Environmental Pollution

1. Introduction

Developmental activities such as construction, transportation, and manufacturing not only deplete natural resources but also produce large amounts of waste that leads to pollution of air, water, and soil. Untreated or improperly treated waste is a major cause of pollution in the environment. In this lesson, you will study the major causes of pollution, their effects on our environment, and the various measures that can be taken to control such pollution.

1.1 The Environment Definition:

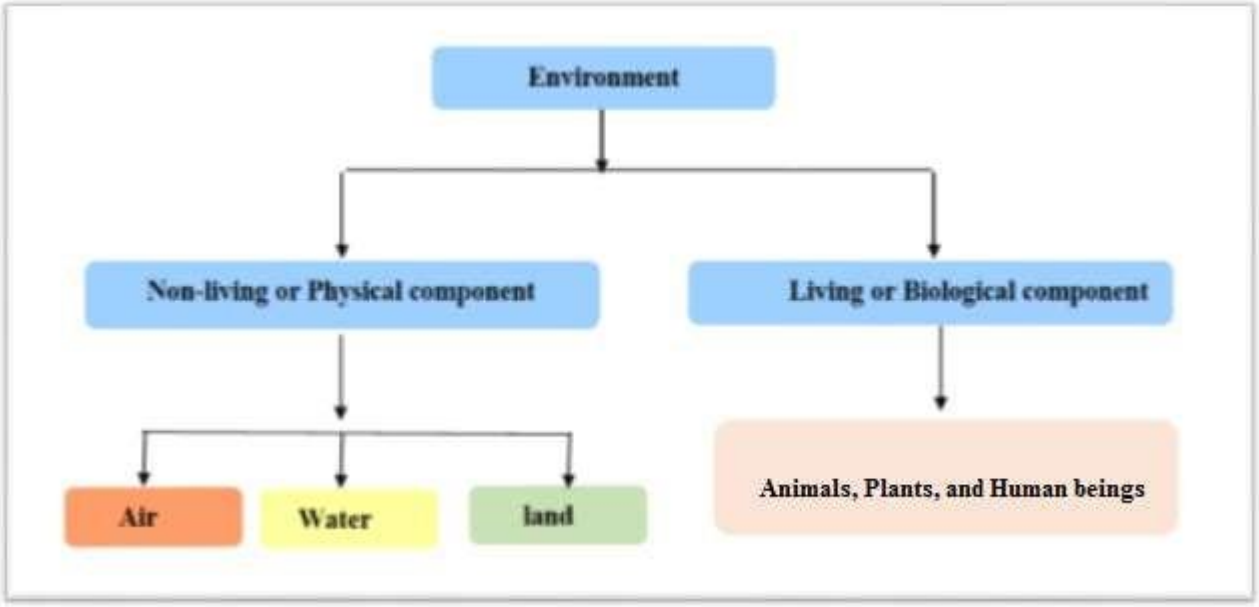
The term Environment has been defined: "Environment Protection Act to include water, air, land and inter-relationship between water, air, land, and human beings, other living creatures, plants, microorganisms and property."

The term environment includes two components; the first is Non-living or Physical (air, water, land), and the second is Living or Biological (animals, plants, as well as human beings), and the inter-relationship between them.

The sum total of all surroundings of a living organism, including natural forces and other living things, which provide conditions for development and growth as well as danger and damage.

1.2 Elements of Environment

The environment consists broadly of two components-Non-living or Physical and Living or Biological.



1.3 Pollution and Pollutants

Human activities directly or indirectly affect the environment adversely. A stone crusher adds a lot of suspended particulate matter and noise into the atmosphere. Automobiles emit from their tail pipes oxides of nitrogen, sulphur dioxide, carbon dioxide, carbon monoxide and a complex mixture of unburnt hydrocarbons and black soot which pollute the atmosphere. Domestic sewage and run off from agricultural fields, laden with pesticides.

Pollution is defined as the addition of undesirable material into the environment as a result of human activities. The agents which cause environmental pollution are called pollutants. Pollutants may be defined as physical, chemical, or biological substance unintentionally released into the environment which is directly or indirectly harmful to humans and other living organisms.

1.4 Classification of Pollutants

a. Classification based on environment:

1. Air pollution
2. Water pollution
3. Soil pollution

b. Classification based on nature of pollutants

1. Chemical pollution
2. Noise pollution
3. Pollution by radio activity.

2. Air Pollution:

Air pollution consists of gaseous, liquid, or solid substances that, when present in sufficient concentration, for a sufficient time, and under certain conditions, tend to interfere with human comfort, health or welfare, and cause environmental damage. Air pollution causes acid rain, ozone depletion, photochemical smog, and other such phenomena.

The substances causing air pollution are collectively known as **air pollutants**. They may be solid, liquid or gaseous in nature. Pollutants are classified as primary and secondary air pollutants. **Primary pollutants** are those which are emitted directly to atmosphere, whereas, **secondary pollutants** are formed through chemical reactions and various combinations of the primary pollutants. These pollutants originate from the following four types of sources:

1. **Point sources,** which include facilities such as factories and electric power plants.
2. **Mobile sources,** which include cars and trucks but also lawn mowers, airplanes, and anything else that moves and releases pollutants into the air.
3. **Biogenic sources,** which include trees and vegetation, gas seeps, and microbial activity.
4. **Area sources,** which consist of smaller stationary sources such as dry cleaners and degreasing operations.

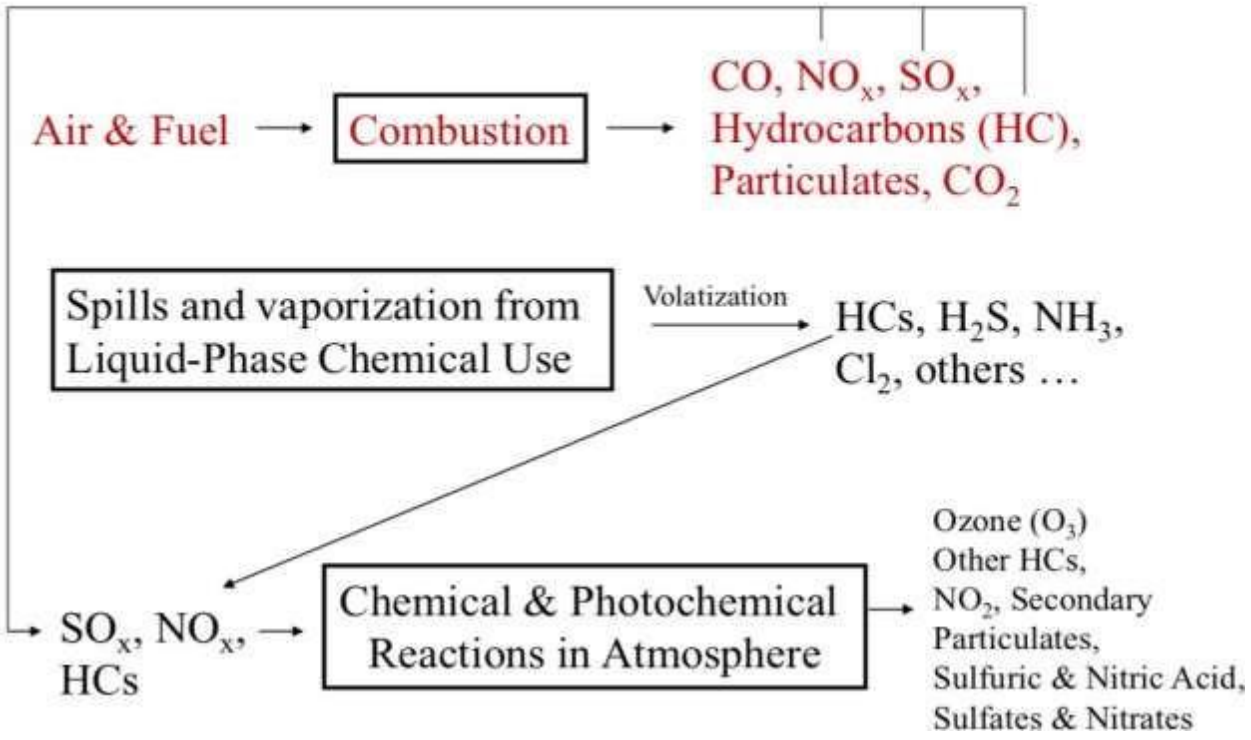
2.1 Combustion

Combustion = burning something

- **For example: -**
  - Burning gasoline in automobiles
  - Burning diesel fuel in trucks
  - Burning "residual oil" (bunker fuel) in ships
  - Burning coal in power plants
  - Burning natural gas (methane, CH_4) in power plants
  - Burning wood and other biomass in wildfires & controlled burns

2.1.1 Air Pollution from Fuel Combustion

Focus on Combustion …



2.1.2 Internal combustion engines:

Internal combustion engines are devices that generate work using the products of combustion as the working fluid rather than as a heat transfer medium. Carbon monoxide, nitrogen oxides, and hydrocarbons are released when fuel is burned in an **internal combustion engine** and when **air**/fuel residuals are emitted through the vehicle tailpipe. Motor vehicle **pollution** also contributes **to** the formation of acid rain and adds **to** the greenhouse gases that **cause** climate change.

There are three major types of internal combustion engines in use today:

1. The spark ignition engine.
2. The diesel engine.
3. The gas turbine.

2.1.3 Diesel Exhaust:

Diesel exhaust is produced when an engine burns diesel fuel. It is a complex mixture of thousands of gases and fine particles (commonly known as soot) that contains more than 40 toxic air contaminants.

These include many known or suspected cancer-causing substances, such as benzene, arsenic and formaldehyde. It also contains other harmful pollutants, including nitrogen oxides.

2.2 Evaporative Emissions from Engines Occur in Several Ways:

1. **Diurnal:** (Emissions while Parked and Engine is Cool)- Even when the vehicle is parked for long periods of time, gasoline evaporation occurs as the temperature rises during the day, heating the fuel tank and venting gasoline vapors.
2. **Running Losses:** The hot engine and exhaust system can vaporize gasoline when the car is running.

3. **Hot Soak:** soak (Cooling Down) - The engine remains hot for a period of time after the vehicle is turned off, and gasoline evaporation continues when the car is parked while cooling down.
4. **Refueling:** Gasoline vapors escape from the vehicle's fuel tank while the tank is being filled.

2.3 Emissions Pollutants from Internal Consumption Engines:

1. **Hydrocarbons:**

Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn only partially. Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone, a major component of smog. Ozone irritates the eyes, damages the lungs, and aggravates respiratory problems.

2. **Nitrogen Oxides (NOx)**:

Under the high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as NO_x. Nitrogen oxides, like hydrocarbons, are precursors to the formation of ozone. They also contribute to the formation of acid rain.

$$N_2 + O_2 = NO + N$$

$$N + O_2 = NO + O$$

3. **Carbon Monoxide:**

Carbon monoxide (CO) is a product of incomplete combustion and occurs when carbon in the fuel is partially oxidized rather than fully oxidized to carbon dioxide (CO). Carbon monoxide reduces the flow of oxygen in the blood stream and is particularly dangerous to persons with heart disease.

4. **Carbon Dioxide**:

Carbon dioxide does not directly impair human health, but it is a "greenhouse gas" that traps the earth's heat and contributes to the potential for global warming. Evaporative Emissions Hydrocarbon pollutants also escape into the air through fuel evaporation.

5. **Sulfur Oxides:**

During the combustion process, essentially all the sulfur in the fuel is oxidized to SO_2. The oxidation of SO_2 gives sulfur trioxide (SO_3), which reacts with water to give sulfuric acid (H_2SO_4), a contributor to acid precipitation. Sulfuric acid reacts with basic substances to give sulfates, which are fine particulates that contribute to PM-10 and visibility reduction. Sulfur oxide emissions also contribute to corrosion of the engine parts.

6. **Lead (Pb):**

The largest source of Pb in the atmosphere has been from leaded gasoline combustion. Other airborne sources include combustion of solid waste, coal, and oils, emissions from iron and steel production and lead smelters, and tobacco smoke. Exposure to Pb can affect the blood, kidneys, and nervous, immune, cardiovascular, and reproductive systems.

7. **Smoke and Particulate Matter:**

White, blue, and black smoke may be emitted from engines. Liquid particulates appear as **white smoke** in the exhaust during an engine cold start, idling, or low load operation. **Blue smoke** is emitted when oil leaks or burning. The primary constituent of **black smoke** is agglomerated carbon particles (soot) formed in regions of the combustion mixtures that are oxygen deficient.

- **Solid particles** in the air are classified by their size, their capacity of sedimentation and the possibility to penetrate the organisms, as following:

a. Particles larger than 10 µm are deposited after the law of gravity with a uniform accelerated motion, also known as dust.

b. Particles between 10 µm and 0.1 µm that are deposited after Stokes law, consisting mainly of ash and black smoke from burning fuel results.

c. Particles smaller than 0.1 µm that are deposited and move after Brownian movement law.

2.4 Factors Affecting Emission Rates

The vehicular emissions are due to a variety of factors. The emissions vary according to the environment, fuel quality, vehicle, etc. Fuel adulteration and overloading also cause higher amount of emissions. The emissions from vehicles depend on the following factors:

1. **Travel related factors:** The number of trips, distance travelled and driving mode are the major travel related factors affecting emissions.
2. **Highway Network Related Factors:** These include the geometric design features of the highway such as grade.
3. **Vehicle Related Factors:** Vehicle related factors include the engine sizes, horsepower and weight of the vehicle.
4. **Ambient Temperature:** Evaporative emissions are higher at high temperatures.
5. **Type of engine:** Two stroke petrol engines emit more amounts of pollutants than the four stroke diesel engines.
6. **Urbanization:** Congestion is higher in urban areas, and hence emissions are also higher.

2.5 The health effects of diesel exhaust?

1. As we breathe, the toxic gases and small particles of diesel exhaust are drawn into the lungs. The microscopic particles in diesel exhaust are small enough to penetrate deep into the lungs, where they contribute to a range of health problems.

2. Diesel exhausts have the potential to contribute to mutations in cells that can lead to cancer.
3. Diesel exhaust can irritate the eyes, nose, throat and lungs, and it can cause coughs, headaches, light-headedness and nausea.
4. Diesel engines are a major source of fine-particle pollution.
    - The elderly and people with emphysema, asthma, and chronic heart and lung disease are especially sensitive to fine-particle pollution.
    - Because children's lungs and respiratory systems are still developing, they are also more susceptible than healthy adults to fine particles. Exposure to fine particles is associated with increased frequency of childhood illnesses and can also reduce lung function in children.

2.6. Emissions from the Oil & Natural Gas Industry

High levels of carcinogens have been determined from industrial air emissions. Unsafe emissions may be due to improper production process, poor maintenance practices and internal operational process problems. Many of the chemicals discharged in to the atmosphere during the leakage periods were found particularly sever to children.

The oil and gas industry is the largest industrial source of emissions of volatile organic compounds (VOCs), a group of chemicals that contribute to the formation of ground-level ozone (smog). Exposure to ozone is linked to a wide range of health effects, including aggravated asthma and premature death.

The oil and natural gas industry also is a significant source of emissions of methane, a greenhouse gas that is more than 20 times as potent as carbon dioxide. Emissions of air toxics such as CO, CO_2, SO_2, NOx, benzene, ethylbenzene, and n-hexane, also come from this industry. Air toxics are pollutants known, or suspected of causing cancer and other serious health effects.

2.7. Some Causes of Industrial Air pollution

1. **Burning of Fossil Fuels:** Fossil fuel is a natural fuel such as coal or gas, formed in the geological past from the remains of living organisms by exposure to heat and pressure in the Earth's crust over millions of years.

   When fossil fuels, especially coal, are burned for energy, many impurities are released, including sulfur dioxide and nitrogen oxides. When these pollutants disperse through the atmosphere or dissolve in rainwater, they cause the phenomenon of acid rain. Acid rain is a term referring to a mixture of wet and dry deposition (deposited material) from the atmosphere containing higher than normal amounts of nitric acid (HNO_3) and sulfuric acid (H_2SO_4). Acid rain from air pollution damages vegetation, causes changes in soil chemistry and pollutes waterways.
2. **Exhaust from factories and industries:** Manufacturing industries release large amount of carbon monoxide, hydrocarbons, organic compounds, and chemicals into the air thereby depleting the quality of air.

Petroleum refineries also release hydrocarbons and various other chemicals that pollute the air and also cause land pollution. Oil refineries cause smog and air pollution. Oil refineries emit various chemicals every day. These include metals like lead which makes it hard for children to learn. They also include very small dust particles called PM10, that get deep into our lungs and harms our ability to breathe.

3. **Mining operations:** Mining operations like drilling, blasting, hauling, collection, and transportation are the major sources of emissions and air pollution. Mining is a process wherein minerals below the earth are extracted using large equipment. Some of the nonfuel minerals mined, such as stone, which is a nonmetallic or industrial mineral, can be used directly from the earth. Metallic minerals, which are also nonfuel minerals, conversely, are usually combined in nature with other materials as ores. These ores must be treated, generally with chemicals or heat to produce the metal. Dust and coal particles stirred up during the mining process, as well as soot released during coal transport, contributes to emissions and respiratory problems.
4. **Industrial chimney wastes:** Better dispersion of pollutants emitted by tall chimneys leads to better dilution in the air and thus lower local concentrations of pollutants. This has however led to pollution being dispersed more widely and to transboundary air pollution. Air pollutants spread on the largest area, through designed chimneys depends on several points:

   1) Desired height of chimney.

   2) The speed throwing pollutants from the chimney.

   3) The wind speeds.

   4) The physical properties of pollutants.

2.8. Solutions for Air Pollution

1. **Use public mode of transportation:** Encourage people to use more public modes of transportation to reduce pollution.
2. **Conserve energy:** Switch off fans and lights to reduce consumption of electricity. Large amount of fossil fuels is burnt to produce electricity. You can save the environment from degradation by reducing the amount of fossil fuels to be burned.
3. **Understand the concept of Reduce, Reuse and Recycle:** Do not throw away items and reuse them for some other purpose.

4. **Emphasis on clean energy resources:** Clean energy technologies like solar, wind and geothermal are on high these days. Governments of various countries have been providing grants to consumers who are interested in installing solar panels for their home. This will go a long way to curb air pollution.
5. Ensure that houses, schools, restaurants and playgrounds are not located on busy streets.
6. Plant trees along busy streets as they remove particulates, carbon dioxide and absorb noise.
7. Industries and waste disposal sites should be situated outside the city preferably on the downwind of the city.

2.9. Examples:

2.9.1. Emissions Calculations Using Fuel Analysis:

Fuel analysis can be used to predict emissions based on the application of mass balance. The presence of certain elements in fuels may be used to predict their presence in emission streams. These include toxic elements such as metals found in coal; as well as other elements such as sulfur, that may be converted to other compounds during the combustion process.

The basic equation used in fuel analysis emission calculations is:

Equation ER = R * PC * (MWp/MWf)

Where:

ER = pollutant emission rate R = fuel flow rate (lb/hr)

PC = pollutant concentration in fuel (%/100)

MWp = molecular weight of pollutant emitted (lb/lb-mole) MWf = molecular weight of pollutant in fuel (lb/lb-mole)