

**Environmental pollution
caused by power plants,
open burning of solid wastes**

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.



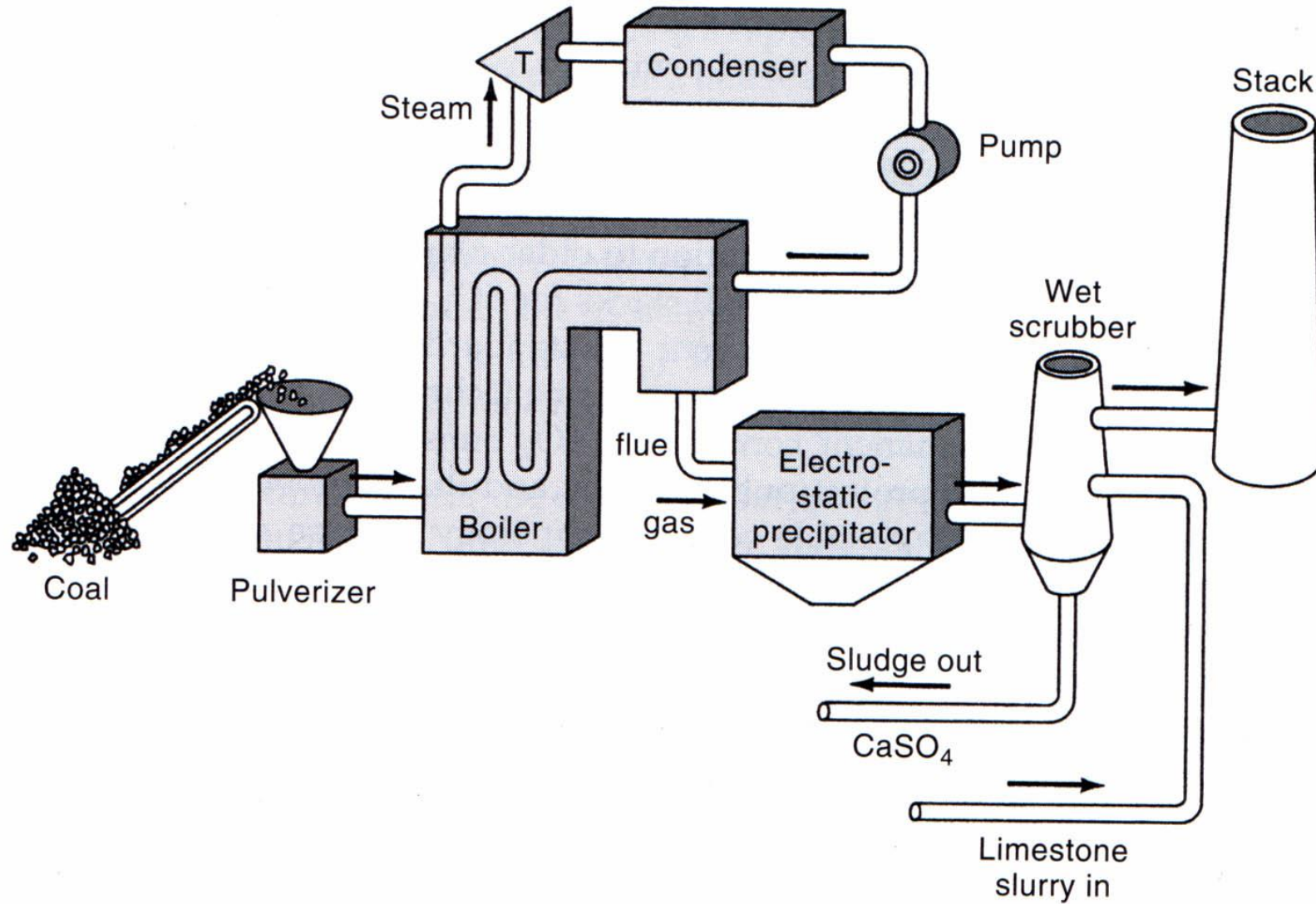
Fly-ash, a resultant of combustion of coal at high temperature, has been regarded as a problematic solid waste all over the world.

Pollutant due to Thermal Power Plants

- The pollutants or emission from thermal power plants can be classified as follows:
 - Gaseous emission: SO_2 , NO_x , 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 NO_x are released 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 CO₂

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

Control of SO₂

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

Control of NO_x

- 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 CO₂ have increased over 30 percent.

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 ashlandfills. 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.

Solid Waste

(Open burning)

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)

Classification of Waste according to their 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. Open burning of waste is a process in which unwanted products, byproducts and materials are incinerated, typically at low temperatures and in an uncontrolled manner.

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.**





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 iv pollutants are especially harmful to unborn fetuses, infants and children who come into contact with the pollutants either through their mothers or through exposure to the pollutants themselves. Consequently, several of the pollutants emitted by open waste burning can cause severe developmental damage in the young

Open Burning Alternatives

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 include:

- a) Combustion
- b) Pyrolysis
- c) Gasification

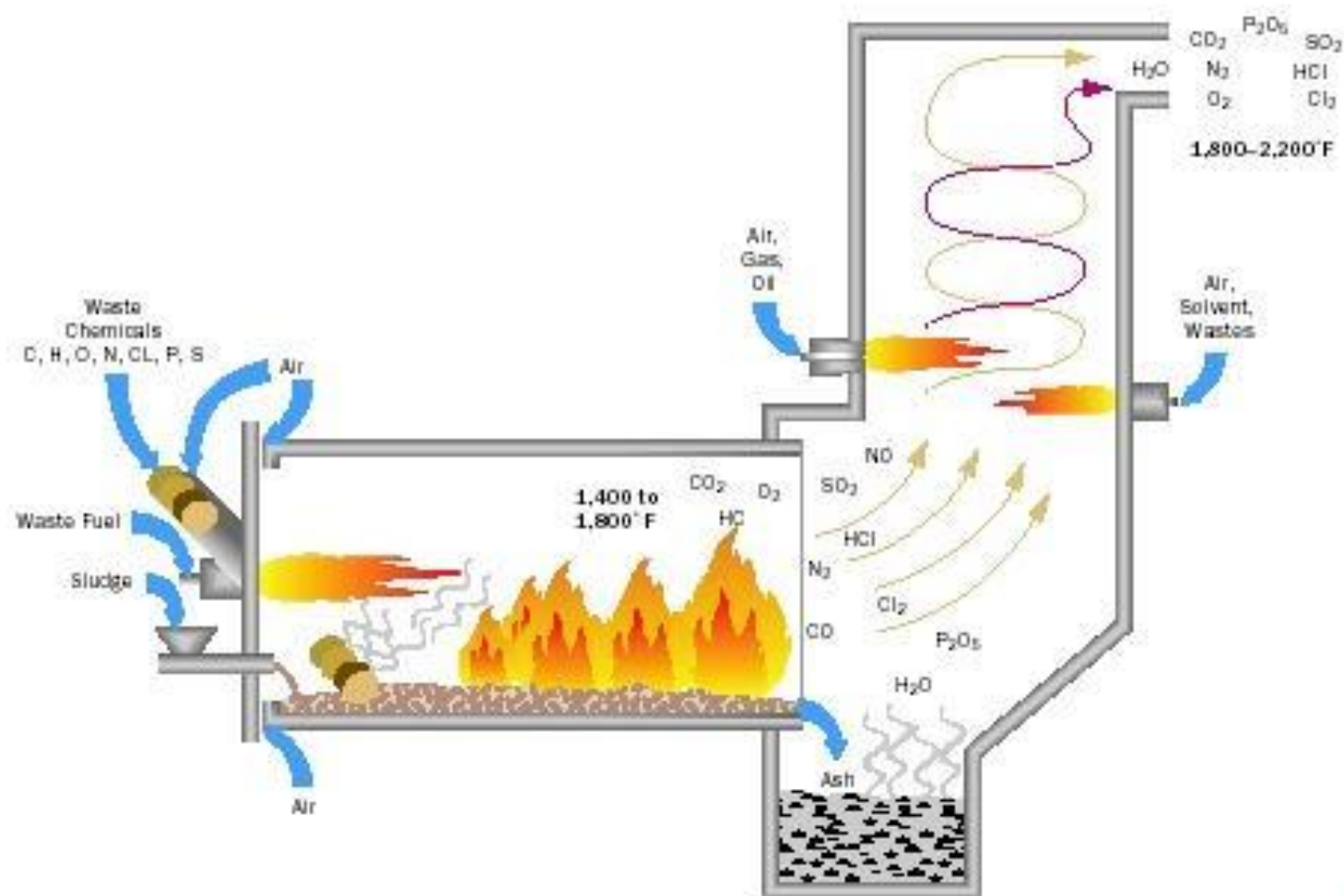
Combustion

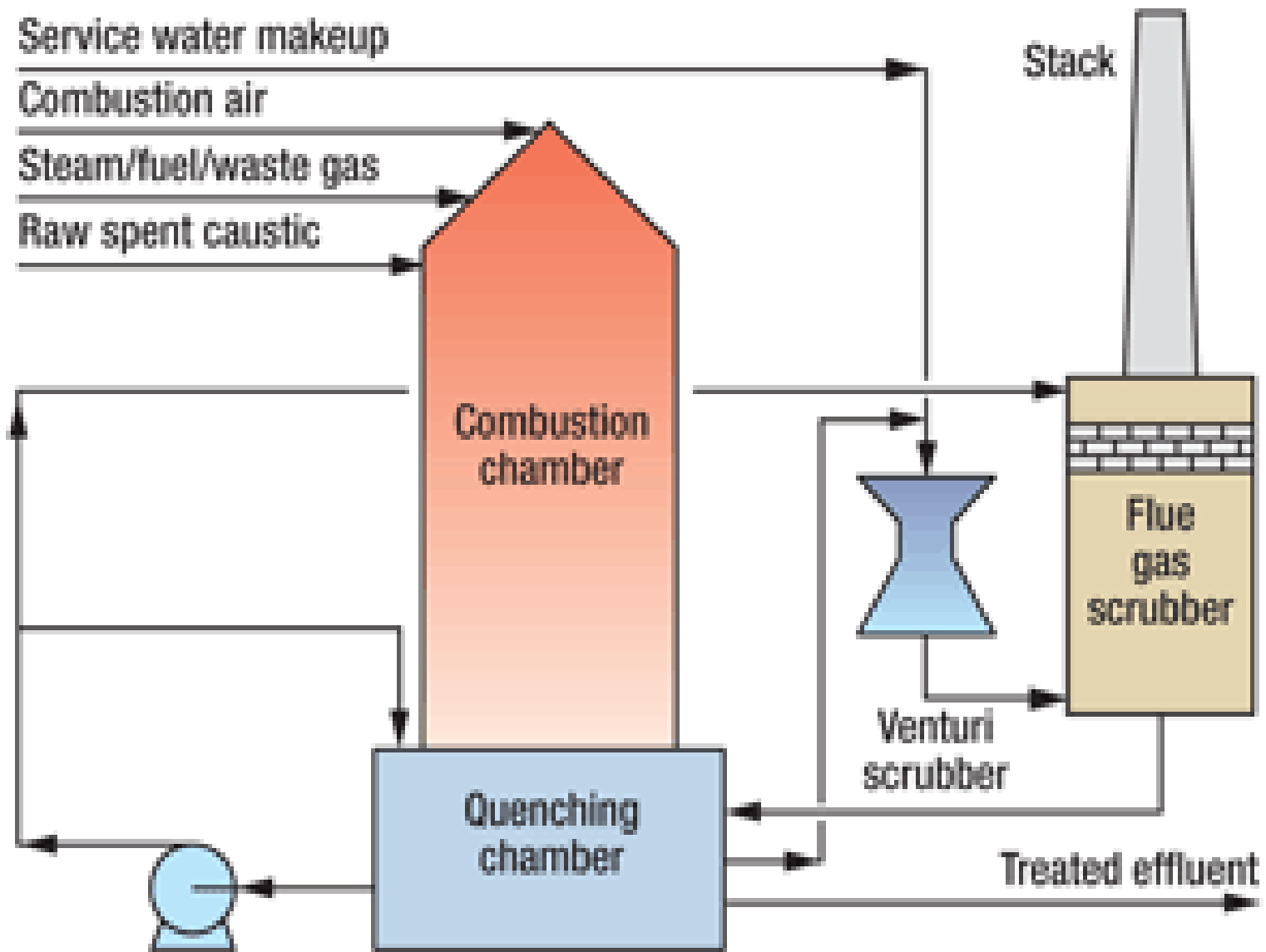
- **Incineration** is the burning of waste in a specially **designed combustion chamber**.
- At mass burn incinerators, also known as mass burn combustors, the heat generated from the burning material is turned into useable electricity.
- Incineration refer to high temperature combustion of waste in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

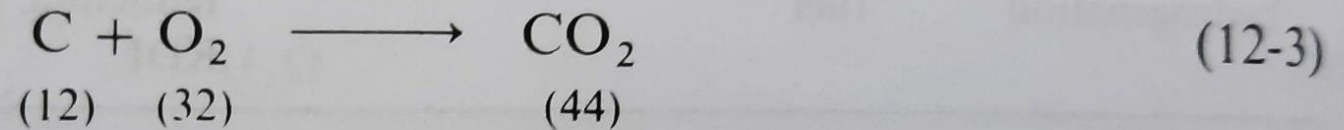




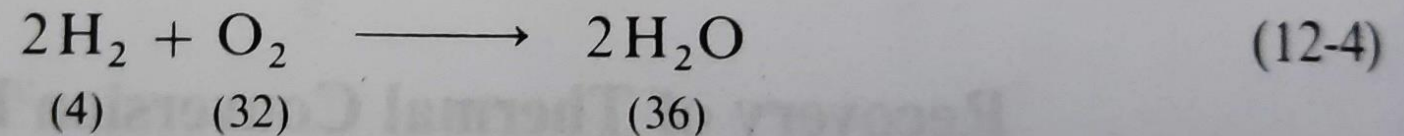
Air Requirements For Combustion

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:

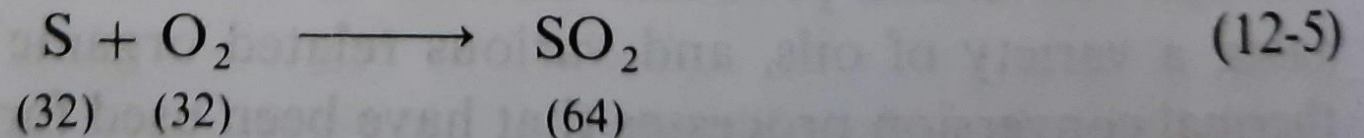
For carbon



For hydrogen:



For sulfur:



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 $C_{50}H_{100}O_{40}N$
 $= (50 \times 12) + (100 \times 1) + (40 \times 16) + (1 \times 14) = 1354$

Step 2. Now, % distribution of basic elements:

Elements	% by Mass
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C	$[(50 \times 12) / 1354] \times 100 = 44.3$
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H	$[(100 \times 1) / 1354] \times 100 = 7.4$
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O	$[(40 \times 16) / 1354] \times 100 = 47.3$
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N	1.0
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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
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C	$0.443 \times 11.52 \times 1000 = 5103 \text{ kg/T}$
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H	$0.0149 \times 34.56 \times 1000 = 515 \text{ kg/T}$
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Total	$= 5618 \text{ kg/T}$
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PYROLYSIS

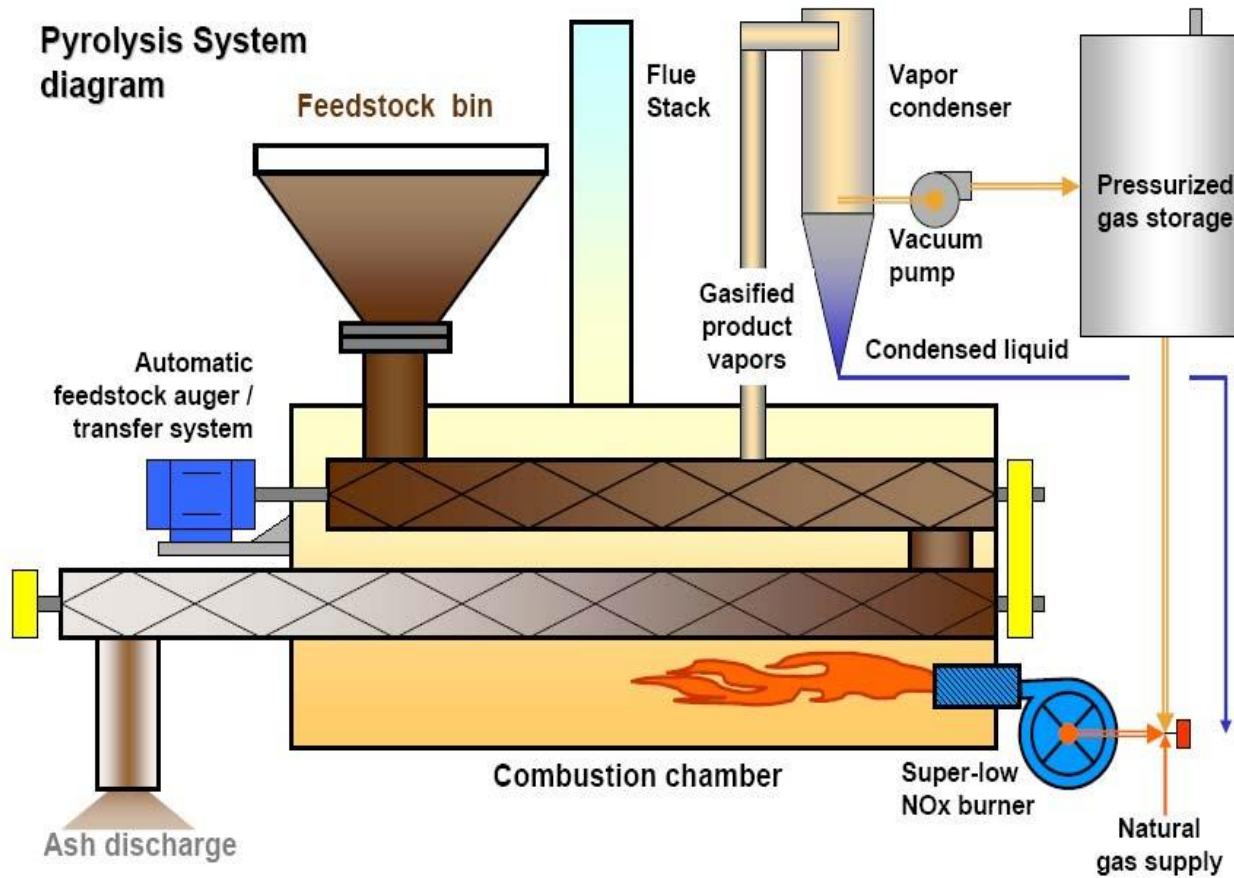
Pyrolysis is a thermochemical decomposition of organic material at elevated temperature ($>430^{\circ}\text{C}$) in the **absence of oxygen**.

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 $200\text{-}300^{\circ}\text{C}$ ($390\text{-}570^{\circ}\text{F}$).

PYROLYSIS

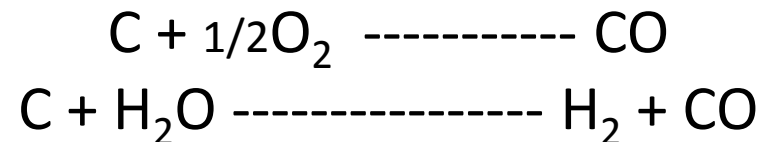
Pyrolysis Process



GASIFICATION

Gasification is a process that converts organic or fossil fuel based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. 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.



GASIFICATION

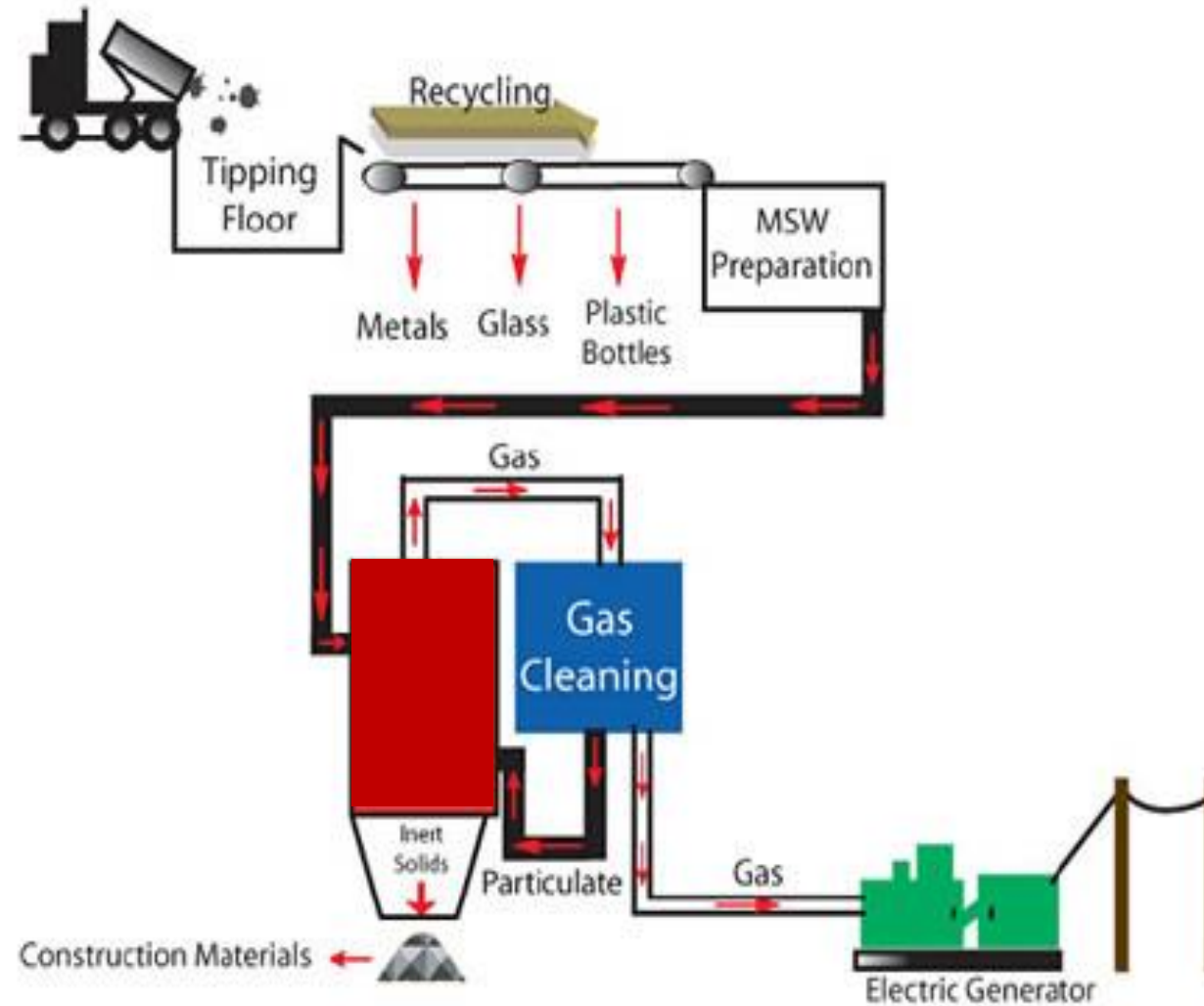


Figure 1: Schematic of MSW Gasification and Power Generation Plant

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

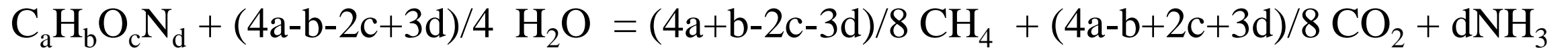


Anaerobic Reaction



Estimation of Methane Gas

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



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:

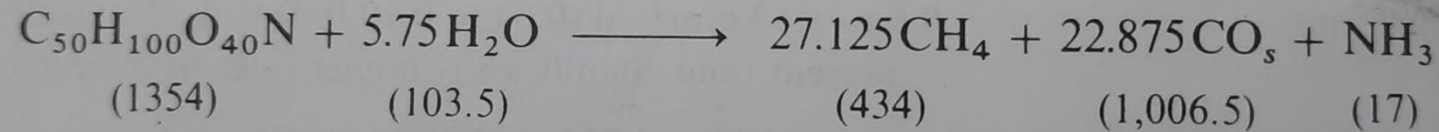
$$a = 50$$

$$b = 100$$

$$c = 40$$

$$d = 1$$

b. Using these coefficients the resulting equation is:



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

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

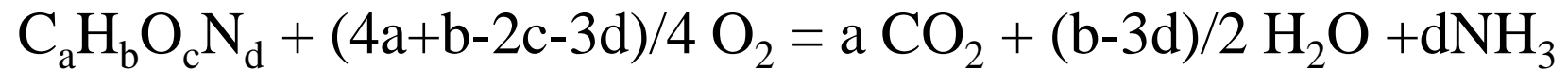
3. Using a density value for methane of 0.7167 kg/m^3 , determine the volume of methane gas.

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

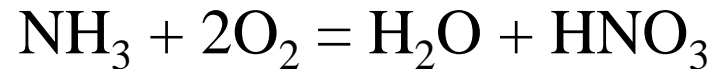
COMMENT In practice, a portion of the waste would be used for the synthesis of cell tissue. The actual volume of gas would be about 0.85 times the value determined in step 3.

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:



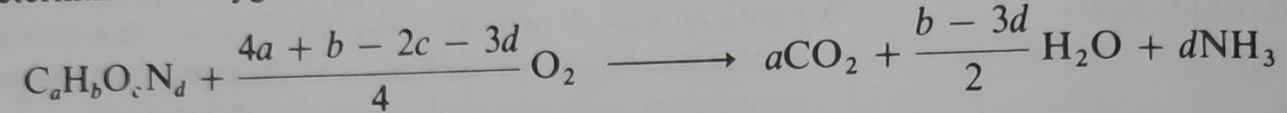
If the ammonia is oxidized to nitrate, the amounts of oxygen required can be completed with by equation:



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).



- a. The required coefficients are:

$$a = 50$$

$$b = 100$$

$$c = 40$$

$$d = 1$$

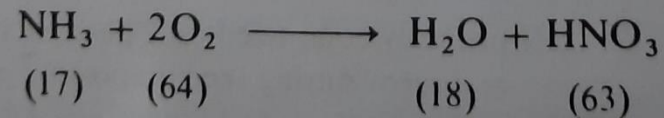
- b. Using these coefficients the resulting equation is:



- c. The oxygen required per tonne is:

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

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



The oxygen required per tonne of waste is:

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

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

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

- 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

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

Thank You.