CHAPTER THREE

MOBILE SOURCE POLLUTION

5.1: Introduction:

Mobile sources, alternatively called transportation or vehicular sources include cars, trucks, buses, ships and various aircraft. Air pollutants emitted will vary, depending on the fuel being combusted or reacted (in the case of fuel cells or batteries) and the engine design of each vehicle.

The large majority of today's cars and trucks travel by using internal combustion engines that burn gasoline or other fossil fuels. The process of burning gasoline to power cars and trucks contributes to air pollution by releasing a variety of emissions into the atmosphere.

Emissions that are released directly into the atmosphere from the tailpipes of cars and trucks are the primary source of vehicular pollution. However, motor vehicles also pollute the air during the processes of manufacturing, refueling, and from the emissions associated with oil refining and distribution of the fuel, they burn. Primary pollution from motor vehicles is pollution that is emitted directly into the atmosphere, whereas secondary pollution results from chemical reactions between pollutants after they have been released into the air.

Despite decades of efforts to control air pollution, at least 92 million Americans still live in areas with chronic smog problems. The U.S. Environmental Protection Agency (EPA) predicts that by 2010, even with the benefit of current and anticipated pollution control programs, more than 93 million people will live in areas that violate health standards for ozone (urban smog), and more than 55 million Americans will suffer from unhealthy levels of fine-particle pollution, which is especially harmful to children and senior citizens. While new cars and light trucks emit about 90 percent fewer pollutants than they did three decades ago, total annual vehicle-miles driven have increased by more than 140 percent since 1970 and are expected to increase another 25 percent by 2010.

The emission reductions from individual vehicles have not adequately kept pace with the increase in miles driven and the market trend toward more-polluting light trucks, a category that includes sports utility vehicles (SUVs). As a result, cars and light trucks are still the largest single source of air pollution in most urban areas, accounting for one quarter of emissions of smog-forming pollutants nationwide.

5.2: Ingredients of Vehicular Pollution

The following are the major pollutants associated with motor vehicles:

• Ozone (O_3): The primary ingredient in urban smog, ozone is created when hydrocarbons and nitrogen oxides (NO_x)—both of which are chemicals released by automobile fuel combustion—react with sunlight. Though beneficial in the upper atmosphere, at the ground level ozone can irritate the respiratory system, causing coughing, choking, and reduced lung capacity.

• Particulate Matter (PM): These particles of soot, metals, and pollen give smog its murky color. Among vehicular pollution, fine particles (those less than one-tenth the diameter of a human hair) pose the most serious threat to human health by penetrating deep into lungs. In addition to direct emissions of fine particles, automobiles release nitrogen oxides, hydrocarbons, and sulfur dioxide, which generate additional fine particles as secondary pollution.

• Nitrogen oxides (NO_x): These vehicular pollutants can cause lung irritation and weaken the body's defenses against respiratory infections such as pneumonia and influenza. In addition, they assist in the formation of ozone and particulate matter. In many cities, NO_x pollution accounts for one-third of the fine particulate pollution in the air.

• Carbon monoxide (CO): This odorless, colorless gas is formed by the combustion of fossil fuels such as gasoline. Cars and trucks are the source of nearly two-thirds of this pollutant. When inhaled, CO blocks the transport of oxygen to the brain, heart, and other vital organs in the human body. Newborn children and people with chronic illnesses are especially susceptible to the effects of CO.

• Sulfur dioxide (SO_2): Motor vehicles create this pollutant by burning sulfur-containing fuels, especially diesel. It can react in the atmosphere to form fine particles and can pose a health risk to young children and asthmatics.

• Hazardous air pollutants (toxics): These chemical compounds, which are emitted by cars, trucks, refineries, gas pumps, and related sources, have been linked to birth defects, cancer, and other serious illnesses. The EPA estimates that the air toxics emitted from cars and trucks account for half of all cancers caused by air pollution.

• Carbon dioxide (CO_2): is produced by oxidation of carbon compounds; that is, all combustion, all respiration, and all slow oxidative decay of vegetable matter produce CO_2. The world's oceans absorb CO_2 as carbonate, and plant photosynthesis removes CO_2 from the air. However, these natural phenomena have not kept pace with the steadily increasing concentration of CO_2 in the air, even though increasing CO_2 concentrations increases the rate of photosynthesis somewhat in accordance with the Law of Mass Action. Fossil fuel combustion for electrical production and for transportation appears to be the greatest contributors to increased CO_2concentration.

5.3: Vehicular Emissions That Contribute to Global Warming

Carbon monoxide, ozone, particulate matter, Carbon dioxide (CO_2) and the other forms of pollution listed above can cause smog and other air quality concerns, but there are vehicular emissions that contribute to a completely different pollution issue: global warming. The gases that contribute to global warming are related to the chemical composition of the Earth's atmosphere. Some of the gases in the atmosphere function like the panes of a greenhouse.

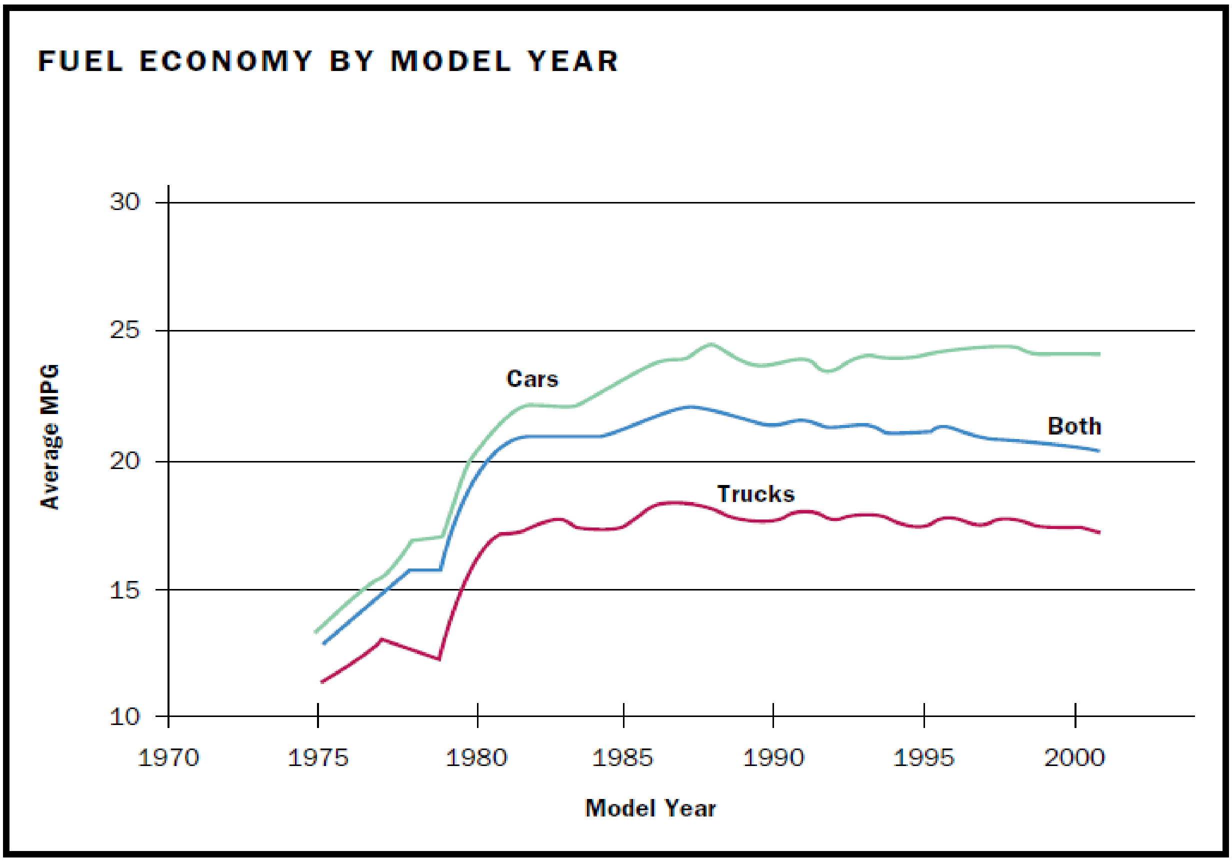
They let some radiation (heat) in from the sun but do not let it all back out, thereby helping to keep the Earth warm. The past century has seen a dramatic increase in the atmospheric concentration of heat-trapping gasses, due to human activity. If this trend continues, scientists project that the earth's average surface temperature will increase between 2.5°F and 10.4°F by the year 2100.

One of these important heat-trapping gasses is carbon dioxide (CO_2). Motor vehicles are responsible for almost one-quarter of annual U.S. emissions of CO_2. The

U.S. transportation sector emits more CO_2 than all but three other countries' emissions from all sources combined.

5.4: Curbing Vehicular Pollution

Vehicular emissions that contribute to air quality problems, smog, and global warming can be reduced by putting better pollution-control technologies on cars and trucks, burning less fuel, switching to cleaner fuels, using technologies that reduce or eliminate emissions, and reducing the number of vehiclemiles traveled.



5.5: Pollution Control Technology:

Federal and California regulations require the use of technologies that have dramatically reduced the amount of smog-forming pollution and carbon monoxide coming from a vehicle's tailpipe. For gasoline vehicles, "three-way" catalysts, precise engine and fuel controls, and evaporative emission controls have been quite successful.

More advanced versions of these technologies are in some cars and can reduce smog-forming emissions from new vehicles by a factor of ten. For diesel vehicles, "two-way" catalysts and engine controls have been able to reduce hydrocarbon and carbon monoxide emissions, but nitrogen oxide and toxic particulate-matter emissions remain very high.

More advanced diesel-control technologies are under development, but it is unlikely that they will be able to clean up diesel to the degree already achieved in the cleanest gasoline vehicles. Added concerns surround the difference between new vehicle emissions and the emissions of a car or truck over a lifetime of actual use.

Vehicles with good emission-control technology that is not properly maintained can become "gross polluters" that are responsible for a significant amount of existing air-quality problems. New technologies have also been developed to identify emission-equipment control failures, and can be used to help reduce the "gross polluter" problem.

5.5.1: *Burning Less Fuel*:

The key to burning less fuel is making cars and trucks more efficient and putting that efficiency to work in improving fuel economy. The U.S. federal government sets a fuel-economy standard for all passenger vehicles. However, these standards have remained mostly constant for the past decade. In addition, sales of lower-fuel-economy light trucks, such as SUVs (Sports utility vehicles), pickups, and minivans, have increased dramatically. As a result, on average, the U.S. passenger-vehicle fleet actually travels less distance on a gallon of gas than it did twenty years ago. This has led to an increase in heat-trapping gas emissions from cars and trucks and to an increase in smog-forming and toxic emissions resulting from the production and transportation of gasoline to the fuel pump.

This trend can be reversed with existing technologies that help cars and trucks go farther on a gallon of gasoline. These include more efficient engines and transmissions, improved aerodynamics, better tires, and high strength steel and aluminum. More advanced technologies, such as hybrid-electric vehicles that use a gasoline engine and an electric motor plus a battery, can cut fuel use even further.

These technologies carry with them additional costs, but pay for themselves through savings at the gasoline pumps.

5.5.2: *Zero-Emission Vehicles*:

As more cars and trucks are sold and total annual mileage increases, improving pollution-control technology and burning less fuel continues to be vital, especially in rapidly growing urban areas. However, eliminating emissions from the tailpipe goes even further to cut down on harmful air pollutants. Hydrogen fuel cell and electric vehicles move away from burning fuel and use electrochemical processes instead to produce the needed energy to drive a car down the road. Fuel-cell vehicles run on electricity that is produced directly from the reaction of hydrogen and oxygen. The only byproduct is water, which is why fuel-cell cars and trucks are called zero-emission vehicles.

Electric vehicles store energy in an onboard battery, emitting nothing from the tailpipe. The hydrogen for the fuel cell and the electricity for the battery must still be produced somewhere, so there will still be upstream emissions associated with these vehicles. These stationary sources, however, are easier to control and can ultimately be converted to use wind, solar, and other renewable energy sources to come as close as possible to true zero-emission vehicles.

5.5.3: *Cleaner Fuels*:

The gasoline and diesel fuel in use today contains significant amounts of sulfur and other compounds that make it harder for existing control technology to keep vehicles clean. Removing the sulfur from the fuel and cutting down on the amount of light hydrocarbons helps pollution-control technology to work better and cuts down on evaporative and refueling emissions.

Further large-scale reductions of other tailpipe pollution and CO_2 can be accomplished with a shift away from conventional fuels. Alternative fuels such as natural gas, methanol, ethanol, and hydrogen can deliver benefits to the environment while helping to move the United States away from its dependence on oil. All of these fuels inherently burn cleaner than diesel and gasoline, and they have lower carbon content resulting in less CO_2.

Most of these fuels are also more easily made from renewable resources, and fuels such as natural gas and methanol help provide a bridge to producing hydrogen for fuel cell vehicles.

5.5.4: *Reducing Driving*:

Because we are still dependent on fossil fuels and the number of cars on the road is expected to double, a significant reduction in vehicular pollution requires more than gains in fuel efficiency. Measures that encourage us to drive less can help curb vehicular pollution and protect natural resources and public health. Alternatives that can reduce the number of vehicle-miles traveled include

- providing transportation alternatives to cars, including mass transit, bicycle, and pedestrian routes;
- promoting transit-oriented, compact developments in and around cities and towns; and adopting policies to improve existing roads and infrastructure.

5.5.5: *Personal Contributions*:

Individuals can also make a difference in the effort to reduce pollution from cars and trucks. How we drive and how we take care of our vehicles affects fuel economy and pollution emissions. The following are several ways people can reduce the harmful environmental impact of cars.

- Driving as little as possible is the best way to reduce the harmful environmental impact of transportation needs. Carpooling, mass transit, biking, and walking are ways to limit the number of miles we drive. Choosing a place to live that reduces the need to drive is another way.
- Driving moderately, avoiding high-speed driving, frequent stopping, and starting can reduce both fuel use and pollutant emissions.

- Simple vehicle maintenance—such as regular oil changes, air-filter changes, and spark plug replacements—can lengthen the life of your car as well as improve fuel economy and minimize emissions.
- Keeping tires properly inflated saves fuel by reducing the amount of drag a car's engine must overcome.
- During start-up, a car's engine burns extra gasoline. However, letting an engine idle for more than a minute burns more fuel than turning off the engine and restarting it.
- During warm periods with strong sunlight, parking in the shade keeps a car cooler and can minimize the evaporation of fuel.

5.6: Control of Carbon Dioxide:

Carbon dioxide (CO_2) could be scrubbed from power plant effluent gas by alkaline solution and fixed as carbonate, but this relatively inefficient process would require large quantities of scrubber solution and would produce very large amounts of carbonate. The current approach to CO_2 emission reduction is substitution of other electrical generating sources for fossil fuel combustion.

Nuclear, hydroelectric, solar, and wind generation do not produce CO_2, although, like all energy conversion methods, all have some adverse environmental impacts. Hydroelectric and wind generation are limited by the finite number of physical locations where they can be implemented. Nuclear power generation produces radioactive waste, even with reprocessing of fissile materials, and solar power is relatively inefficient and requires a very large land area. Biomass combustion produces CO_2.

Energy conservation is an obvious method for reducing CO_2. It produces no effluent at all, but significantly limiting CO_2 emission by energy conservation alone would require more than voluntary conservation and could result in considerable lifestyle and social changes.

A discussion of non-fossil-fuel energy conversion methods is beyond the scope of this text. However, we may expect to see increased utilization of such methods in the coming century.

5.7: Control of Moving Sources:

Mobile sources pose special pollution control problems, and one such source, the automobile, has received particular attention in air pollution control. Pollution control for other mobile sources, such as light-duty trucks, heavy trucks, and diesel engine-driven vehicles, requires controls similar to those used for control of automobile emissions.

The important pollution control points in an automobile are shown in Figure 1, and are:

• Evaporation of hydrocarbons (HC) from the fuel tank,

• Evaporation of HC from the carburetor,

• Emission of unburned gasoline and partly oxidized HC from the crankcase, and

• CO, HC and NO/NO_2 from the exhaust.

Evaporative losses from the gas tank and carburetor often occur when the engine has been turned off and hot gasoline in the carburetor evaporates. These vapors may be trapped in an activated-carbon canister, and can be purged periodically with air, and then burned in the engine, as shown schematically in Figure (2). The crankcase vent can be closed off from the atmosphere, and the blowby gases recycled into the intake manifold. The positive crankcase ventilation (PCV) valve is a small check valve that prevents buildup of pressure in the crankcase.

The exhaust accounts for about 60% of the emitted hydrocarbons and almost all of the NO, CO, and lead, and poses the most difficult control problem of mobile sources. Exhaust emissions depend on the engine operation, as is shown in Table (1). During acceleration, the combustion is efficient, CO and HC are low, and high compression produces a lot of NO/NO_2. On the other hand, deceleration results in low NO/NO_2 and high HC because of the presence of unburned fuel in the exhaust. This variation in emissions has prompted EPA to institute a standard acceleration deceleration cycle for measuring emissions. Testing proceeds from a cold start through acceleration, cruising at constant speeds (on a dynamometer in order to load the engine), deceleration, and a hot start.

Emission control techniques include engine tune-ups, engine modifications, exhaust gas recirculation, and catalytic reactors. A well-tuned engine is the first line of defense for emission control.

A wide range of acceptable engine modifications is possible. Injection of water can reduce NO emissions, and fuel injection (bypassing or eliminating the carburetor) can reduce CO and HC emissions. Fuel injection is not compatible with water injection, however, since water may clog the fuel injectors. The stratified charge engine operates on a very lean air/fuel mixture, thus reducing CO and HC, but does not increase NO appreciably. The two compartments of the engine (the "stratification") accomplish this result: the first compartment receives and ignites the air/fuel mixture, and the second compartment provides a broad flame for an efficient bum. Better than 90% CO reduction can be achieved by this engine.

Recirculating the exhaust gas through the engine can achieve about 60% reduction of CO and hydrocarbons. The only major modification to an ordinary engine required by exhaust gas recirculation (EGR), in addition to the necessary fittings, is a system for cooling the exhaust gas before recirculating it, to avoid heat deformation of the piston surfaces. Exhaust gas recirculation, although it increased the rate of engine wear, was a popular and acceptable emission control method until 1980, but present-day exhaust emission standards require 90% CO control, which cannot be realized by this method.

New cars sold in the United States since 1983 have required the use of a catalytic reactor ("catalytic converter") to meet exhaust emission standards, and the device is now standard equipment on new cars. The modem three-stage catalytic converter performs two functions: oxidation of CO and hydrocarbons to CO_2 and water, and reduction of NO to N_2. A platinum-rhodium catalyst is used, and reduction of NO is accomplished in the first stage by burning a fuel-rich mixture, thereby depleting the oxygen at the catalyst. Air is then introduced in the second stage, and CO and hydrocarbons are oxidized at a lower temperature. Catalytic converters are rendered inoperable by inorganic lead compounds, so that cars using catalytic converters require the use of unleaded gasoline. Catalytic converters require periodic maintenance.

Diesel engines produce the same three major pollutants as gasoline engines, although in somewhat different proportions. In addition, diesel-powered heavy-duty vehicles produce annoying black soot, essentially unburned carbon. Control of diesel exhaust was not required in the United States until passage of the 1990 Clean Air Act (nor is it required anywhere else in the world), and therefore little research on diesel exhaust emission control has reached the stage of operational devices.

Drastic lowering of emissions to produce a virtually pollution-free engine would require an external combustion engine, which can achieve better than 99% control of all three major exhaust pollutants. However, although work began in 1968 on a mobile external combustion engine, a working model has yet to be built. A working model requires a working fuel “steam” that is not flammable but has a lower heat capacity than water, and a linkage between the working fuel and the burning fuel that would allow the rapid acceleration characteristic of an external combustion engine-powered cars.

Natural gas may be used to fuel cars, but the limited supply of natural gas serves a number of competing uses. In addition to a steady supply, a changeover would require a refueling system different from that used for gasoline. Electric cars are clean, but can store only limited power and have limited range. Generation of the electricity to power such cars also generates pollution, and the world’s supply of battery materials would be strained to provide for a changeover to electric cars. The “hybrid” gasoline/electric automobiles introduced in 2001 use the engine to charge the electric motor. The 1990 Clean Air Act requires that cities in violation of the National Ambient Air Quality Standards sell *oxygenated fuel* during the winter months. Oxygenated fuel is gasoline containing 10% ethanol (CH_3CH_2OH) and is intended to bring about somewhat more efficient conversion of CO to CO_2. Its efficacy in cleaning up urban air remains to be seen.

5.8 CONTROL OF GLOBAL CLIMATE CHANGE

The two types of compounds involved in global climate change are those that produce free halogen atoms by photochemical reaction, and thus deplete the stratospheric ozone layer, and those that absorb energy in the near-infrared spectral region, which may ultimately produce global temperature change. The first group is comprised mostly of chlorofluorocarbons. Control of chlorofluorocarbon emission involves control of leaks, as from refrigeration systems, and eliminating use of the substances. While chlorofluorocarbon aerosol propellants are useful and convenient, they are not necessary for most applications. Aerosol deodorant, cleaners, paint, hairspray, and so on can be replaced by roll-on deodorant, wipe-on cleaners, rolled-on paint, hair mousse, etc. In many applications, atomized liquids appear to work as well as aerosolized liquids.

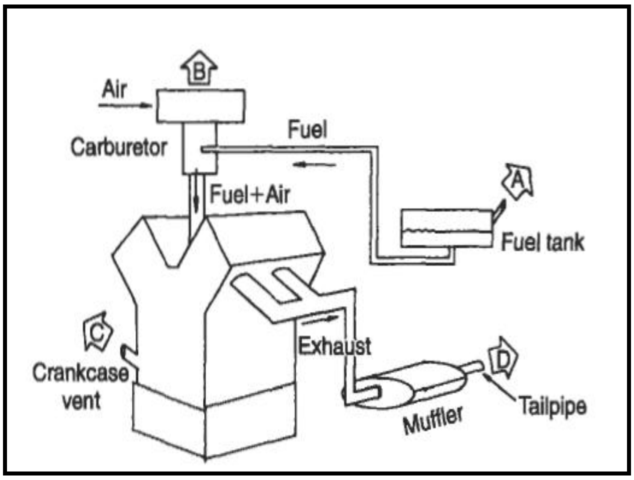


Figure (5.1): Internal combustion engine showing four major emission points

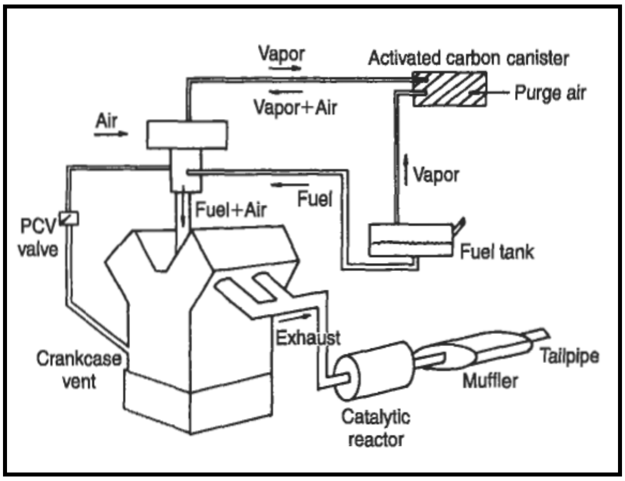


Figure (5.2): Internal combustion engine showing methods of controlling emissions

Table (5.1): Effect of Engine Operation on Exhaust Emissions, Shown as Fractions on Emissions at Idle

	CO	**HC**	**NO/NO_2**
Idling	1.0	1.0	1.0
Accelerating	0.6	0.4	100.0
Cruising	0.6	0.3	66.0
Decelerating	0.6	11.4	1.0

General Questions about Mobile Source Pollution

1. What are the factors that air pollutants emitted from mobile source depending on?
2. How mobile source can contributes to air pollution? Explain in brief.
3. Distinguish between the pollution resulting from the tailpipes and motor vehicles.
4. What are the ingredients of vehicular pollution?
5. Explain the effect of the following pollutants on the air:
   a. O_3 ***b.*** PM ***c.*** NO_x ***d.*** CO ***e.*** SO_2 ***f.*** Toxics ***g.*** CO_2
6. How can the vehicular emissions contribute global warming? Explain in detail.
7. How can be reducing the vehicular emissions that contribute to air quality problems?
8. List with explain the ways of pollution control technology to reduce the amount of pollutants for: ***a.*** Gasoline vehicles ***b.*** Diesel vehicles
9. What are the new technologies that can be used to help reduce the gross polluter problem?
10. What are the existing technologies that help cars and trucks go farther on a gallon gasoline?
11. What is the meaning of Zero- Emission Vehicles?
12. What are the ways by which people can reduce the harmful environmental impact of cars?
13. How can we control CO_2?
14. What are the important pollution control points in an automobile? List it with drawing.
15. How can we control the global climate change?
16. Define: ***Primary Pollution***, ***Secondary Pollution*** and ***Global Warming***.