Environmental pollution *caused by* open burning of solid waste and power plants

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What is Waste?

Waste (also known as **rubbish**, **trash**, **refuse**, **garbage**, **junk**, **litter etc.**) is unwanted or useless materials.

Basel Convention Definition of Waste

"substances or objects which are disposed off or are intended to be disposed of or are required to be disposed of by the provisions of the law"

Disposal means

"any operation which may lead to **resource recovery**, **recycling**, direct **re-use** or alternative uses".

Types of Waste

Solid Waste: waste in solid forms

Examples: *Food Waste, plastics, styrofoam containers, bottles, cans, papers, scrap iron, and other trash*

Liquid Waste: waste in liquid form

Examples: *domestic washings, chemicals, oils, waste water, manufacturing industries and other sources.*

Classification of Waste according to their Properties

Bio-degradable

can be degraded, Mainly organic (paper, wood, fruits, vegetables and others)

Non-biodegradable

cannot be degraded (plastics, bottles, old machines, cans, styrofoam containers and others)

Effects on Human Health and the Environment

Hazardous

- Substances unsafe to use commercially, industrially, agriculturally, or economically and have any of the following properties- toxicity, ignitability, corrosivity, reactivity, etc.

Non-hazardous

- Substances safe to use commercially, industrially, agriculturally, or economically and do not have any of those properties mentioned above.

Classification of wastes according to their origin and types

- **Municipal solid waste:** include household garbage, rubbish, construction & demolition debris, sanitation residues, packaging materials, trade refuges etc. are managed by any municipality.

- **Bio-medical waste:** Solid or liquid wastes including containers, intermediate or end products generated during diagnosis, treatment & research activities of medical sciences.

- **Industrial waste:** Liquid and solid wastes that are generated by manufacturing & processing units of various industries like chemical, petroleum, coal, metal gas, sanitary & paper etc.

- **Agricultural waste:** Waste generated from farming activities. These substances are mostly biodegradable.

Classification of waste
according to their origin and types

- Fishery waste: Waste generated due to fishery activities. These are extensively found in coastal & estuarine areas.

- Radioactive waste: Waste containing radioactive materials. Usually these are byproducts of nuclear processes. Sometimes industries that are not directly involved in nuclear activities, may also produce some radioactive wastes, e.g. radio-isotopes, chemical sludge etc.

- E-waste: Electronic waste generated from any modern establishments. They may be described as discarded electrical or electronic devices. Some electronic scrap components, such as Cathode Ray Tubes (CRTs), may contain contaminants such as Pb, Cd, Be or brominated flame retardants.

What is Open Burning?

- Open burning is any burning outdoors that does not pass through a stack, duct, or chimney. This includes outdoor residential, agricultural, and prescribed burning.
- Open burning also applies to material that is burned in burn barrels, air curtain destructors, or other such devices.

Open burning of solid waste

Waste is a worldwide issue that is not likely to go away. Waste production rates have increased in recent years and are projected to increase significantly in the coming years to 2.2 billion tons per year in 2025, according to the World Bank.

An estimated 41% of global waste is burned openly. In developing, low income countries that figure is even higher. This practice is popular because it is a **fast, effective and inexpensive way to reduce waste.**

Open burning

Farmer burning, on a large scale, pruning and agricultural waste, leading to smog and loss of organic matter, among other things. Can be used as a raw material for sustainable paper and board.

Why Limit Open Burning?

- Smoke from open burning pollutes the air and is unhealthy to breathe
- Potential health effects include
  - Lung and Eye irritation
  - Headaches, Dizziness
  - Asthma attacks
  - Coughing and wheezing
    and
  - Even death in some cases

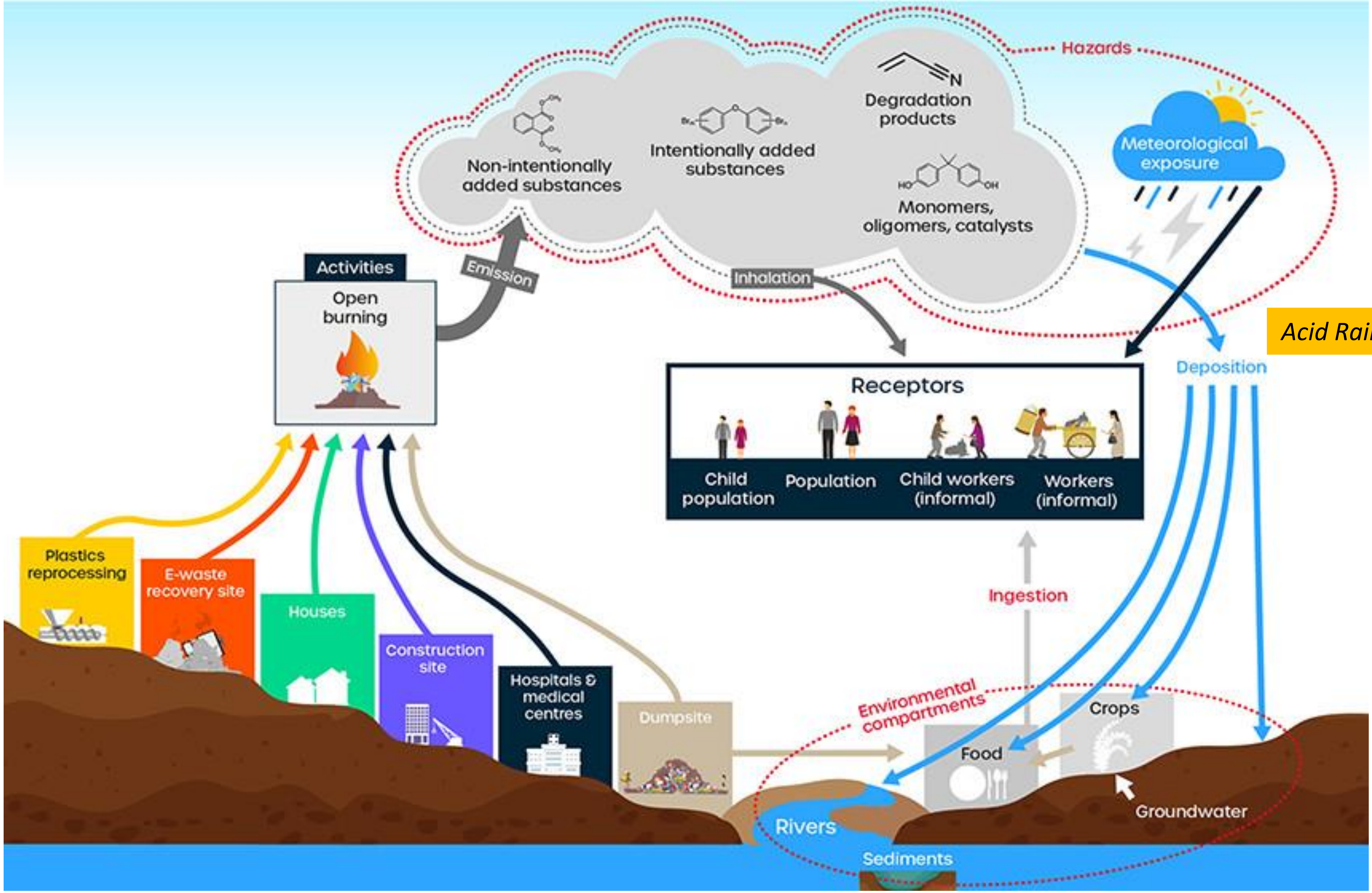
Effects of open burning of solid waste:

- Open burning of waste releases a variety of toxic pollutants into the air and also can exacerbate soil pollution, water pollution and food contamination.

- Open waste burning releases significant amounts of greenhouse gases into the atmosphere. Such compounds include carbon dioxide, methane and particulate matter, which are typically associated with air pollution and can lead to severe cases of respiratory disease.

- Open burning of waste is especially associated with the emission of persistent organic pollutants. This includes polycyclic aromatic hydrocarbons, dioxins and furans, all of which are carcinogenic and have been linked to a variety of other diseases.

- The impacts of these pollutants are especially harmful to unborn fetuses, infants and childrens who come into contact with the pollutants either through their mothers or through exposure to the pollutants themselves.


Hazards
Degradation products
Non-intentionally added substances
Intentionally added substances
Monomers, oligomers, catalysts
Meteorological exposure
Activities
Open burning
Emission
Inhalation
Deposition
Receptors
Child population
Population
Child workers (informal)
Workers (informal)
Ingestion
Plastics reprocessing
E-waste recovery site
Houses
Construction site
Hospitals & medical centres
Dumpsite
Environmental compartments
Crops
Food
Groundwater
Rivers
Sediments

Acid Rain

Open Burning Alternatives

Solid Waste Transformation

Transformation means a process of **reduction of waste** by volume and weight and **recovering the energy** from them.

Typically waste transformations are used to improve the efficiency of solid waste and management systems, to recover reusable and recyclable materials, and to recover conversion products and energy which include the following method they are -

1) Physical transformation

2) Chemical transformation

3) Biological transformation

1. Physical transformation

Physical transformations of solid waste typically involve a change of phase.

To reduce the volume and to recover conversion products, the principal physical processes used to transform municipal solid waste include:

a) Component separation
b) Mechanical volume reduction
c) Mechanical size-reduction

2. Chemical transformations

Chemical transformations of solid waste typically involve a change of phase. To reduce the volume and to recover conversion products, the principal chemical processes used to transform municipal solid waste includes:

a) Combustion
b) Pyrolysis
c) Gasification

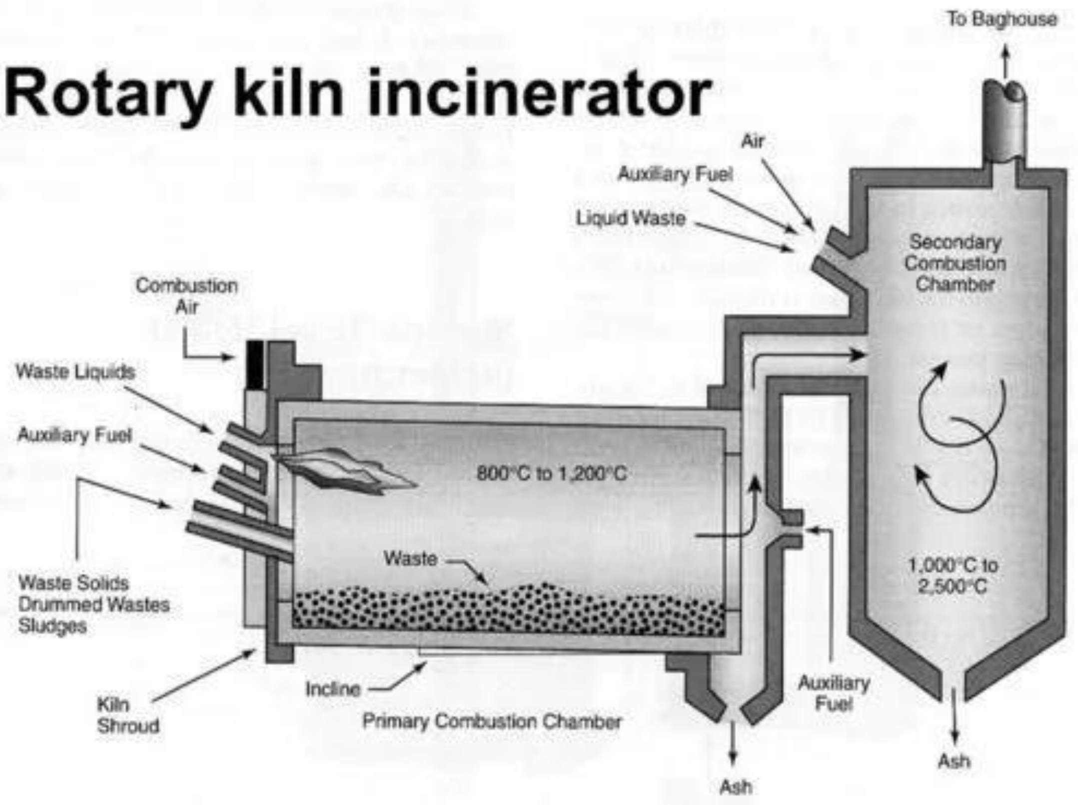
Combustion

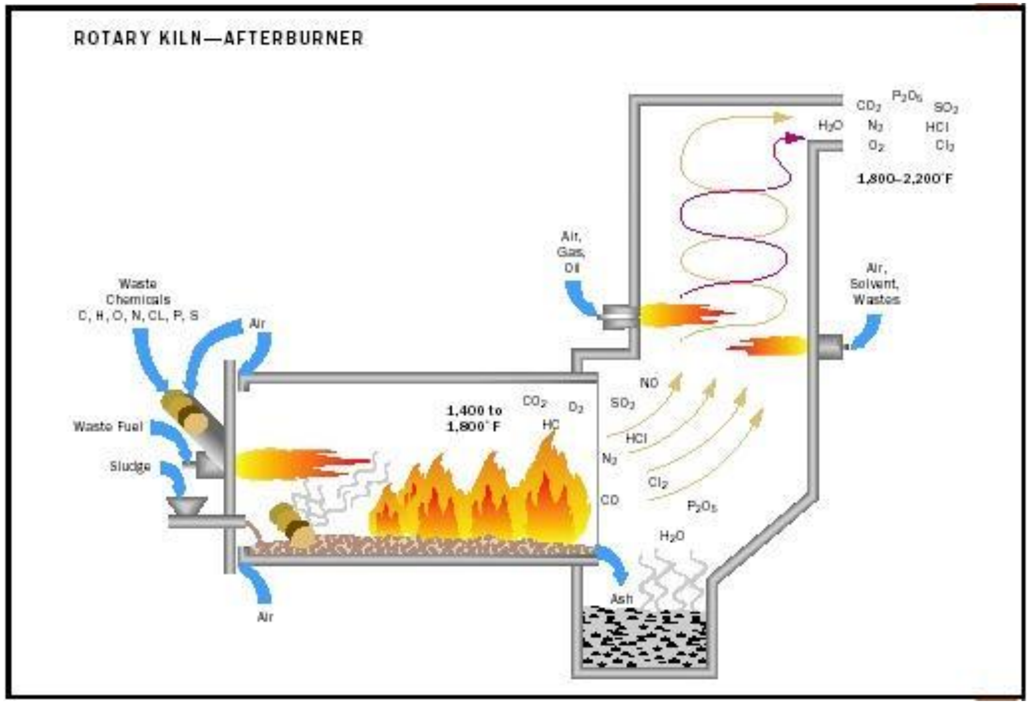
- **Incineration** is the burning of waste in a specially **designed combustion chamber.**
- At mass burn incinerators, also known as mass burn combustors, the heat generated from the burning material is turned into useable electricity.
- Incineration refer to high temperature combustion of waste in the presence of Oxygen, and converted into ash, flue gas and Heat etc. at about 850^{o}C.

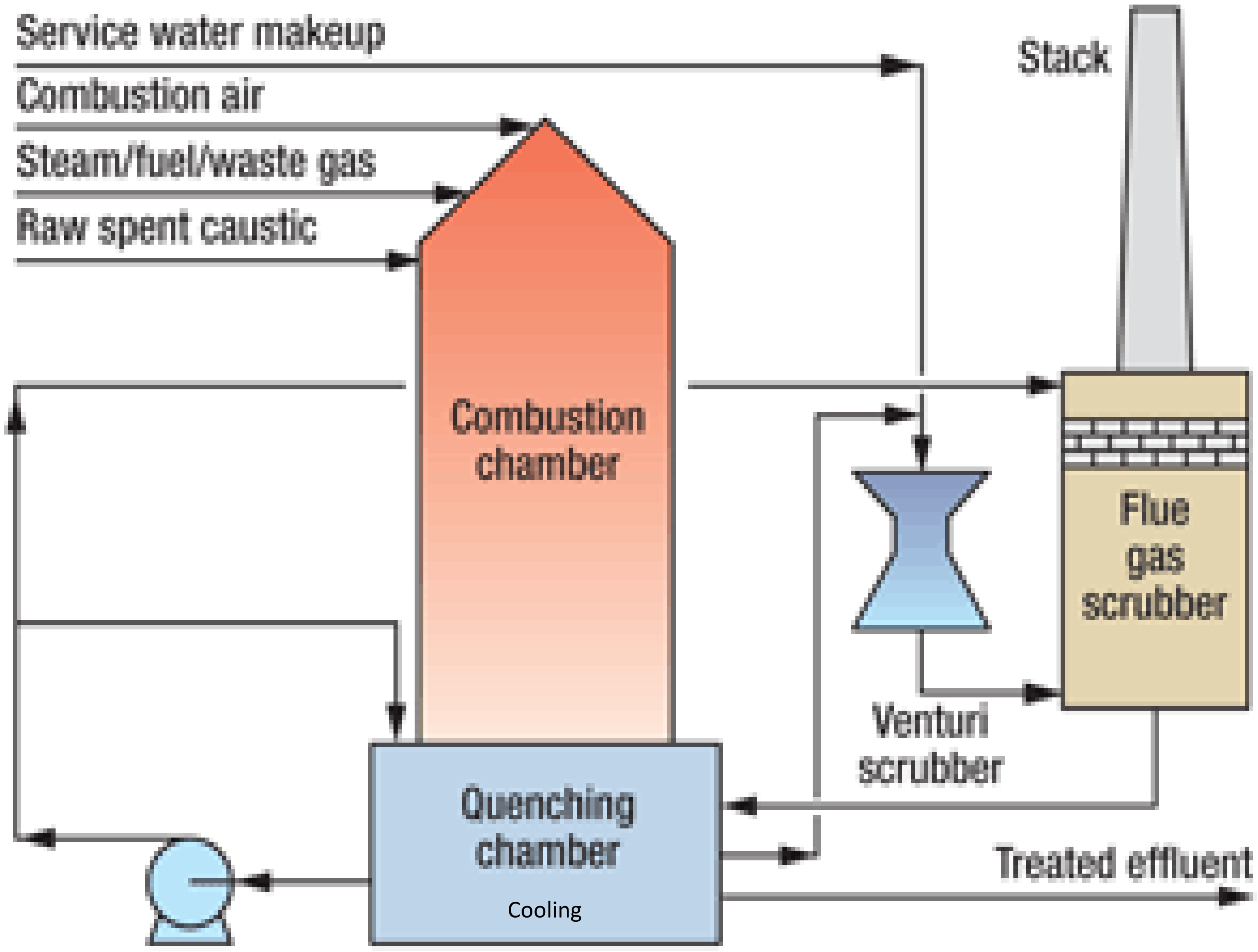
Depending on the type of incinerator, the following objectives can be achieved:

- Destruction of pathogens
- Reduction of the hazard and pollution potentials as far as possible
- Reduction of volume and quantity
- Conversion of remaining residues into a form which is utilizable or suitable for landfill
- Use of the released heat

Rotary kiln incinerator






Service water makeup
Combustion air
Steam/fuel/waste gas
Raw spent caustic
Stack
Combustion chamber
Flue gas scrubber
Venturi scrubber
Quenching chamber
Cooling
Treated effluent

Incinerators

Air Requirements For Combustion

To determine the amount of oxygen required for the complete combustion of solid wastes, it is necessary to compute the oxygen requirements for the oxidation of carbon, hydrogen, and sulfur contained in waste. The basic reactions are:

For carbon

$$\underset{(12)}{C} + \underset{(32)}{O_2} \longrightarrow \underset{(44)}{CO_2} \tag{12-3}$$

For hydrogen:

$$\underset{(4)}{2H_2} + \underset{(32)}{O_2} \longrightarrow \underset{(36)}{2H_2O} \tag{12-4}$$

For sulfur:

$$\underset{(32)}{S} + \underset{(32)}{O_2} \longrightarrow \underset{(64)}{SO_2} \tag{12-5}$$

Combustion Calculation:

Ques: Determine the amount of total air required to complete combustion of one tonne of a waste having the chemical composition $C_{50}H_{100}O_{40}N$.

(assume air required for complete combustion of 1 kg of: Carbon = 11.52 kg and Hydrogen = 34.56 kg).

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Solution:

Step 1. Molecular mass of $C_{50}H_{100}O_{40}N$

= (50x12) + (100x1) + (40x16) +(1x14) = **1354**

Step 2. Now, % distribution of basic elements:

Elements	**% by Mass**
C	[(50x12)/1354] 100 = **44.3**
H	[(100x1)/1354] 100 = **7.4**
O	[(40x16)/1354] 100 = **47.3**
N	1.0

Step 3. The net available hydrogen not bound as water:

= 7.4% - 47.3 %/8 = **1.49 %**

Step 4. Now, Air required per tonne of waste:

Elements	**kg/tonne**
C	0.443 x 11.52 x 1000 = **5103 kg/T**
H	0.0149 x 34.56 x 1000 = **515 kg/T**

Total = 5618 kg/T

Ans.

Comments:

Nitrogen gas is not highly reactive i.e does not support combustion with other molecules in the atmosphere and is mainly present in air as N_2 *(78%). unreactive behaviour results from the powerful triple bonds that form between the three pairs of electrons shared between two nitrogen atoms.*

In the presence of very high temperature, nitrogen and oxygen do react together to form nitric oxide. These conditions are found in the combustion of coal and oil at electric power plants, and also during the combustion of gasoline in automobiles.

PYROLYSIS

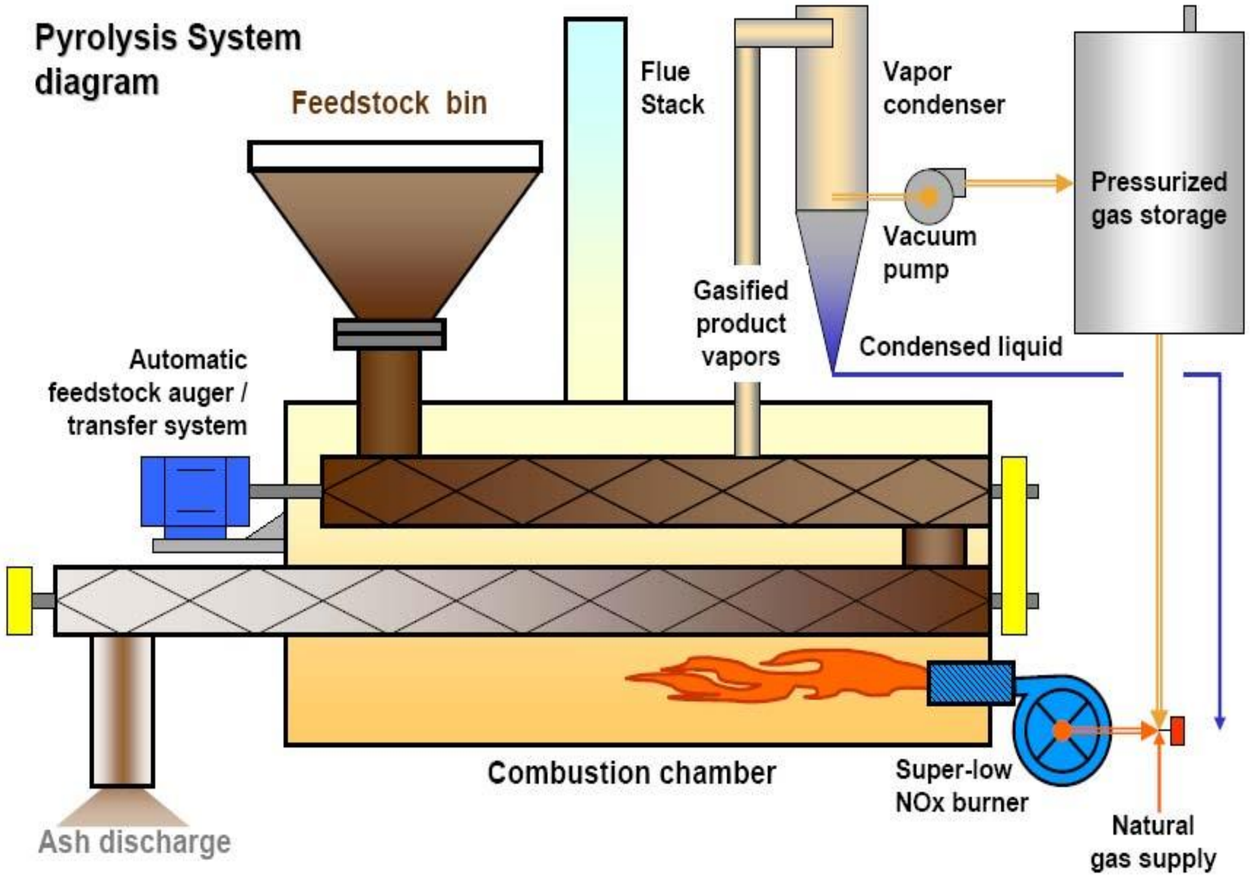
Pyrolysis is a thermochemical decomposition of organic material at elevated temperature (>430^{o}C) in the absence of oxygen.

It involves the simultaneous change of chemical composition and physical phase, and is irreversible. The word is coined from the Greek derived elements ***pyro*** **"fire"** and ***lysis*** **"separating".**

Pyrolysis is a type of thermolysis, and is most commonly observed in organic materials exposed to high temperatures. It is one of the processes involved in charring wood, starting at 200-300°C (390-570 °F).

PYROLYSIS

Pyrolysis Process



GASIFICATION

Gasification is a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen. This is achieved by reacting the material at high temperatures (>700°C), without combustion, with a controlled amount of oxygen and/or steam.

The resulting gas mixture is called syngas (from synthesis gas or synthetic gas) or producer gas and is itself a fuel. The power derived from gasification and combustion of the resultant gas is considered to be a source of renewable energy if the gasified compounds were obtained from biomass.

$$C + 1/2O_2 \text{ ----------- } CO$$
$$C + H_2O \text{ ---------------- } H_2 + CO$$

GASIFICATION

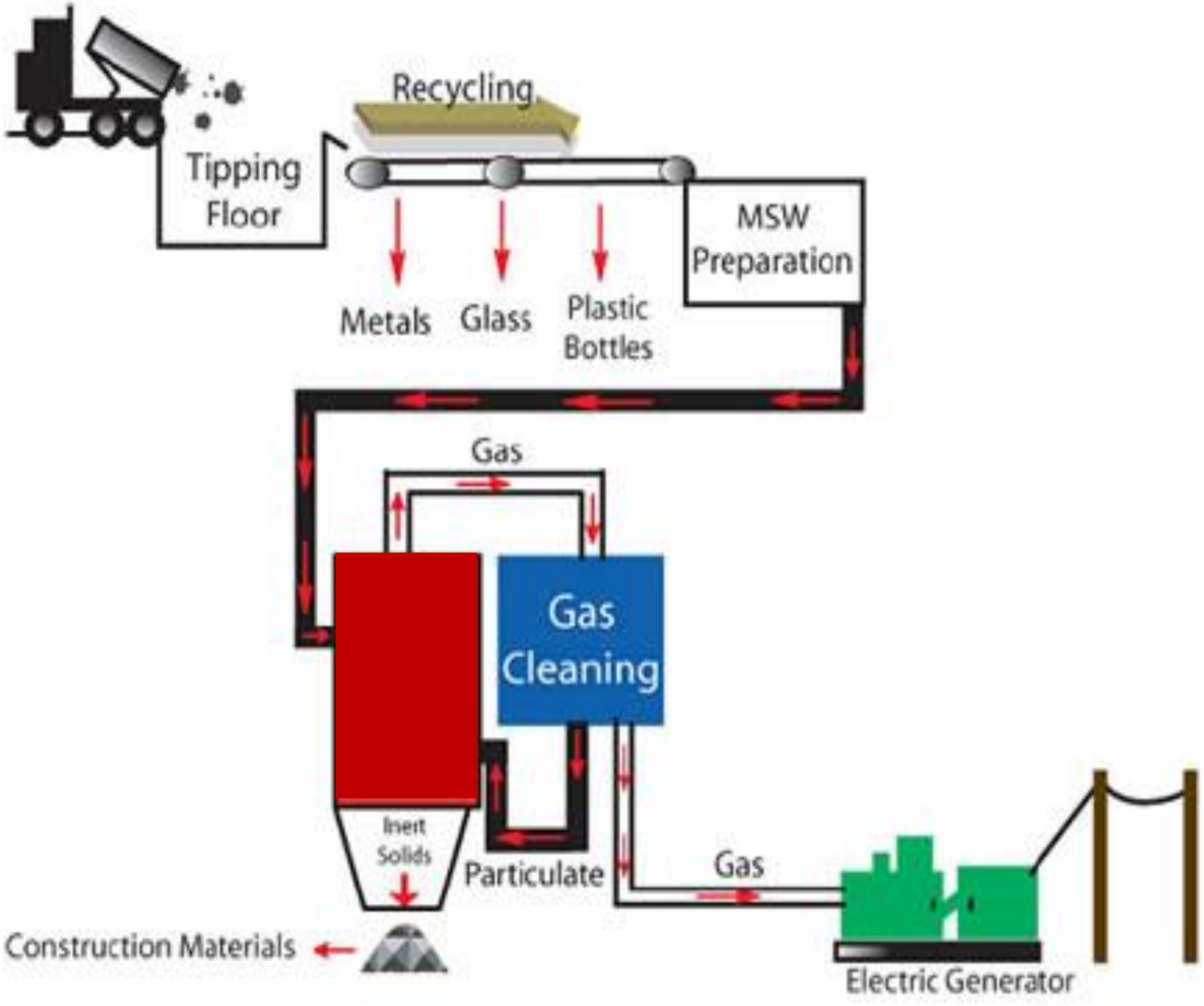


Figure 1: Schematic of MSW Gasification and Power Generation Plant

3. Biological transformation

The biological transformations of the organic fraction of Solid Waste may be used:

a) to reduce the volume and weight of the material

b) to produce compost: aerobic composting

c) to produce methane:, low-solids anaerobic digestion, high-solids anaerobic digestion

Aerobic Reaction

$$\text{Organic waste} \xrightarrow[+O_2]{\text{Microorganisms}} \text{New Cells} + \text{ROM} + CO_2 + NH_3 + SO_4^{--} + H_2O + \text{Heat}$$

Anaerobic Reaction

$$\text{Organic waste} + H_2O \xrightarrow[-O_2]{\text{Microorganisms}} \text{New Cells} + \text{ROM} + CH_4 + CO_2 + NH_3 + H_2S + \text{Heat}$$

Estimation of Methane Gas

The volume of methane gas that would be expected from anaerobic digestion can be estimated by following equation:

$$C_aH_bO_cN_d + (4a-b-2c+3d)/4 \ H_2O = (4a+b-2c-3d)/8 \ CH_4 + (4a-b+2c+3d)/8 \ CO_2 + dNH_3$$

Estimation of Methane Gas

Ques: Estimate the mass and volume of methane gas that would be expected from the anaerobic digestion of a tonne of a waste having the composition $C_{50}H_{100}O_{40}N$. (Assume density of methane = 0.7167 kg/m^3).

a. The coefficients are:

$a = 50$

$b = 100$

$c = 40$

$d = 1$

b. Using these coefficients the resulting equation is:

$$\underset{(1354)}{C_{50}H_{100}O_{40}N} + \underset{(103.5)}{5.75\,H_2O} \longrightarrow \underset{(434)}{27.125\,CH_4} + \underset{(1{,}006.5)}{22.875\,CO_s} + \underset{(17)}{NH_3}$$

2. Determine the mass of methane produced per tonne of waste.

$$\text{Methane} = \frac{434}{1354} \times 1000\ \text{kg/tonne} = 320.5\ \text{kg/tonne}$$

3. Using a density value for methane of 0.7167 kg/m^3, determine the volume of methane gas.

$$\text{Volume of methane gase} = \frac{320.5\ \text{kg/tonne}}{0.7167\ \text{kg/m}^3} = 447.2\ \text{m}^3\text{/tonne of waste}$$

COMMENT In practice, a portion of the waste would be used for the synthesis of cell tissue. The actual volume of gas would be about 0.85 times the value determined in step 3.

Estimation of Amount of Oxygen

The amount of oxygen required for the complete aerobic stabilization of solid waste can be estimated by using the following equation:

$$C_aH_bO_cN_d + (4a+b-2c-3d)/4\ O_2 = a\ CO_2 + (b-3d)/2\ H_2O + dNH_3$$

If the ammonia is oxidize to nitrate, the amounts of oxygen required can be completed with by equation:

$$NH_3 + 2O_2 = H_2O + HNO_3$$

Question: Determine the amount of total air required to oxidize completely one tonne of a waste having the chemical composition $C_{50}H_{100}O_{40}N$. (assume air contents 23.15% oxygen by weight and density of air is 1.2928 kg/m^3).

SOLUTION

1. Determine the oxygen requirement for the given waste, using Eq. (12-1).

$$C_aH_bO_cN_d + \frac{4a + b - 2c - 3d}{4} O_2 \longrightarrow aCO_2 + \frac{b - 3d}{2} H_2O + dNH_3$$

a. The required coefficients are:

$a = 50$

$b = 100$

$c = 40$

$d = 1$

b. Using these coefficients the resulting equation is:

$$\underset{(1354)}{C_{50}H_{100}O_{40}N} + \underset{(1736)}{54.25O_2} \longrightarrow \underset{(2200)}{50CO_2} + \underset{(873)}{48.5H_2O} + \underset{(17)}{NH_3}$$

c. The oxygen required per tonne is:

$$O_2 = \tfrac{1736}{1354} \times 1000 = 1.282 \times 10^3 \text{ kg/tonne}$$

2. Using Eq. (12.2), determine the oxygen required to stabilize the ammonia.

$$\underset{(17)}{NH_3} + \underset{(64)}{2O_2} \longrightarrow \underset{(18)}{H_2O} + \underset{(63)}{HNO_3}$$

The oxygen required per tonne of waste is:

$$O_2 = \tfrac{17}{1354} \times \tfrac{64}{17} \times 1000 = 47.3 \text{ kg/tonne}$$

3. Determine the amount of air required. Assume air contains 23.15 percent oxygen by weight and that the density of air is 1.2928 kg/m^3.

a. The total amount of oxygen required is

$$O_{2,\,\text{total}} = (1.282 + 47.3)\ \text{kg/tonne} = 1329\ \text{kg/tonne}$$

b. The mass of air required is

$$\text{Air}_{\text{mass}} = \frac{1329\ \text{kg/tonne}}{0.2315} = 5742\ \text{kg/tonne}$$

c. The volume of air required is

$$V_{\text{air}} = \frac{5742\ \text{kg/tonne}}{1.2928\ \text{kg/m}^3} = 4442\ \text{m}^3\text{/tonne}$$

Power Plants

A power plant is an industrial facility that generates electricity from primary energy.

Most power plants use one or more generators that convert mechanical energy into electrical energy in order to supply power.

Types of Power Plants

- Coal-fired power plants (burns coal to generate electricity)
- Nuclear power plants (use the process of nuclear fission in order to generate electricity)
- Hydroelectric power plants (uses a dam to store river water in a reservoir)
- Diesel-fired power plants (diesel engine is used as the prime mover)
- Geothermal power plants (use of geothermal energy (the Earth's internal thermal energy)
- Gas-fired power plants (Natural gas is combusted in a gas turbine burner which drives a generator to produce electricity)
- Solar power plants (conversion of energy from sunlight into electricity)
- Wind power plants (converts wind energy into electric energy)

Thermal Power Plants

- A thermal power plant is a power station that converts heat energy into electric power.
- These power plants do this by primarily heating fossil fuels (coal, natural gas, heating oil, biomass etc.), which heats up water into steam.
- Thermal power plants are known to pump out a lot of greenhouse gases and ash, which are by-products of burning the fossil fuels.
- **Carbon dioxide** is one of the main gases that is released from the burning of the fossil fuels and is known to be a greenhouse gas and a contributor of global warming.
- **Sulfur dioxide** is another gas that is released from power plants. Whilst it is technically not a greenhouse gas, it is known to have indirect effects to the atmosphere because it can affect the scattering of incoming sunlight, the formation of clouds and precipitation patterns.
- **Nitrogen oxides** are another set of gases that are released to the atmosphere by thermal power plants. Thermal power plants are also one of the biggest contributors to the global nitrogen oxide levels.

The other big pollutant to the atmosphere is Ash. Ash often contains harmful particulate matter, as well as heavy metals. Ash can have multiple effects; it can get into waterways and soil wherever it falls (it doesn't have to be the local environment) and change the alkalinity of the soil/water, which can render the soil unusable for agricultural purposes and the water undrinkable, and it can cause visibility issues.

Fly-ash, a resultant of combustion of coal at high temperature, has been regarded as a problematic solid waste all over the world.

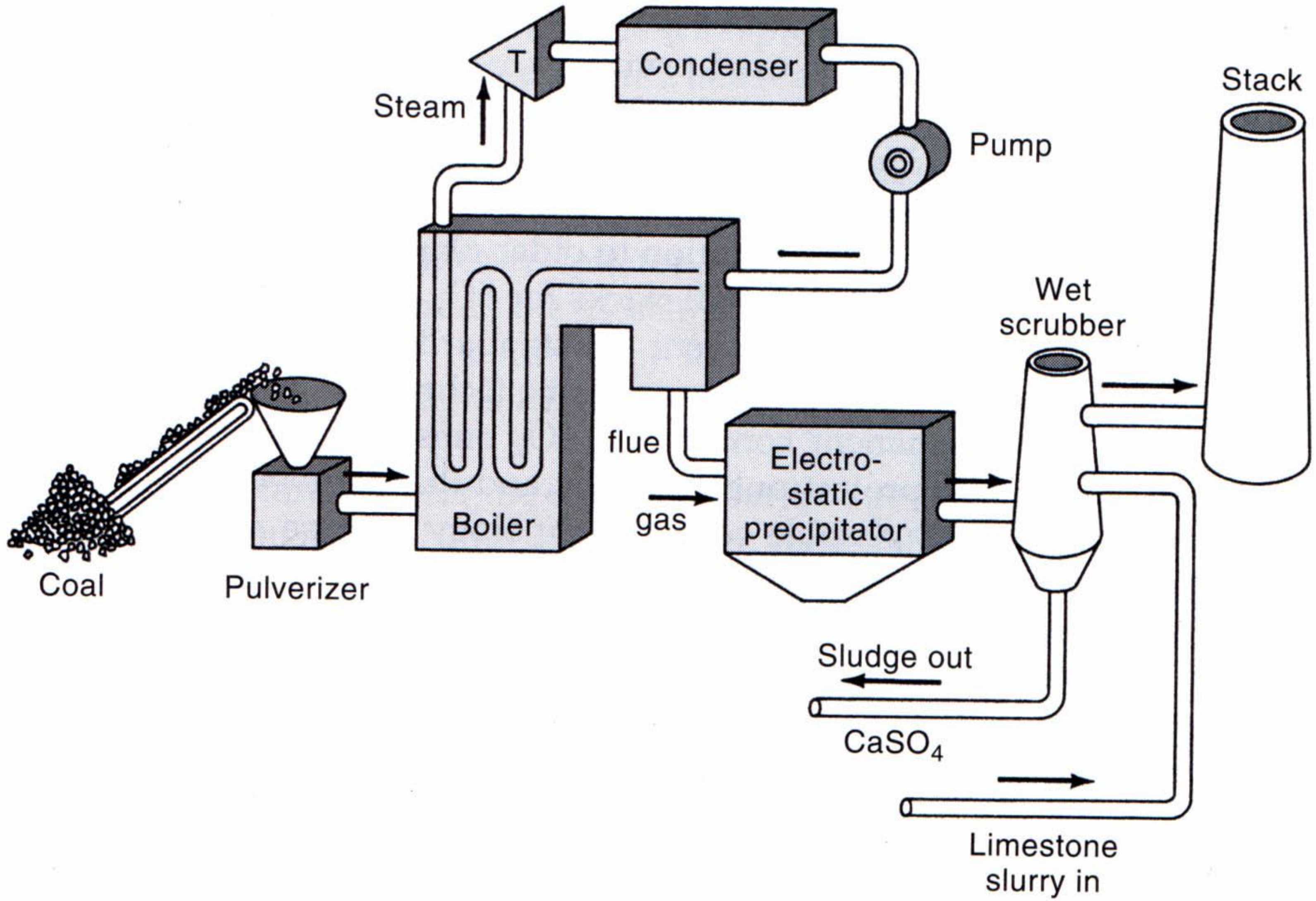
Pollutant due to Thermal Power Plants

- The pollutants or emission from thermal power plants can be classified as follows:
- Gaseous emission: SO_2, Nox, CO_2, CO, H_2S, and many other.
- Particulate emission: smoke, dust, fumes, fly-ash, cinders
- Solid waste emission: ash
- Thermal pollution: waste heat.

- During stack emission, SO_2 and Nox are realeased which subsequently get oxidised to sulphate(So_4) and nitrate(NO_3). In the presence of water vapours in the atmosphere these are changed to sulphuric acid and nitric acid.

→ **Acid Rain**

Power Plant Pollution Control



Pollution Control

Control of CO_2

- Cleaning coal
- Improved ESP Design
- Increasing the height of chimney

Control of SO_2

- Desulpherisation of fuel
- Use low Sulphur fuels
- Use of tall stacks
- Flue gas cleaning

Control of NOx

- Reduction of combustion temperature
- Reduction of combustion timing

Impact on the Local Environment

- Thermal pollution is one of the biggest issues on local environments. When the water in a power plant is no longer usable, it often gets discharged into a local waterway. This wastewater generally has a higher temperature than the local natural water, so it can increase the temperature of the water, which in turn can have a negative impact on the local ecosystem.

- Moreover, this wastewater often contains metals and metalloids which have dissolved—such as boron, arsenic and mercury—which can also affect the balance of the local ecosystem.

- Even though ash is discharged through a flue, the affects of its release can enter the local environment near the power plant.

Other Impacts on the Environment

Global Climate

The planet's ability to retain solar heat is dependent on concentrations of "greenhouse gases" (GHGs) that are in the atmosphere. Since the beginning of the industrial revolution when large-scale consumption of fossil fuels began, atmospheric concentrations of CO_2 have increased over 30%.

Land and Soil

Different power plant types and designs have a wide range of land requirements. Coal-fired powerplants need land not only for boilers and turbines but also for rail lines, coal storage piles, and ash landfills. Nuclear power plants may need specific areas for specialized dry cask storage of spent fuel rods. Natural gas-fired plants generally need less space than coal or nuclear plants, but need a large natural gas supply line and sometimes a large tank of oil for backup fuel. Apart from land degradation, Soil erosion and sedimentation into nearby waters or wetlands is a risk.

Vegetation impacts can be of two basic kinds:

- Direct impacts of vegetation removal or damage during construction.
- Indirect impacts on vegetation from air pollution or surface water impacts caused by the power plant.

Wildlife

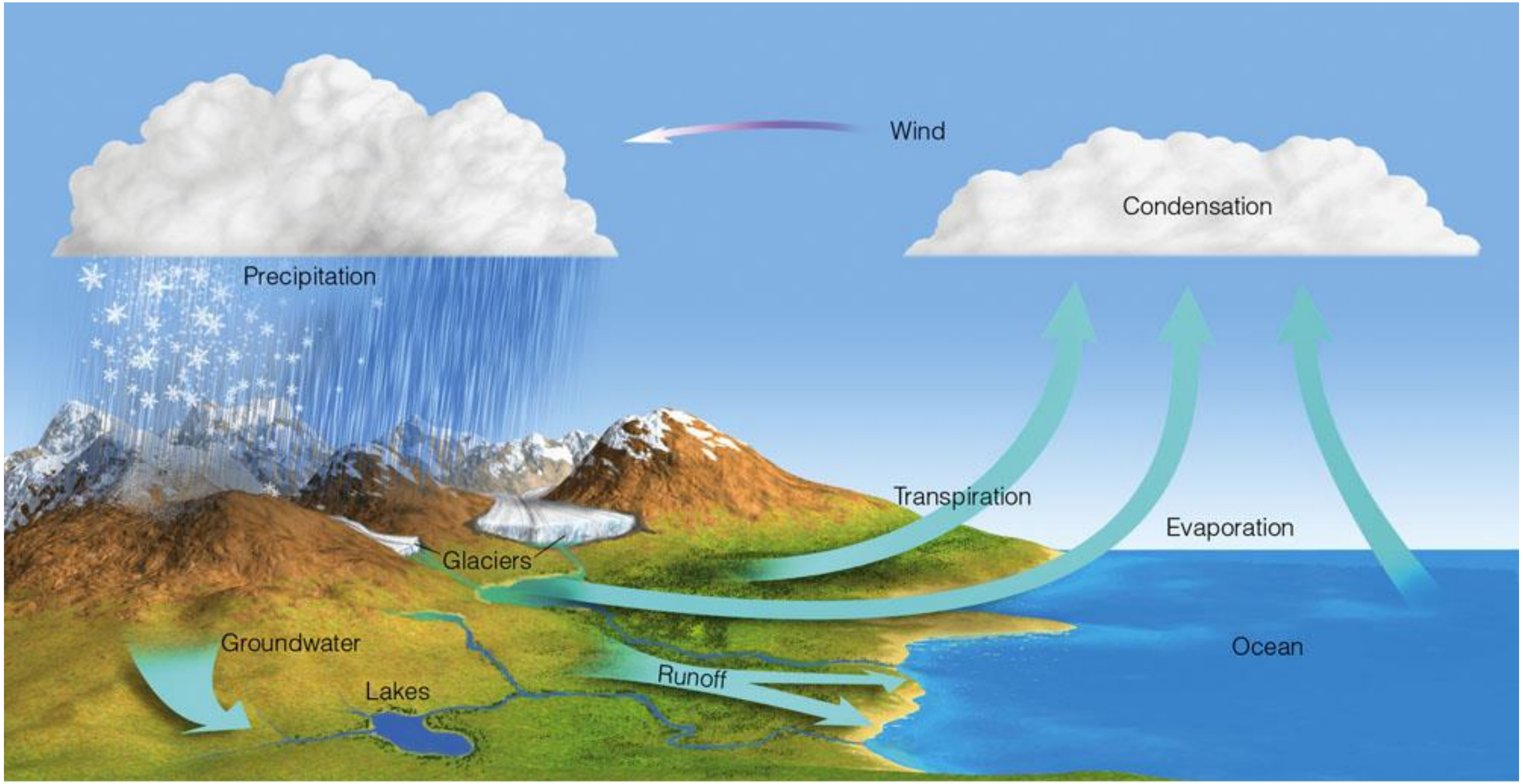
Impacts to vegetation could create a chain of wildlife impacts. Impacts on local or migrating wildlife could occur when their habitat and source of food is removed or damaged. The food source could be the vegetation itself or bugs, animals, birds, or organisms that rely on the vegetation for food. Nesting and den areas would be destroyed.

Agriculture

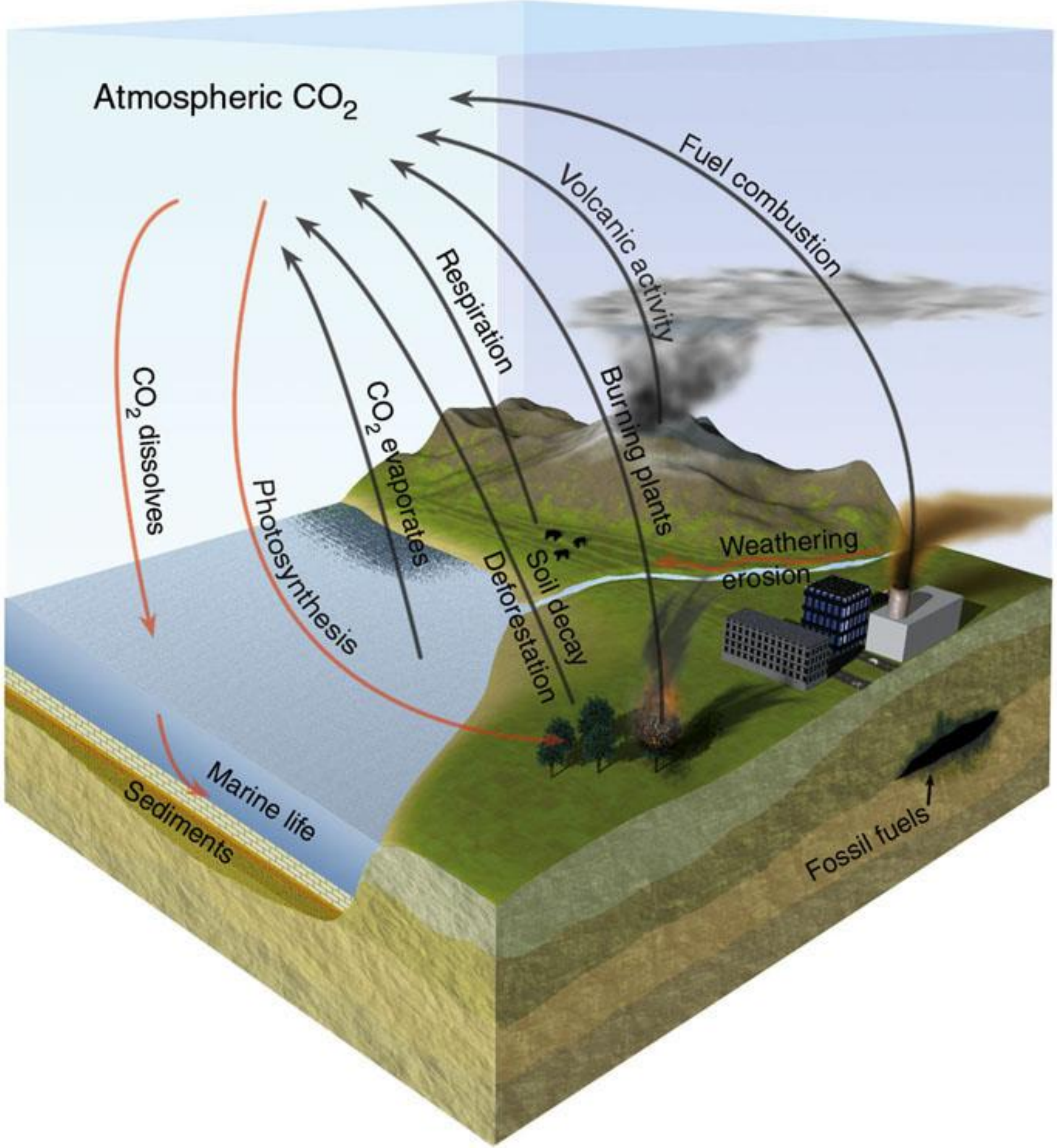
Farmlands, particularly prime farmlands (areas having more fertile soils), are a valuable resource. Construction of power plant facilities on local farmlands would permanently take those fields out of agricultural production and could affect the economic viability of the farm and, indirectly, the local farm community.

Composition of the Atmosphere

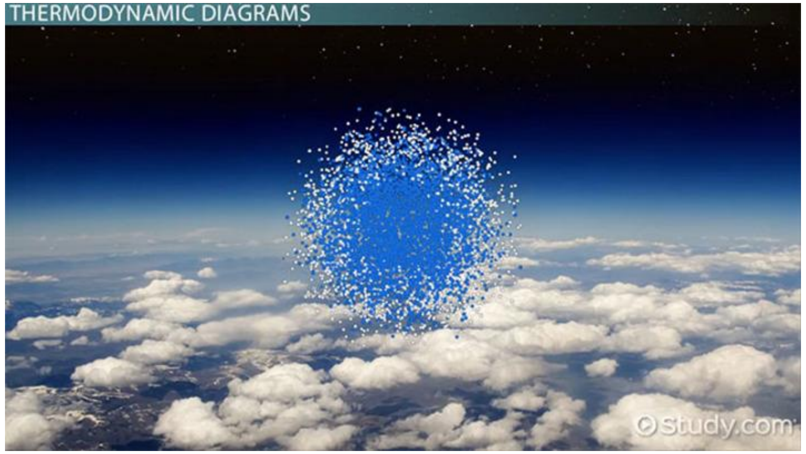
The Hydrological Cycle

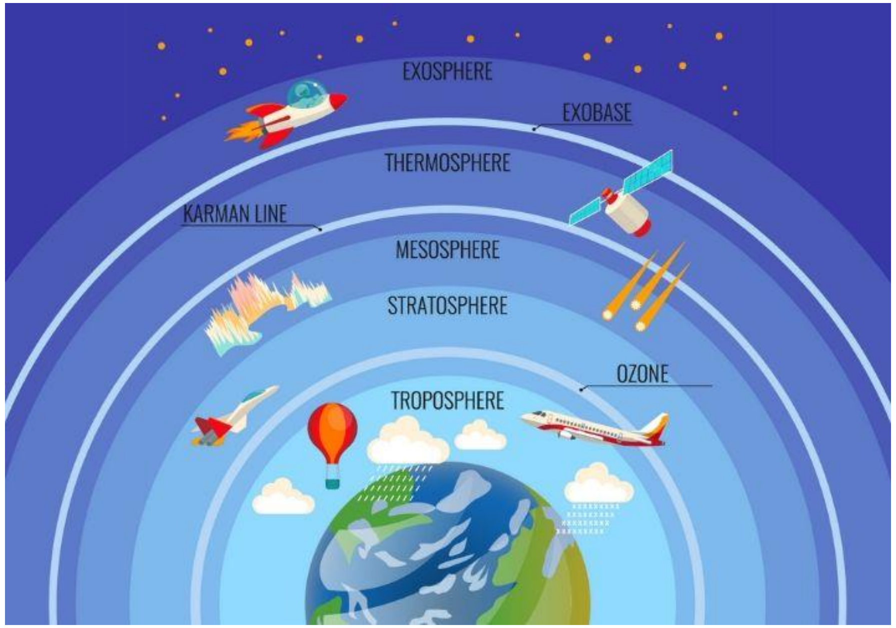


The Global Carbon Cycle



Origin of the Atmosphere





Origin of the Atmosphere

- Initially, no O_2 or O_3, so no land organisms!
- Volcanoes release H_2, CO_2, H_2O_v, N_2, NH_3, CH_4
- single-celled aquatic organisms release CO_2 to atmosphere when breaking down food through fermentation.
- Simple aquatic plants took in CO_2 and released O_2 to atmosphere via photosynthesis
  - O_3 formed from the O_2
- CO_2 gets stored in shells and decaying plants
- N_2 builds up in atmosphere
- Then free oxygen also get buildup, then Animals get started respiration
- And then, life originated

ORIGIN AND EVOLUTION OF THE ATMOSPHERE

● Early atmosphere [H, He, Ammonia (NH_3) and Methane (CH_4)] was driven away by solar radiation and lost by their low atomic masses.

● Primordial Earth melted completely and gases bubbled out or erupted from early volcanoes. Result was a N-rich atmosphere.

● Evolution of blue-green algae changed everything! Photosynthesis by these algae absorbed CO_2 from the atmosphere and released O_2.

● Most of that oxygen was dissolved in the oceans where it combined with iron and precipitated until about 2.5 billion years ago (2.5 Ga) to form iron oxides in *banded iron formation.*

● At about 2.5 Ga, oceans were saturated with oxygen and free oxygen was added to the atmosphere. Resulting surface oxidation produced first *redbeds* on the continents.

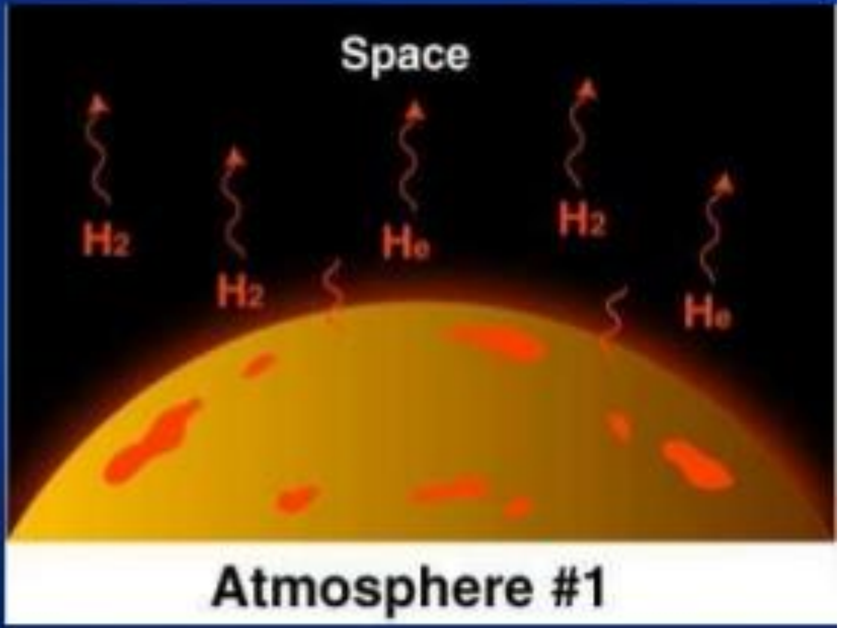
●At about 1 Ga, reservoirs of oxidizable rock at the surface were saturated and oxygen began to build up in the atmosphere.

● Ultraviolet light split O_2 molecules forming ozone (O_3) that shielded the surface from intense solar radiation. At that point, life could emerge from the ocean and colonize the continents.

Origin of the Earth's atmosphere

First Atmosphere:

- ❖Solar composition – Hydrogen and Helium
- ❖Blown away by solar wind
- ❖Mean speed greater than escape velocity
- ❖Occurred 4.6 billion years ago

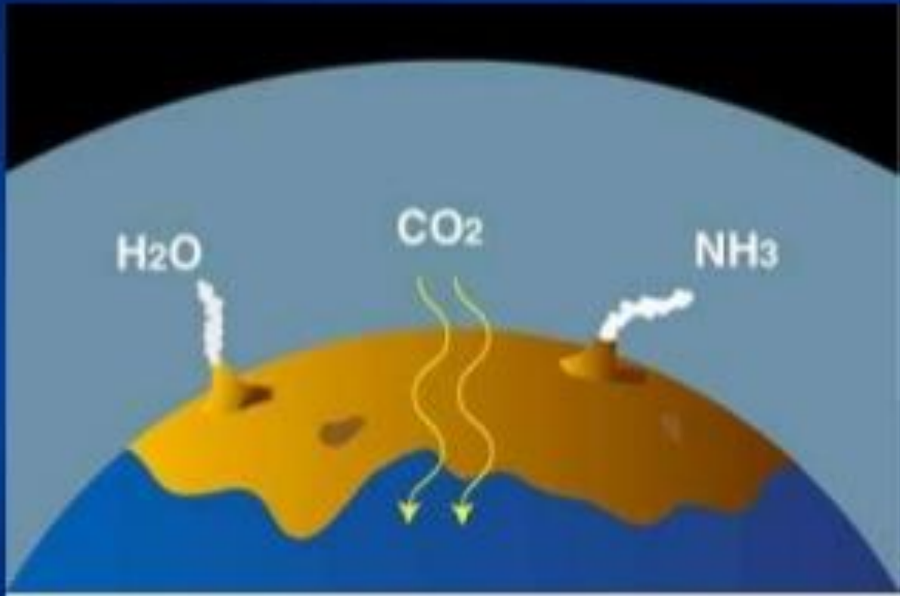


https://scijinks.gov/atmosphere-formation

Origin of the Earth's atmosphere

Second Atmosphere:

- ❖Formed from out gassing
- ❖Chemically reduced gas components (not containing O2)
- ❖Occurred 3.6 billions years ago
- ❖ Component also include CH_4, CO_2 , NH_3 and H_2O



Atmosphere #2

https://scijinks.gov/atmosphere-formation

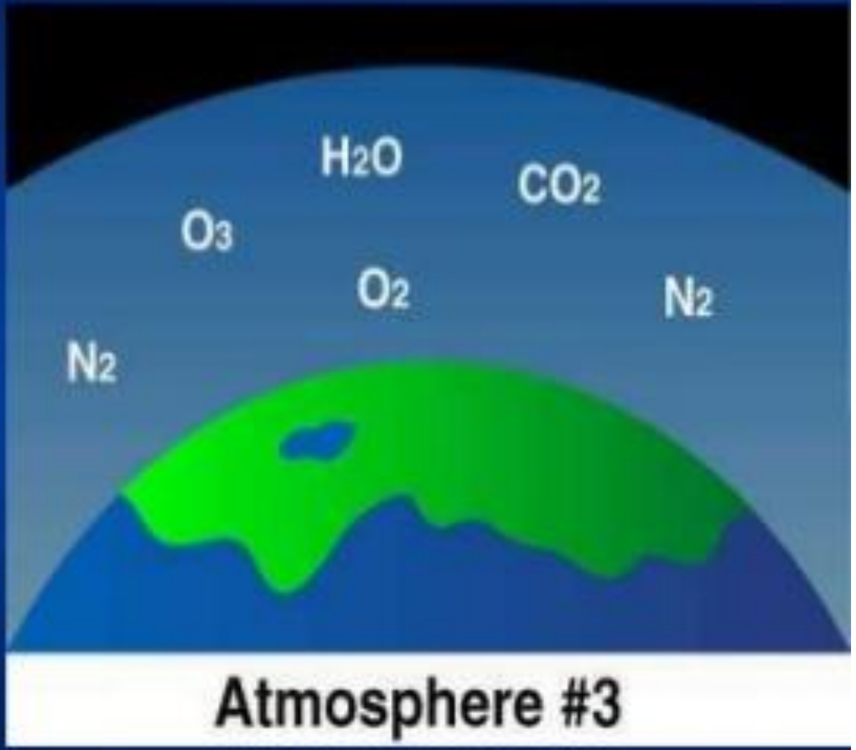
Origin of the Earth's atmosphere

Third (Present) atmosphere

- Chemically oxidizing atmosphere
- $2CO_2$ + UV-radiation → $2CO + O_2$
- $2H_2O$ + UV-radiation → $2H_2 + O_2$
- $6\ CO_2 + 6\ H_2O + hv$ + Chlorophyll → $C_6H_{12}O6 + 6O_2$
- Oxygen (21%), Nitrogen (78%)
- Small amount of water vapour,

carbon dioxide and other gases

- About 2.4 billions years existed



https://scijinks.gov/atmosphere-formation

Summary

❖The Atmosphere protects us from Ultraviolet radiation

❖ The atmosphere supports life on Earth e.g breathing, plants and animals

❖The Atmosphere protects us from Debris of Comets, Asteroid or Meteoroid.

Thank You.