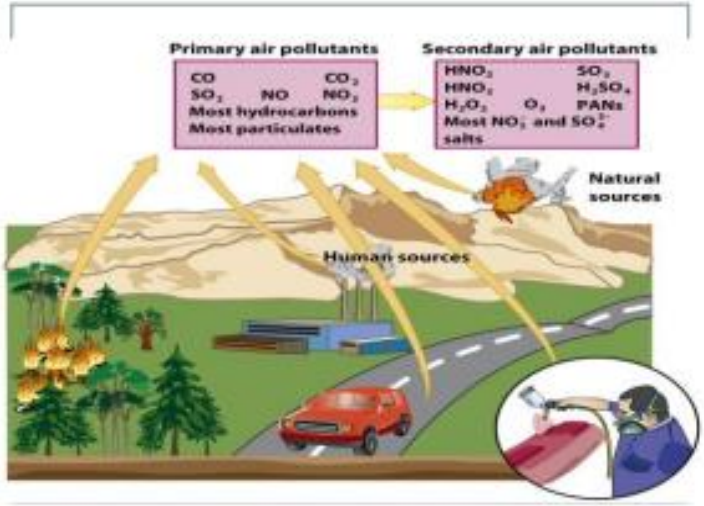
- Aerosols
  - Particulates solid phase
    - Dust
    - Ash
    - Fumes
  - Solid and liquid
    - Smoke (from combustion)
    - Coastal aerosols
  - Liquid
  - Aggregate gases (sulfate, nitrate)
- Gases
  - COx
  - SOx
  - NOx
  - PAH

Types and Sources of Air Pollution

- Two categories
  - Primary Air Pollutant
    - Harmful substance that is emitted directly into the atmosphere
  - Secondary Air Pollutant
    - Harmful substance formed in the atmosphere when a primary air pollutant reacts with substances normally found in the atmosphere or with other air pollutants

Six primary or "criteria" air pollutants

- Carbon monoxide (CO)
- Ozone (O_3)
- Nitrogen dioxide (NO_2)
- Sulfur oxides (SO_x)
- $PM_{2.5}$ and PM_{10}
- Lead (Pb)



Combustion pollutants

- VOCs
- NOx
- N-organics
- Halo-organics
- Metals
- CO

Sources of combustion

- Tobacco
- Power plants
- Incinerators
- Automobiles
- Industry

Diesel pollutants

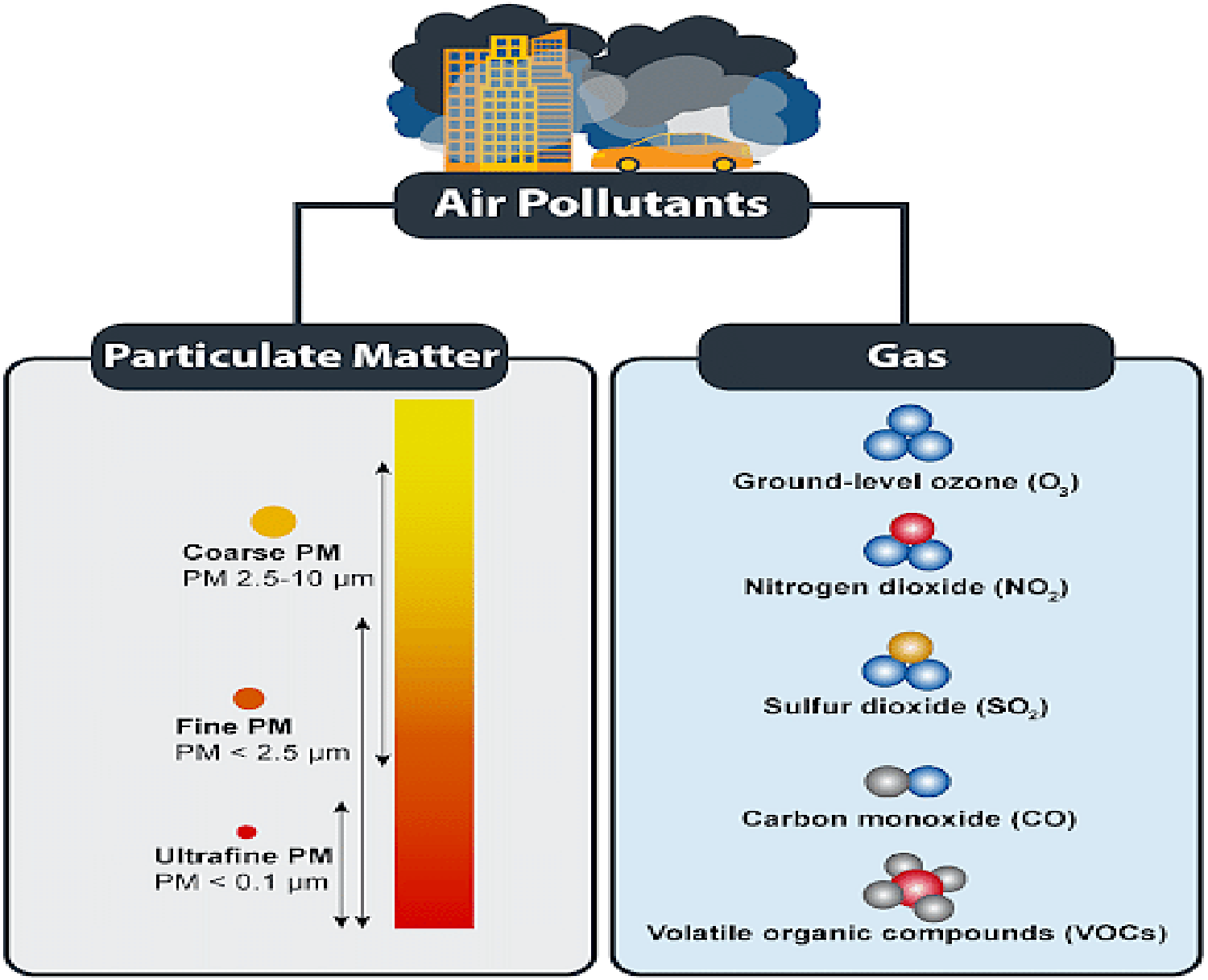
- Particulate matter
  - C + PAHs + N-aromatics
- Gases
  - NOx, CO, SOx
- VOCs
  - formaldehyde, acrolein, aldehydes

- Respiratory inflammation
- Cytotoxicity to airway cells

Outdoor air pollution

Delhi

Beijing


Air Pollutants
Particulate Matter
Coarse PM
PM 2.5-10 µm
Fine PM
PM < 2.5 µm
Ultrafine PM
PM < 0.1 µm
Gas
Ground-level ozone (O_3)
Nitrogen dioxide (NO_2)
Sulfur dioxide (SO_2)
Carbon monoxide (CO)
Volatile organic compounds (VOCs)

Sources of Carbon Monoxide

Industrial Emissions

Gas Appliances

Forest Fires

Biomass Burning

Power Generation

On-Road Vehicles

Sink for CO: Sink is a system which absorbs/store the pollutant, thereby, nullifying its harmful effect. A large mass of CO is generated and also there is continued increase in CO emissions within recent years. So it is obvious that the amount of CO should also increase in the atmosphere. But it has been found that the amount of CO in the atmosphere remains relatively constant suggesting that a sink or scavenging process also exists in the atmosphere. The micro organisms present in the soil act as a major sink for CO.

A significant amount of CO is converted into CO_2 by these micro organisms.

12228124

Which of the following is a sink for CO?

(a) Micro-organism present in the soil

(b) Oceans

(c) Plants

(d) Haemoglobin

Sink is a medium present in the environment which consumes certain completely / partially pollutants.

Carbon monoxide: health effect

- CO combines with Fe in haemoglobin in blood – bonds 320 times stronger than oxygen – oxygen cannot bond onto heamoglobin
- Less oxygen supplied to body cells
- Effects:
  - headaches,
  - shortness of breath,
  - in case of high concentration (e.g. rush hour): unconsciousness, death

Effects: The levels of CO present in the urban air do not effect significantly the plants and materials. However, these levels adversely affect human health. In urban areas, the soil available is insufficient to act as a sink thereby increasing the level of CO beyond permissible limits.

Carbon monoxide interferes with the blood's ability to carry oxygen to different parts of the body. The oxygen combines with haemoglobin, which is also known as oxygen carrier, to form oxyhaemoglobin. This oxyhaemoglobin travels to the different body cells where it gives oxygen to the cell and takes up CO_2 through the lungs.

$$Hb + O_2 \longrightarrow HbO_2 \longrightarrow Hb + O_2$$

However, if large amount of CO is present in the surroundings, is inhaled, it readily binds to haemoglobin to form carboxyhaemoglobin. Carbon monoxide, in fact, has a much greater affinity for haemoglobin (about 250 times) than oxygen because it forms a stronger complex with haemoglobin.

$$Hb + CO \rightleftharpoons HbCO$$

Thus the blood (haemoglobin) would carry less oxygen to various parts which inturn affects the brain function. The symptoms include laziness, exhaustion, headache. Acute starvation of oxygen (asyphyxiation) can lead to coma and death.

Physiological effects can be noted even at small percentage of COHb. As ... as is evident from

Control of CO pollution:

(1) Modification of Engine Design-

right proportion of oxygen in fuel for complete combustion of C and H to form CO_2 and H_2O

(2) Fuel Modification-

Fuels emits less amount of CO for e.g. Natural Gas, blends of Methane gas and lower hydrocarbons

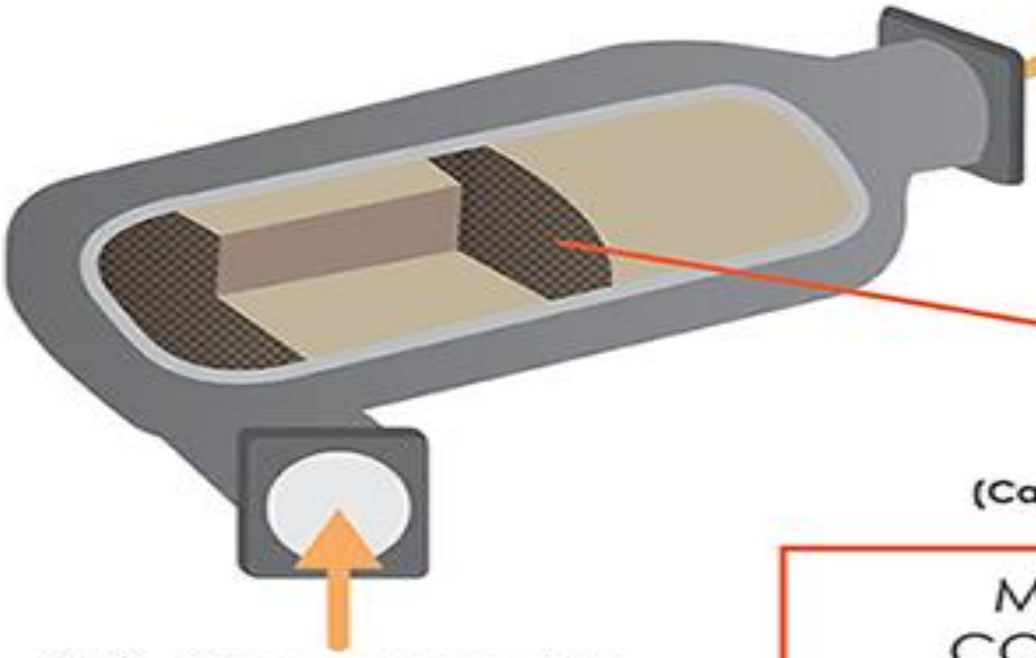
(3) Treatment of exhaust gases:

Two-Stage catalytic converter with catalyst is used.

Ist stage: N_2 to NH_3; catalyst Pd, Pt and Ruthenium

IInd stage: CO to CO_2; Catalyst – noble gases

Catalytic Converter



CO_2 - Carbon Dioxide
H_2O - Water
N_2 - Nitrogen

Catalyst Substrate
(Catalytic Active Material)

CO - Carbon Monoxide
HC - Hydrocarbons
NO_x - Nitrogen Oxides

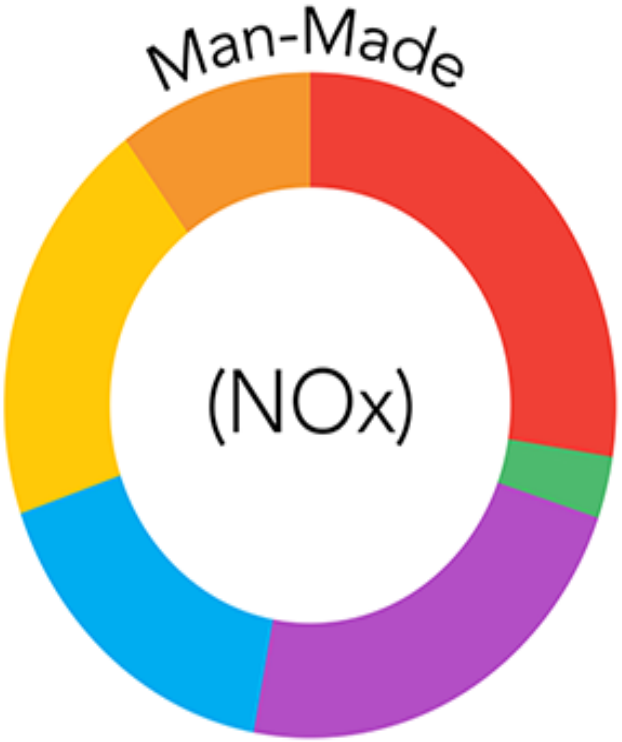
Major reaction

$$CO + \tfrac{1}{2}O_2 \rightarrow CO_2$$
$$H_4C_2 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$
$$CO + NO_x \rightarrow CO_2 + N_2$$

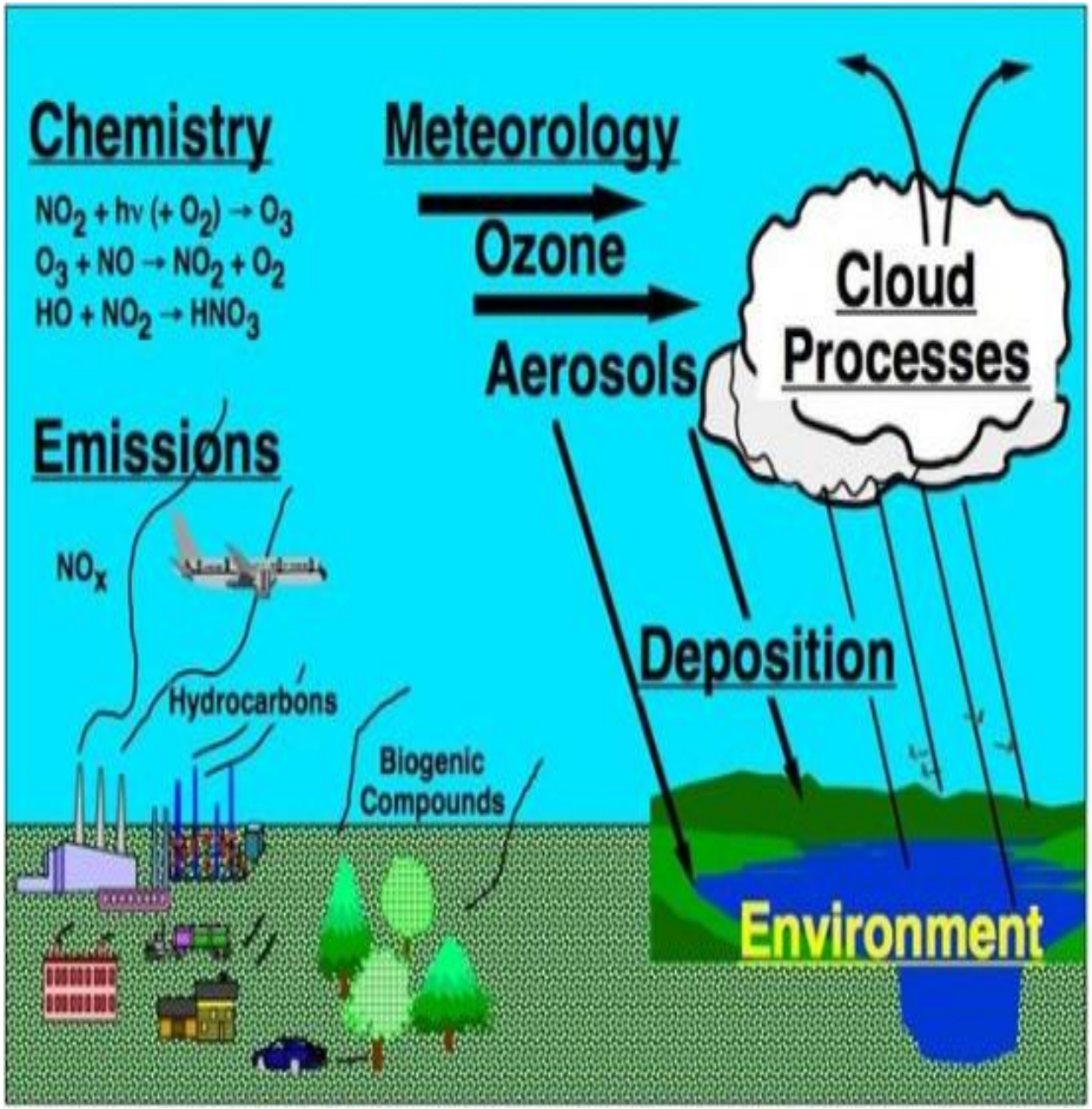
Sources of NOx : **(1) Natural Sources** : Lightening Discharge, Fixation of Nitrogen in atm

(2) Man-made Sources

Nitrogen Oxides are highly reactive gases primarily formed by the combustion of fuels. Each day, 234 tons of NOx are released from these sources:



Oil & Gas Production	Lawn & Garden	Off-road (tractors, airplanes, boats)	Industrial Plants, Factories & Gas Stations	Cars, SUVs and Motorcycles	Medium to Heavy-duty Vehicles
28%	3%	21%	17%	22%	10%



- The formation of NO_2 Is quite slow but the main reaction of formation of NO_2 is by NO and ground level ozone.

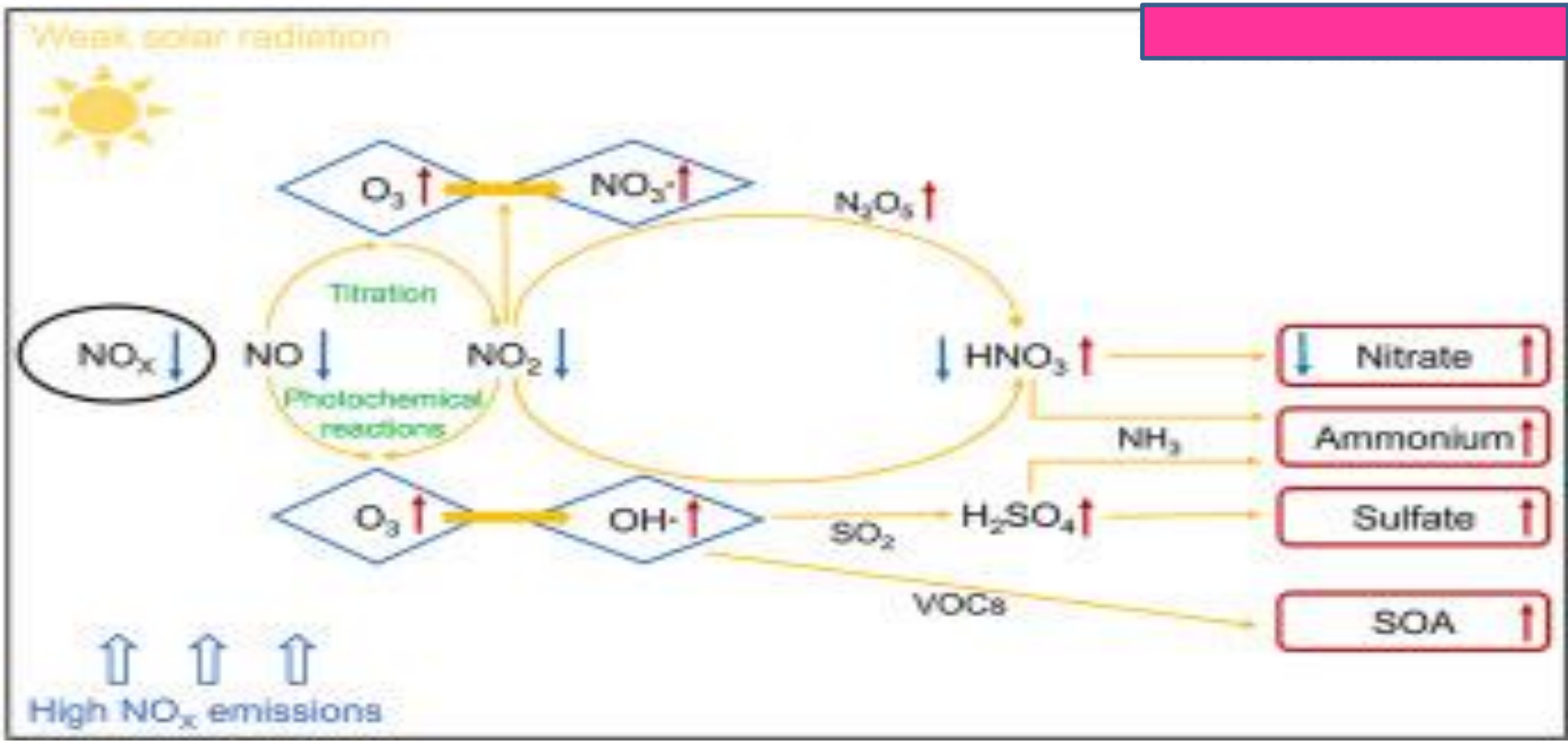
- NOx is produced by Chemical industries as byproducts
- Coal based power plants
- Sulphuric acid and nitric acid manufacturing

Sink for NOx:

(1) Photochemical and Chemical Reactions

(2) Rain: NO_2 and NO gets precipitated during rainfall.

(3) Volatile Organic Compounds (VOCs)



Effects of NOx on Environment and Human beings:

(1)Photochemical Smog

(2)Acid Rain

(3)Acute irritation in Lungs and Eyes, Bronchitis in Children

Control

(1) Modification of Engine design: Reducing the amount of excess air (from 25% to 1.25%)

(2) Scrubbing of flue gases:

(b) *Scrubbing the flue gases:* The flue gas[illegible] a scrubber

$$NO_2 + NO \longrightarrow N_2O_3$$

$$N_2O_3 + 2H_2SO_4 \longrightarrow 2NOHSO_4 + H_2O$$

The reaction product obtained from the scrubber is then decomposed.

$$2NOHSO_4 + \frac{1}{2}O_2 + H_2O \longrightarrow 2H_2SO_4 + 2NO_2$$

$$2NO_2 + H_2O \longrightarrow 2HNO_3 + NO$$

Excess NO and NO_2 are again circulated though the scrubber.

(3) Selective catalytic reduction:

(c) *Selective catalytic reduction:* The selective catalytic reduction can be achieved through CH_4, NH_3 and CO. The NO_x is added to the exhaust gases and mixture is passed over a fixed bed catalyst such as copper oxide.

$$6NO + 4NH_3 \longrightarrow 5N_2 + 6H_2O$$

or

$$NO + 2CO \longrightarrow N_2 + 2CO_2$$

It is interesting to note that the air pollution control methods also require modification of combustion methods. But the combustion process that improve CO emissions tend to make the emissions of NO_x problem worse, and vice versa. For example, to control CO, the air supply should be increased and temperature should be raised so that complete combustion takes place. This however is just the reverse if we want to control the emissions of NO_x which requires just opposite conditions.

Oxides of Nitrogen

Man-made Source – Coal burning power plants

NO
Nitrogen monoxide

NO_2
Nitrogen dioxide

Health problem- Lungs inflammation

Man-made Source – Internal combustion engine of fossil fuel

Natural source – Lightning

Environmental problem – Ground level Ozone Acid Rain

Sulphur Oxides

Introduction:-

- Oxides of Sulphur, especially sulphur dioxide, a chemical compound with the formula SO_2 are common pollutants of the air. SO_2 is produced by volcanoes and in various industrial processes.
- Since coal and petroleum often contain sulphur compounds, their combustion generates sulphfur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain.

OXIDES OF SULPHUR

SOURCES:

Natural sources of sulfur oxides

- **Volcanic action**
  - A volcanic gases: 90% water and CO_2, SO_2 content 1-10 % .
- **Sulfur compounds from biological activity**
  - **(CH_3SCH_3, H_2S, CS_2, COS) will be oxidized in the atmosphere.**
  - **Sulfur emission in highest amount: dimethyl-sulfide from the oceans → biological activity of fitoplankton.**

Sulfur oxides from human activity

Atmospheric sulfur content **is mainly anthropogenic (Human impact on the environmen)origin.**

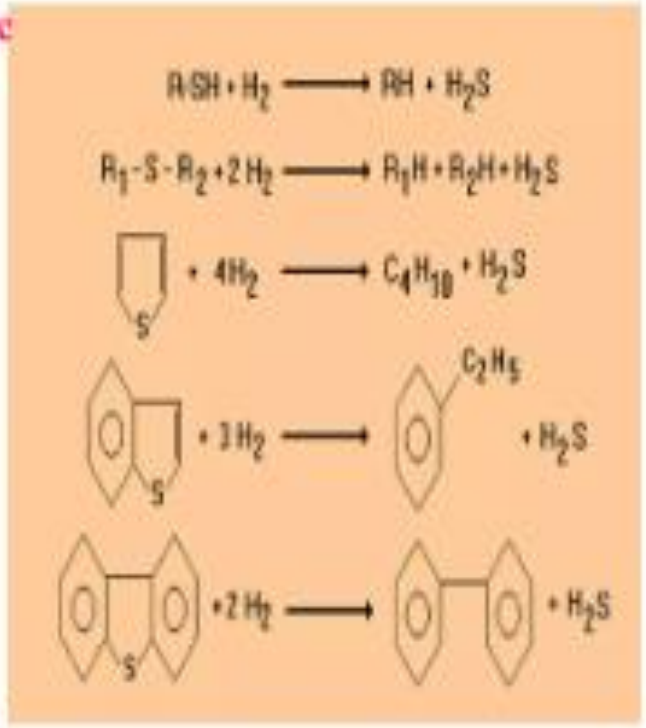
Main source: combustion of fossils fuels

*Sulfur content of coal and crude oil differs:-

Crude oil: mainly organic, (sulfides, mercaptenes, bisulfides, tiofenes) => can be removed by simple technology.

Coal:

- **pyritic (FeS), removable by physical method,**
- **sulfates ($CaSO_4$, $FeSO_4$) removable by physical method (no decay at combustion temperature to SO_3)**



Sinks for SO_x: The sulphur dioxide released in the atmosphere is converted to sulphur SO_3 by photolytic and catalytic processes involving ozone.

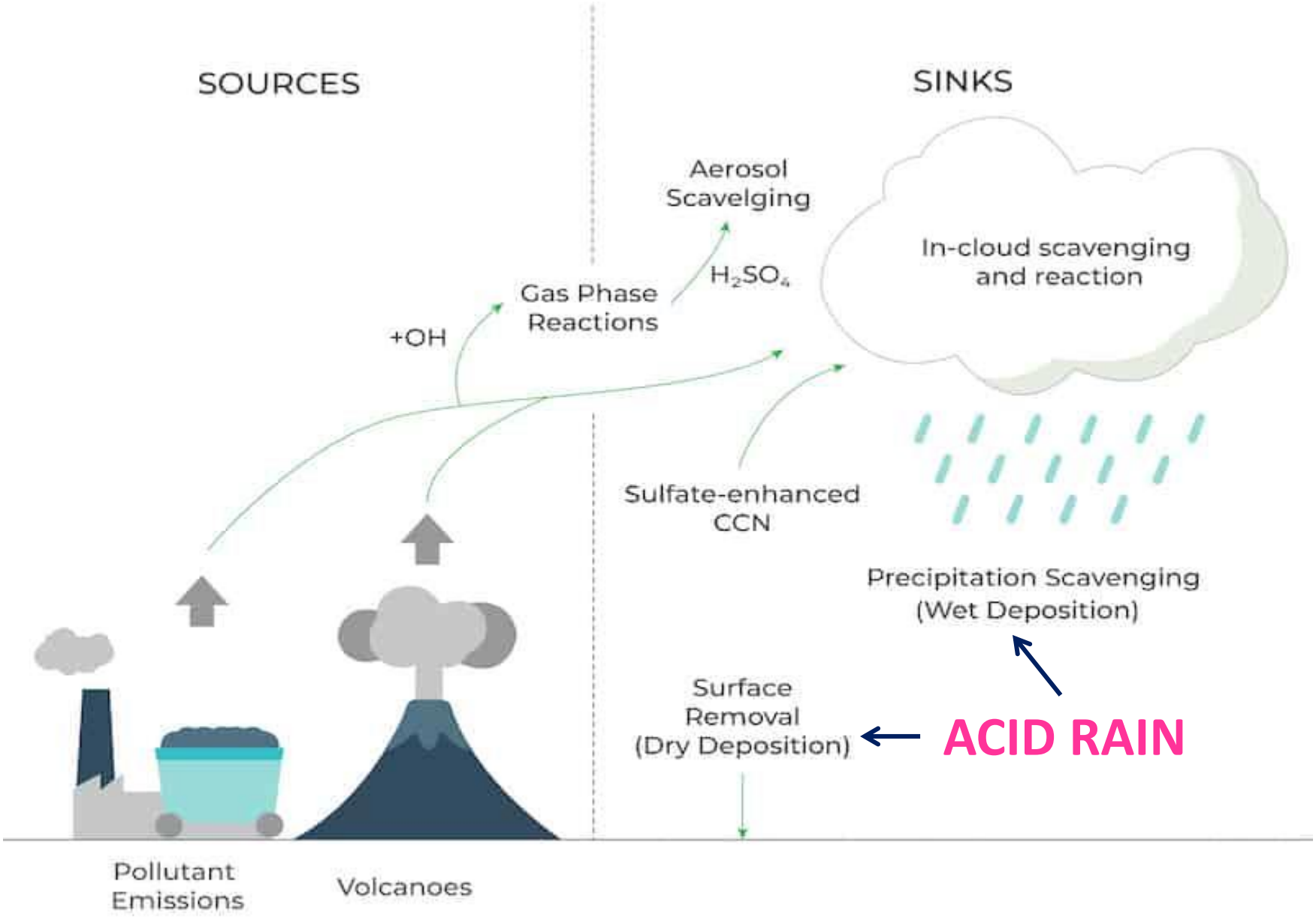
$$SO_2 + O_3 \longrightarrow SO_3 + O_2$$

Sulphur oxides combine with water vapour to produce H_2SO_4 aerosol which give rise to the so called "acid-rain" droplets

$$SO_3 + H_2O \longrightarrow H_2SO_4$$

H_2SO_4 combines with the lime-stone minerals and thus removed from atmosphere. In other words limestone minerals act as a sink for sulphur dioxide.

$CaCO_3$


SOURCES
SINKS
Aerosol
Scavelging
In-cloud scavenging
and reaction
H_2SO_4
Gas Phase
Reactions
+OH
Sulfate-enhanced
CCN
Precipitation Scavenging
(Wet Deposition)
Surface
Removal
(Dry Deposition)
ACID RAIN
Pollutant
Emissions
Volcanoes

EFFECTS:

Effects of Sulfur Dioxide (SO_2)

- Contributes to death and serious respiratory illness (e.g., asthma, chronic bronchitis) due to fine particles.
- Acidifies surface water, reducing biodiversity and killing fish.
- Damages forests through direct impacts on leaves and needles, and by soil acidification and depletion of soil nutrients.
- Contributes to decreased visibility (regional haze).
- Speeds weathering of monuments, buildings, and other stone and metal structures.

SO_X CONTROL

GENERAL METHODS FOR CONTROL OF SO_2 EMISSIONS

(1)

Change to Low Sulfur Fuel

- Natural Gas
- Liquefied Natural Gas
- Low Sulfur Oil
- Low Sulfur Coal

Use Desulfurized Coal and Oil Increase Effective Stack Height

- Build Tall Stacks
- Redistribution of Stack Gas Velocity Profile
- Modification of Plume Buoyancy

(2) Use of Chemical Scrubber:

(a) *Lime stone:*

$$2CaCO_3 + 2SO_2 + O_2 \longrightarrow 2CaSO_4 + CO_2$$

$$CaCO_3 + SO_3 \longrightarrow CaSO_4 + CO_2$$

The flue gases (exhaust gases) are passed through the slurry of $CaCO_3$ which reacts with SO_2 and SO_3 to form $CaSO_4$. Though this method is economical but huge amounts of $CaSO_4$ are produced, the disposal of which is a great problem.

(b) *Citric acid*: Another method employs the use of citric acid which absorbs the SO_2 from the flue gases. The flue gases are passed through a solution containing citrate ions. The HSO_3^- ions, produced from SO_2 and H_2O, combine with citrate ions to form citrate complex.

$$SO_2 + H_2O \rightleftharpoons HSO_3^- + H^+$$

$$HSO_3^- + H_2Cit^- \rightleftharpoons [HSO_3 . H_2Cit]^{2-}$$

The solution containing citrate ion is transferred in a closed vessel and H_2S is passed through it. Sulphur precipitates out and citrate ions are regenerated which are used again.

Particulate matter pollution

- **Properties - varied**
  Mixture of solid phase and absorbed materials (organic, inorganic and biological)
  Carbonaceous core 40-60%, C 7%

- **Sources**
  - Combustion - oil and coal
    - Industry
    - Automobiles
  - Tobacco smoke
  - Biomass burning
  - Metal smelters

NAAQS:
PM_{10}: 150ug/m^3, 24h
50ug/m^3, annual
$PM_{2.5}$: 15ug/m^3, annual
65ug/m^3, 24h

Particulates - features

- Physical size
  - Large
  - Small ~10um
  - Fine ~2.5um
- Aerodynamic diameter (size equivalent of density=1)
  - Large - local irritation (>100um)
  - Inhalable (<100um)
  - Thoracic fraction (<20um) } *respirable*
    - Coarse PM_{10} (<10um)
    - Fine $PM_{2.5}$ (<2.5um)
    - Ultrafine (<0.1um)
- Chemical reactivity
- Shape (fibers) and Water content

Urban Particulates

- In the <2.5um range
- Large water content, trace metals, acid gases, organic chemicals, biological
- Rather uniform distribution
- Include diesel

Health effects of particulate pollutants

- Eye irritation - starting at 10ug/m^3
- Respiratory tract infection
- Exacerbation of asthma
- Bronchial irritation
- Heart disease
- Possibly cancer (controversial) (diesel, TiO_2, talc, carbon black, toner black)
- Elevated hospital admissions, mortality
- Causation(s) not fully understood

Gaseous pollutant features

- Chemical reactivity (ozone)
- Solubility in water
  - Soluble
    - Ambient (NOx, SOx)
    - Occupational (Hydrochloric acid, Ammonia)
  - Less soluble
    - H_2S, ozone

Fine Particulate Matter ($PM_{2.5}$)

HOW IT AFFECTS YOU AND WHAT CAN BE DONE ABOUT IT.

Where does $PM_{2.5}$ come from?

- VEHICLE EMISSIONS
- CONSTRUCTION
- INDUSTRIES
- FOREST FIRES
- RESIDENTIAL BURNING
- AGRICULTURAL BURNING

How can $PM_{2.5}$ affect my health?

- DECREASED LUNG FUNCTION
- ASTHMA ATTACKS & BRONCHITIS
- IRREGULAR HEARTBEATS
- HEART ATTACKS
- EXACERBATES PRE-EXISTING HEALTH CONDITIONS

Prevention & reduction strategies

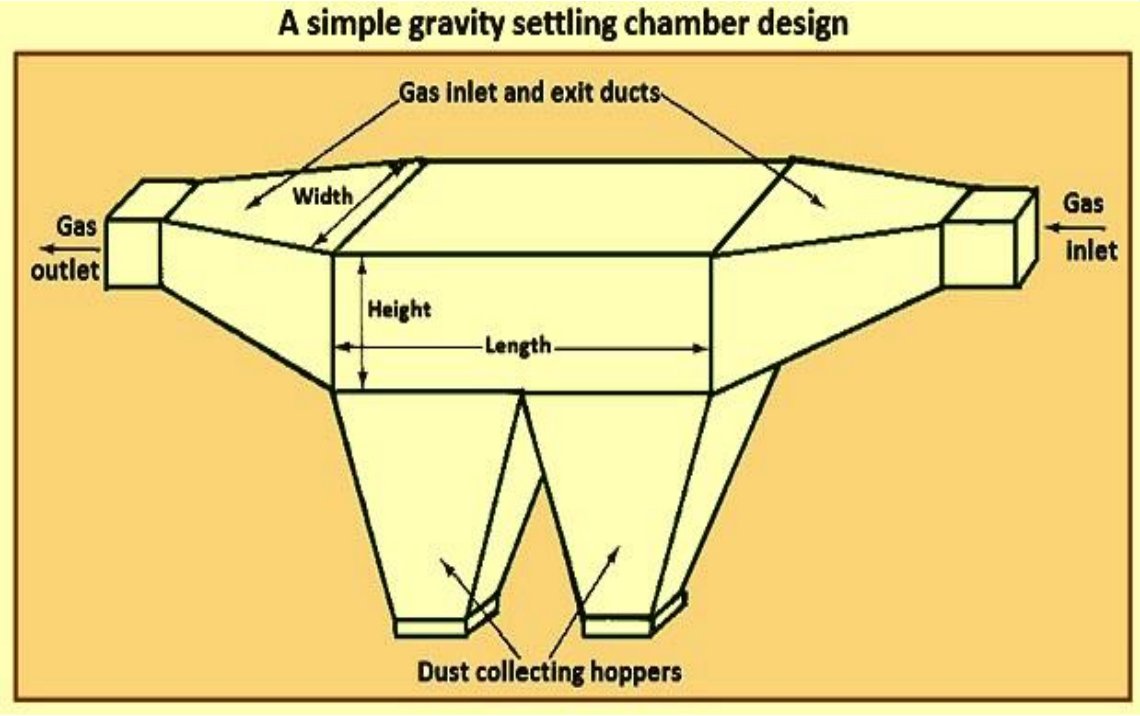
CHECK YOUR LOCAL AIR QUALITY

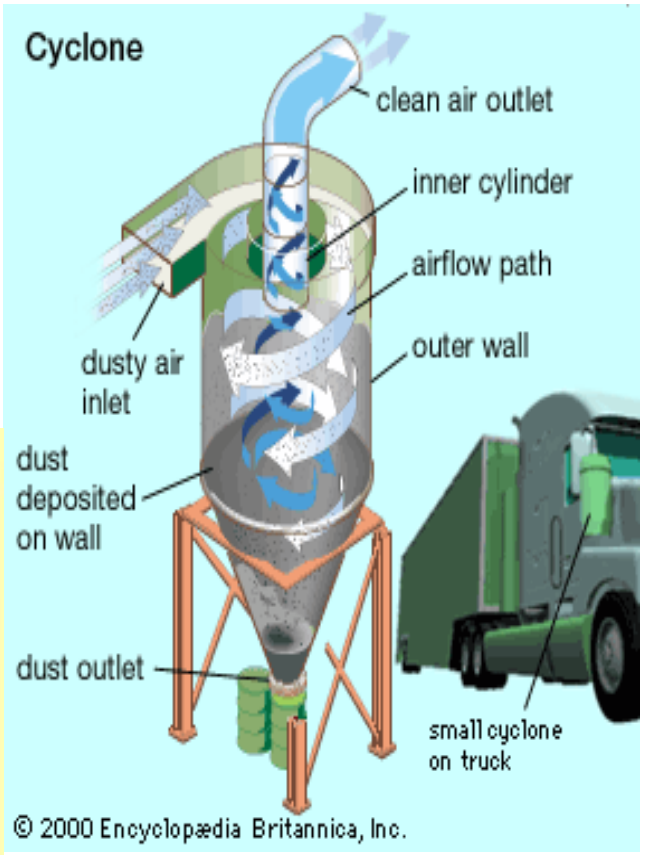
IF ALERT LEVELS ARE HIGH:

- BIKE, WALK, OR USE PUBLIC TRANSIT
- STOP IDLING VEHICLES
- LIMIT INTENSE ACTIVITIES NEAR BUSY ROADS
- ADHERE TO LOCAL BURN BANS
- CONSIDER INDOOR ALTERNATIVES

Control of Particulate Emissions:

(1)Gravity Settling Chamber
(2) Cyclone collector
(3) Filters
(4) Scrubbers





5. Hydrocarbons

Many different hydrocarbons are present in air. Most of these are low molecular weight and gases and volatile liquids at ordinary temperatures.

Source

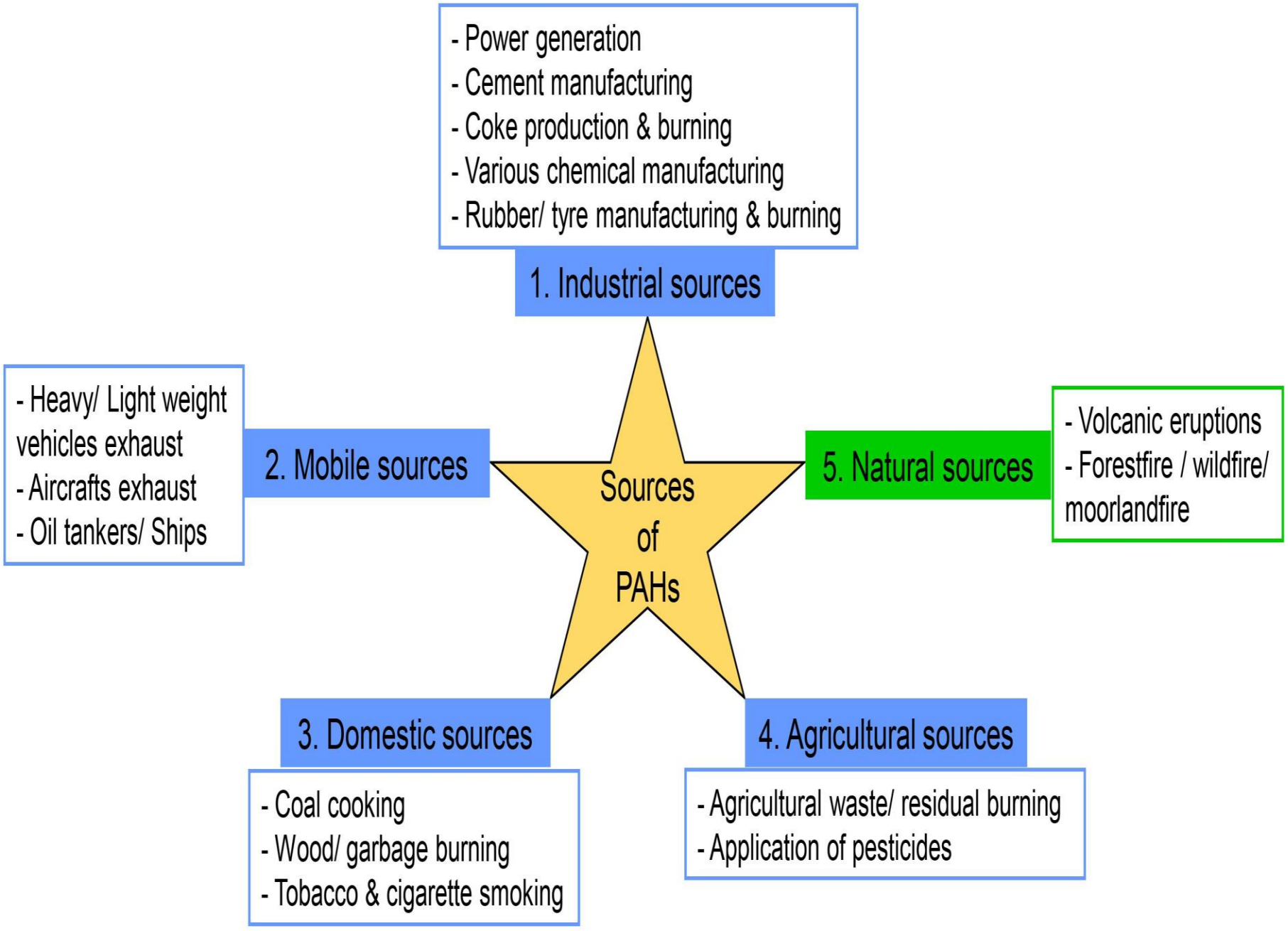
- Natural sources include trees which emit large quantities of hydrocarbons into the air. Methane is the major naturally occuring hydrocarbon emitted in the atmosphere which is produced by aneorobic bacteria through decomposition of organic matter in the soil, water and sediments.

$$\text{Organic Matter} \xrightarrow{\text{Bacteria}} CH_4 + CO_2$$

- Man made sources include motor fuels which are mixtures of hydrocarbons. Automobile exhausts emit maximum amount of hydrocarbons in the atmosphere.
- Evaporation of organic solvents used in paints, such as benzene, carbontetrachloride etc. also emit hydrocarbons in air.

Sinks: Hydrocarbons undergo a number of chemical reactions and photochemical reactions through a number of steps and form water and CO_2 in the end.

$$HC \xrightarrow{O_2} H_2O + CO_2$$


- Power generation
- Cement manufacturing
- Coke production & burning
- Various chemical manufacturing
- Rubber/ tyre manufacturing & burning
1. Industrial sources
- Heavy/ Light weight vehicles exhaust
- Aircrafts exhaust
- Oil tankers/ Ships
2. Mobile sources
Sources of PAHs
5. Natural sources
- Volcanic eruptions
- Forestfire / wildfire/ moorlandfire
3. Domestic sources
- Coal cooking
- Wood/ garbage burning
- Tobacco & cigarette smoking
4. Agricultural sources
- Agricultural waste/ residual burning
- Application of pesticides

Effects

- At high concentrations hydrocarbons have carcinogenic effect on lungs.
- Inhalation of benzene, toluene etc. cause irritation in the mucus membrane.
- They are responsible for the of photochemical smog (discussed later)
- Methane causes narcotic effect on human beings.
- Acetylene and propylene at 50 - 500 ppm show toxicity towards plants, damaging their growth.
- Benzpyrine present in tobacco, charcoal etc. induces cancer.

Control

- Hydrocarbons, being thermodynamically unstable tend to get oxidized in the atmosphere by a series of chemical and photochemical reactions. This gives rise to the formation of various end-products such as CO_2, solid organic particulates and water soluble acids. The solid organic particulates settle down and water soluble acids are washed down by rain.
- The hydrocarbons from vehicular traffic are controlled by the techniques such as incineration, adsorption and absorption.

  Adsorption is carried on a bed of carbon or by passing exhaust gases through a liquid in which hydrocarbons will dissolve or become suspended. Incineration or 'after burning' completes the oxidation of hydrocarbon to CO_2 and H_2O.
- Loss of hydrocarbons by evaporation from fuel tanks and carburettor is reduced by installation of a connection system which eventually returns them to the fuel induction system.

Health Effects of Hydrocarbon:

1. Wheezing & breathlessness
2. Wheezing apart from cold
3. Nocturnal attacks of short-ness of breath
4. Chronic cough & phlegm
5. Lower respiratory tract symptoms

a

1. Psychological stress
2. Depression
3. Post-traumatic stress disorder
4. Elevated anxiety disorders

b

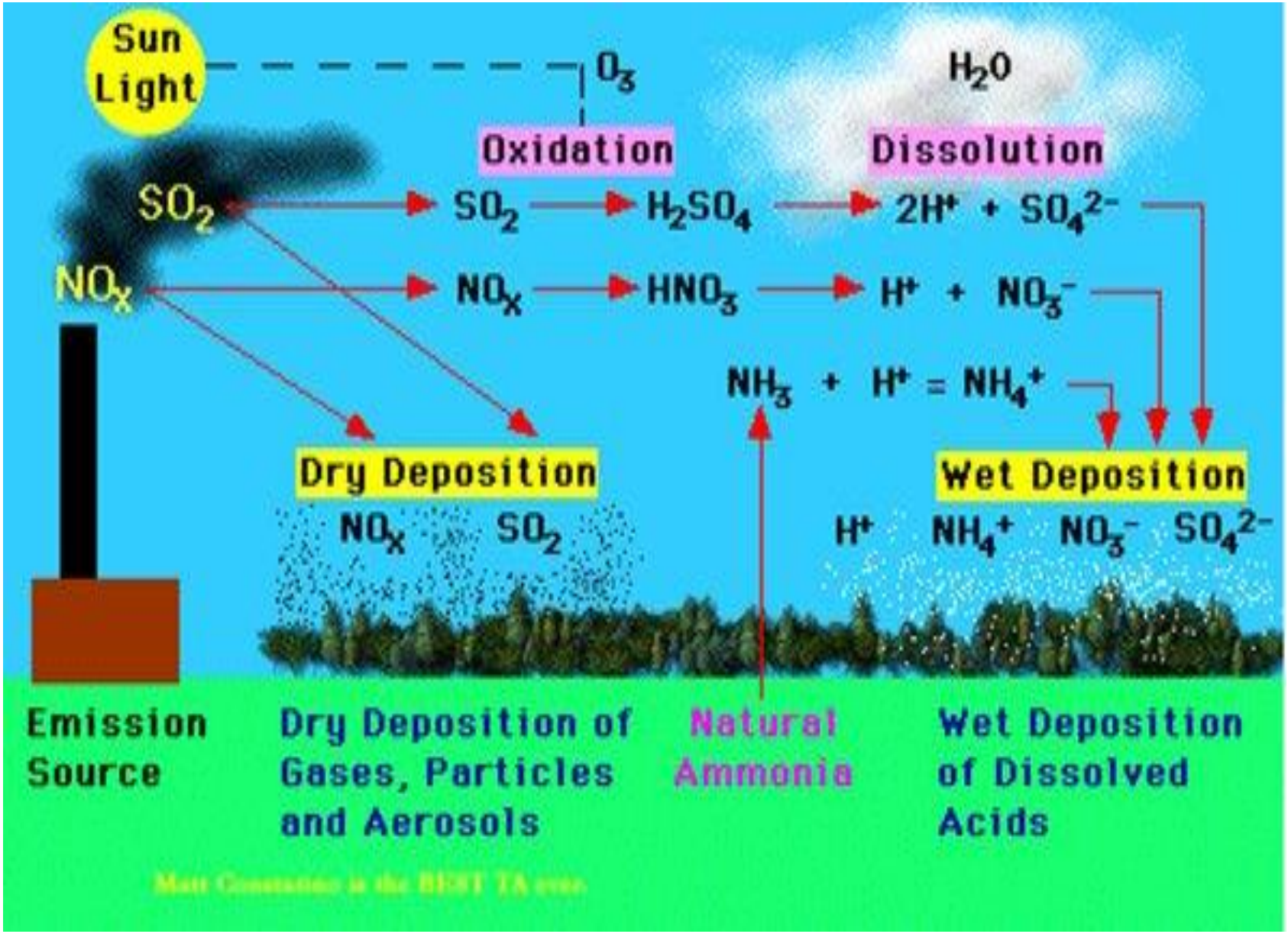
1. Elevated 8-isoprostane levels in exhaled breath condensate
2. Elevated levels of vascular endothelial growth factor
3. Elevated levels of basic fibroblast growth factor
4. Structural chromosomal alterations

c

1. Skin and lung cancer
2. Reproductive toxic effects
3. Developmental toxic effects

d

CHEMISTRY OF ACID RAIN



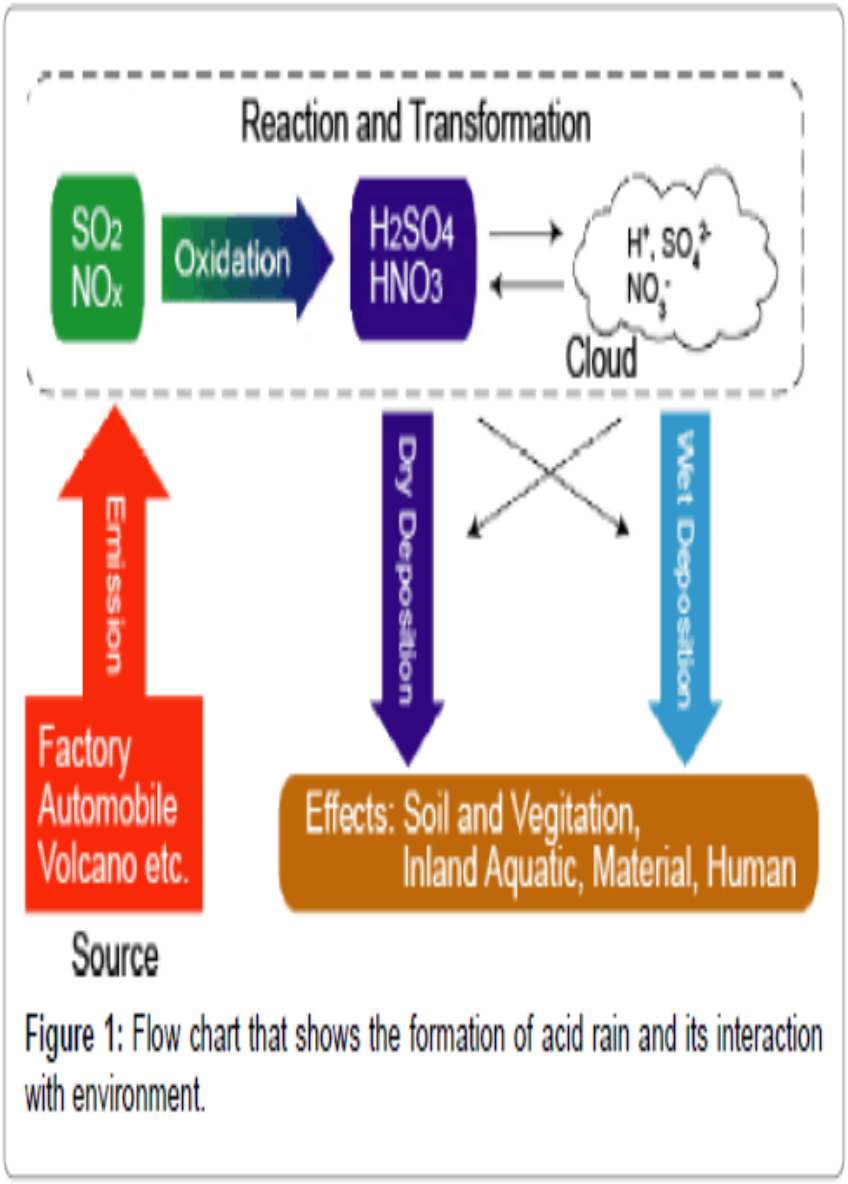
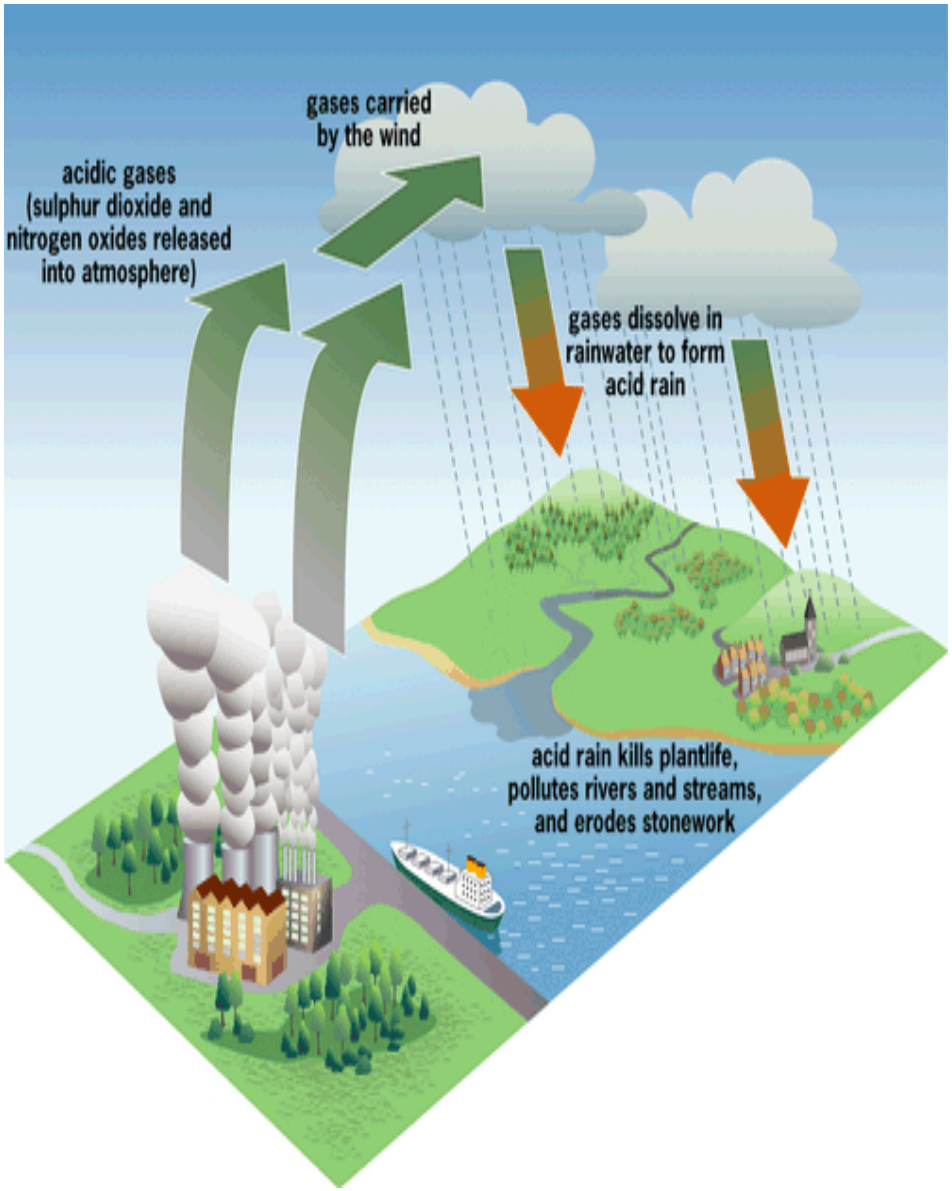
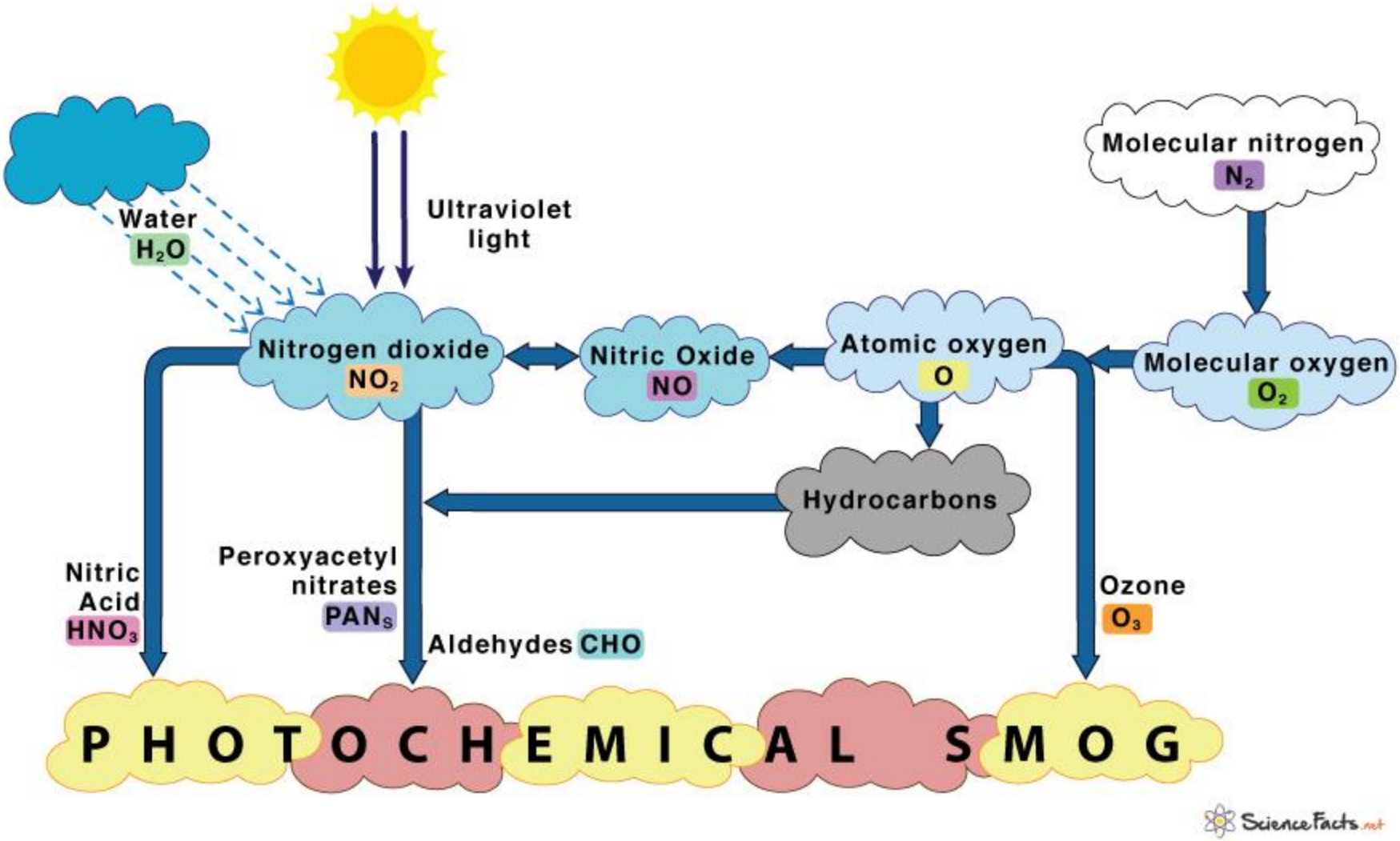


Figure 1: Flow chart that shows the formation of acid rain and its interaction with environment.



Formation of Photochemical Smog



(i) *London Smog*: The smog formed from SO_x particulates (soot, ammonium sulphate) and humidity is known as London smog. This type of smog caused the death of around 4000 people in London in 1952, hence the name. Five days of calm foggy weather created a toxic atmosphere which caused bronchits and acute respiratory problems claiming 4000 human lives. This mixture of smoke, SO_x and fog is chemically a reducing mixture, so it is also termed as *reducing smog*.

SO_2 in the atmosphere is converted into SO_3 by a number of chemicals present in the particulates. SO_3 combines with water in the atmosphere forming a fog of sulphuric acid droplets. These droplets condense on the carbon particles of soot and are drawn into the respiratory tract during breathing.

$$2SO_2 + O_2 \longrightarrow 2SO_3$$
$$SO_3 + H_2O \longrightarrow H_2SO_4$$

or

$$SO_2 + H_2O \longrightarrow H_2SO_3$$
$$H_2SO_3 + \frac{1}{2}O \xrightarrow[\text{salts}]{\text{Metal}} H_2SO_4$$

London smog is formed in the early morning hours of winter months. After sunrise it increases due to the oxidation of SO_2 to SO_3 and subsequent combination with water to form sulphuric acid aerosol.

(ii) *Los Angeles Fog (Photochemical Smog)*: Photochemical smog results from the photochemical reactions of the atmosphere. Photochemical smog is the atmospheric haze that is formed near many large cities and it is due to the action of sunlight on the hydrocarbons and the nitrogen oxides. In this type of smog, the main unhealthy ingredient is 'ground level ozone'. This type of smog was first observed in Los Angeles in 1950 and hence is named as 'Los Angeles smog'.

chain propagation reactions take place.

- The hydrocarbons combine with the oxygen atom produced by the photolysis of NO_2, to form highly reactive intermediates (free radicals)

$$O + RCH_3 \longrightarrow RCH_2^{\bullet} + \text{other products}$$

$$RCH_2^{\bullet} + O_2 \longrightarrow RCH_2O^{\bullet}$$

$$RCH_2O^{\bullet} + NO \longrightarrow RCH_2O^{\bullet} + NO_2$$

Oxygen atom can also react with H_2O to form hydroxyl radicals.

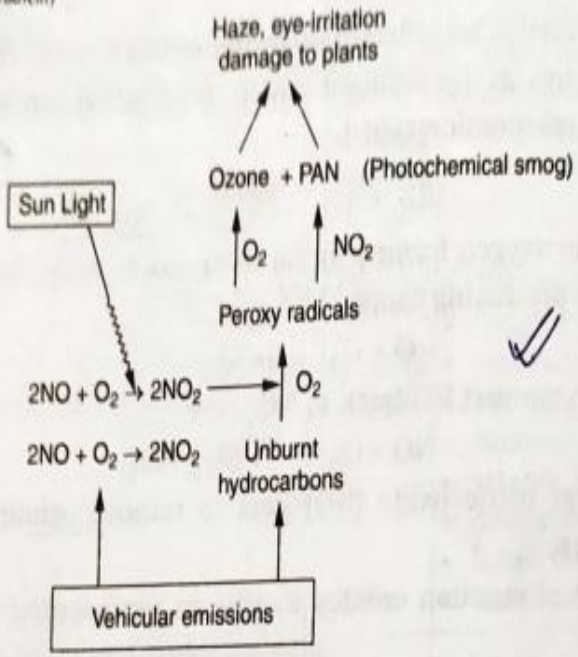
$$H_2O + O \longrightarrow H_2O_2 \xrightarrow[\text{dissociation}]{\text{Photo}} 2\,\dot{O}H$$

- The free radicals then react with O_2 or NO to produce a number of by products which are highly reactive organic oxidants i.e. secondary pollutants such as acrolein, formaldehyde, peroxyacetyl nitrate (PAN). These secondary pollutants collectively form photochemical smog.

These secondary pollutants collectively [illegible] chemical s

1. $RCH_2O^{\bullet} + O_2 \longrightarrow RCHO + H\dot{O}_2$
2. $H\dot{O}_2 + NO \longrightarrow NO_2 + O\dot{H}$
3. $RCHO + {}^{\bullet}OH \longrightarrow RCO^{\bullet} + H_2O$
4. $RCO^{\bullet} + O_2 \longrightarrow R-C(=O)-O-O^{\bullet}$
5. $R-C(=O)-O-O^{\bullet} + NO_2 \longrightarrow R-C(=O)-O-O-ONO_2$ (PAN)

(Acetyl peroxy radical)



Second Mechanism

Formation of secondary pollutants in photochemical smog

- **Aldehydes are produced in the reaction of free radicals with oxygen.**

$$RCH_2O\bullet + O_2 \rightarrow RCHO + HO_2\bullet$$

- **Nitric acid is produced when hydroxyl radicals react with NO_2**

$$HO\bullet + NO_2 \rightarrow HNO_3$$

$$RH + OH^\bullet \rightarrow H_2O + R^\bullet$$

$$R^\bullet + O_2 \rightarrow RO_2^\bullet \text{ very fast}$$

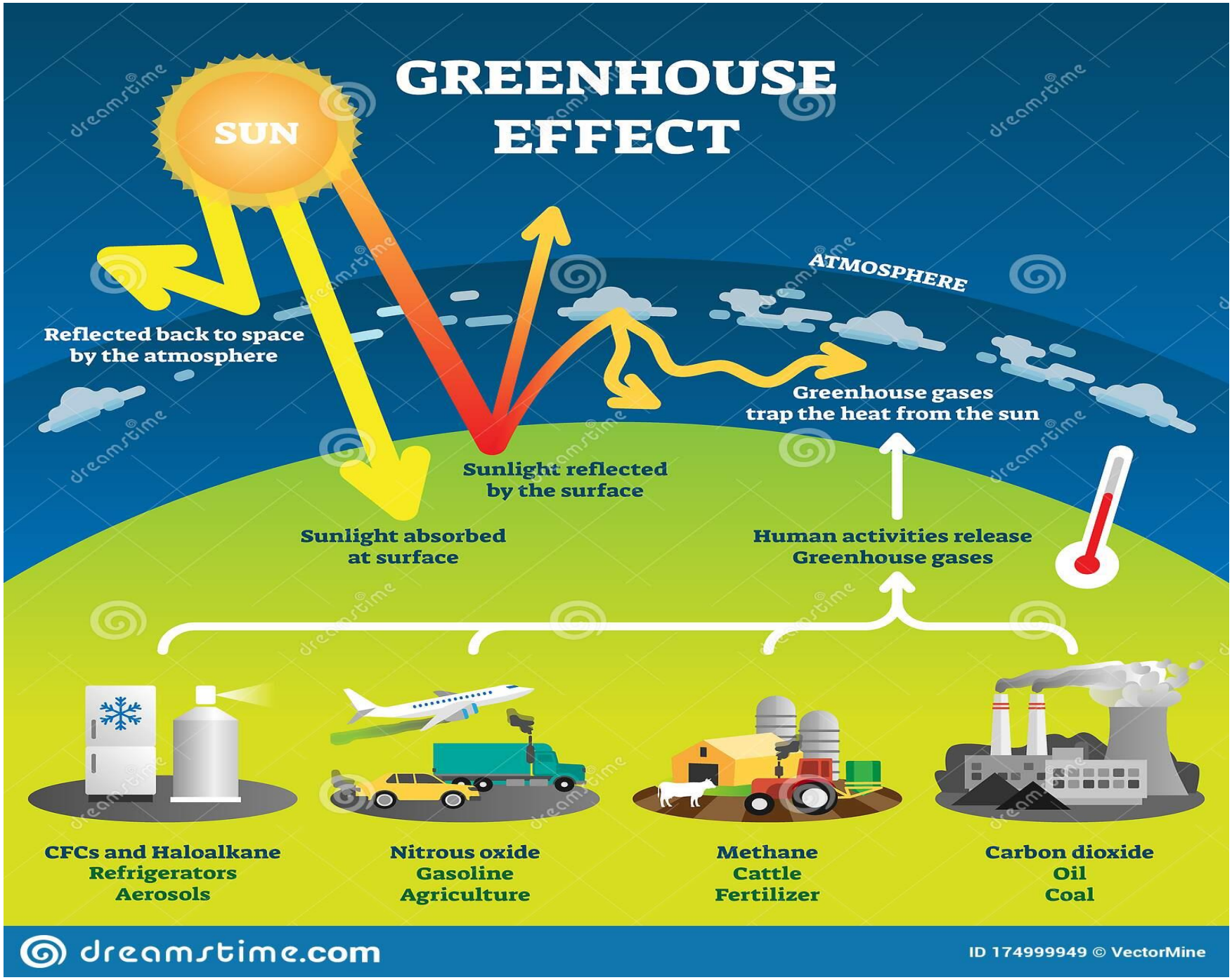
$$RO_2^\bullet + NO \rightarrow NO_2 + RO^\bullet$$

$$RO^\bullet + O_2 \rightarrow R'CHO + HO_2^\bullet \text{ very fast}$$

$$R'CHO + OH^\bullet \rightarrow R'CO^\bullet + H_2O$$

$$R'CO^\bullet + O_2 \rightarrow R'C(O)O_2^\bullet \text{ very fast}$$

$$R'C(O)O_2^\bullet + NO_2 \longrightarrow R'C(O)_2NO_2$$


GREENHOUSE EFFECT
SUN
ATMOSPHERE
Reflected back to space by the atmosphere
Greenhouse gases trap the heat from the sun
Sunlight reflected by the surface
Sunlight absorbed at surface
Human activities release Greenhouse gases
CFCs and Haloalkane
Refrigerators
Aerosols
Nitrous oxide
Gasoline
Agriculture
Methane
Cattle
Fertilizer
Carbon dioxide
Oil
Coal
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What is Global Warming?

Warmer atmosphere and oceans

Rising sea levels

Changing rainfall patterns

Expansion of deserts in the subtropics

More flooding in coastal areas

Melting of polar ice caps

Melting of glaciers

More extreme weather events

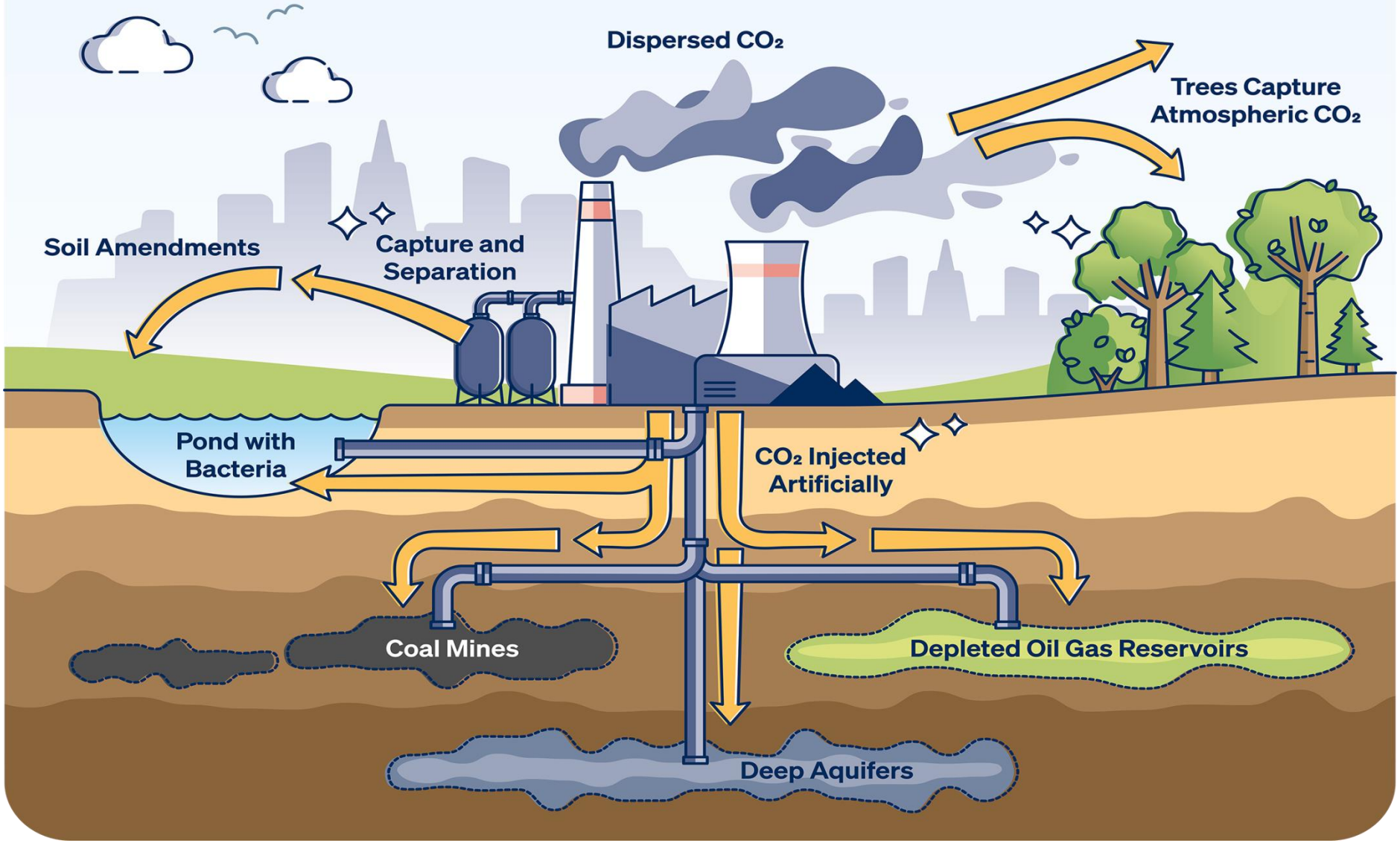
Ocean acidification

Extinction of animal and plant species

Food security threat for humans

The gradual increase in the Earth's temperature caused by high levels of greenhouse gases in the atmosphere.

Carbon Sequestration



Carbon Sequestration

Carbon sequestration refers to the provision of long- term storage of carbon in the terrestrial biosphere, underground or oceans, to reduce the buildup of carbon dioxide concentration in the atmosphere.

Natural Carbon Sequestration:

(1) Reforestation

(2) Oceans : micro size iron ore (hematite or melanterite) particles are added to water to increase the Carbon seq.

The addition of iron particles stimulate the growth of phytoplankton, which in turn remove significant quantity of CO_2 from the atm.

3) Soil : bound carbon dioxide in form of organic carbon

Artificial Carbon Sequestration:

(1) In the Oceans: CO_2 directly pumped in to the water at depth and is expected to form lakes of liquid CO_2 at the bottom.

- This method could be dangerous as CO_2 could react to form carbonic acid. E.g. Lake Nysa Disaster at Cameroon, 1986

(2) *Geo-sequestration: injecting CO_2 directly into underground geological formation.

- Declining oil fields, saline aquifers, and unminable coal seams used as storage sites.
- E.g. North Sea, Canada, Algeria ; Damodar Valley coal field Eastern India

(3) Bio-sequestration: involves plantation of biodiesel crops such as Jatropha curcas, switch grass and algal species

Carbon Credits

- A carbon credit is a financial instrument that represents a tonne of CO_2 or CO_2e (carbon dioxide equivalent gases) removed or reduced from the atmosphere from an emission reduction project
- Carbon credits are measured in units of **certified emission reductions** (CERs).
- Each CER is equivalent to one ton of carbon dioxide reduction (1 credit= reduction of 1 ton of CO_2)
- Such a credit can be sold in the international market at a prevailing market rate

What is Carbon Credit

- Certified Emission Reductions(CER's) is commonly known as carbon credits. They provide a way to reduce greenhouse gas emissions on an industrial scale by assigning a monetary value to any shortfall in emission level in terms of credits.

- These credits can be exchanged between businesses or can be bought and sold in international markets at the prevailing market price or can be used to finance other carbon reduction schemes between trading partners around the world.

- There also many companies that only sells carbon credits to commercial and individual customers who Are interested in lowering their carbon emissions on a voluntary basis.