

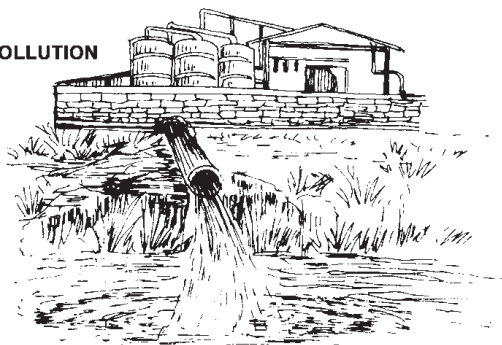
**UNIT 5:**  
**Pollution**

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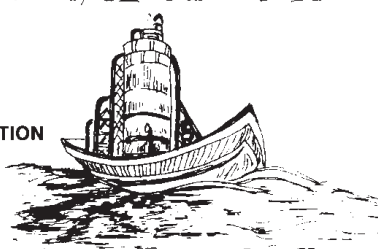
**AIR POLLUTION**



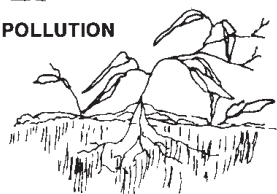
**WATER POLLUTION**



**OIL POLLUTION**



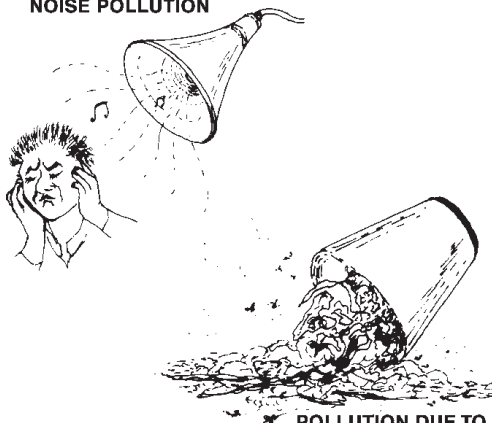
**SOIL POLLUTION**



**LOSS OF RENEWABLE RESOURCES**



**NOISE POLLUTION**



**POLLUTION DUE TO GARBAGE**

'We spray our elms, and the following spring, trees are silent of robin song, not because we sprayed the robins directly but because the poison traveled step by step through the now familiar elm-earthworm-robin cycle'

– Rachael Carson

book has inspired controversy and has initiated a major change in thinking about the safety of using pesticides and other toxic chemicals.

## 5.1 DEFINITION

*Pollution* is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings. This occurs

This quotation appeared in Rachael Carson's book entitled *Silent Spring*. In the years following the publication of *Silent Spring* in 1962, the

when only short-term economic gains are made at the cost of the long-term ecological benefits for humanity. No natural phenomenon has led to greater ecological changes than have been made by mankind. During the last few decades we have contaminated our air, water and land on which life itself depends with a variety of waste products.

Pollutants include solid, liquid or gaseous substances present in greater than natural abundance produced due to human activity, which have a detrimental effect on our environment. The nature and concentration of a pollutant determines the severity of detrimental effects on human health. An average human requires about 12 kg of air each day, which is nearly 12 to 15 times greater than the amount of food we eat. Thus even a small concentration of pollutants in the air becomes more significant in comparison to the similar levels present in food. Pollutants that enter water have the ability to spread to distant places especially in the marine ecosystem.

From an ecological perspective pollutants can be classified as follows:

**Degradable or non-persistent pollutants:** These can be rapidly broken down by natural processes. Eg: domestic sewage, discarded vegetables, etc.

**Slowly degradable or persistent pollutants:** Pollutants that remain in the environment for many years in an unchanged condition and take decades or longer to degrade. Eg: DDT and most plastics.

**Non-degradable pollutants:** These cannot be degraded by natural processes. Once they are released into the environment they are difficult to eradicate and continue to accumulate. Eg: toxic elements like lead or mercury.

## 5.2 CAUSES, EFFECTS AND CONTROL MEASURES OF POLLUTION

### 5.2.1 Air Pollution

**History of air pollution:** The origin of air pollution on the earth can be traced from the times when man started using firewood as a means of cooking and heating. Hippocrates has mentioned air pollution in 400 BC. With the discovery and increasing use of coal, air pollution became more pronounced especially in urban areas. It was recognized as a problem 700 years ago in London in the form of smoke pollution, which prompted King Edward I to make the first antipollution law to restrict people from using coal for domestic heating in the year 1273. In the year 1300 another Act banning the use of coal was passed. Defying the law led to imposition of capital punishment. In spite of this air pollution became a serious problem in London during the industrial revolution due to the use of coal in industries. The earliest recorded major disaster was the 'London Smog' that occurred in 1952 that resulted in more than 4000 deaths due to the accumulation of air pollutants over the city for five days.

In Europe, around the middle of the 19<sup>th</sup> century, a black form of the Peppered moth was noticed in industrial areas. Usually the normal Peppered moth is well camouflaged on a clean lichen covered tree. However the peppered pattern was easily spotted and picked up by birds on the smoke blackened bark of trees in the industrial area, while the black form remained well camouflaged. Thus while the peppered patterned moths were successful in surviving in clean non-industrial areas, the black coloured moths were successful in industrial areas. With the spread of industrialization, it has been observed that the black forms are not only seen in Peppered moth, but also in many other moths. This is a classic case of pollution leading to adaptation.

Air pollution began to increase in the beginning of the twentieth century with the development of the transportation systems and large-scale use of petrol and diesel. The severe air quality problems due to the formation of photochemical smog from the combustion residues of diesel and petrol engines were felt for the first time in Los Angeles. Pollution due to auto-exhaust remains a serious environmental issue in many developed and developing countries including India.

The Air Pollution Control Act in India was passed in 1981 and the Motor Vehicle Act for controlling the air pollution, very recently. These laws are intended to prevent air from being polluted.

The greatest industrial disaster leading to serious air pollution took place in Bhopal where extremely poisonous methyl isocyanide gas was accidentally released from the Union Carbide's pesticide manufacturing plant on the night of December 3<sup>rd</sup> 1984. The effects of this disaster on human health and the soil are felt even today.

## Structure of the atmosphere

The atmosphere is normally composed of 79 percent nitrogen, 20 percent oxygen and one percent as a mixture of carbon dioxide, water vapour and trace amounts of several other gases such as neon, helium, methane, krypton, hydrogen and xenon. The general structure of the atmosphere has several important features that have relevance to environmental problems. The atmosphere is divided into several layers.

The innermost layer the *troposphere* extends 17 kilometers above sea level at the equator and about 8 kilometers over the poles. It contains about 75 percent of the mass of the earth's air. The fragility of this layer is obvious from the fact that if the earth were an apple this particular layer would be no thicker than an apple's skin.

Temperature declines with altitude in the troposphere. At the top of the troposphere temperatures abruptly begin to rise. This boundary where this temperature reversal occurs is called the tropopause.

The tropopause marks the end of the troposphere and the beginning of the *stratosphere*, the second layer of the atmosphere. The stratosphere extends from 17 to 48 kilometers above the earth's surface. While the composition of the stratosphere is similar to that of the troposphere it has two major differences. The volume of water vapour here is about 1000 times less while the volume of ozone is about 1000 times greater. The presence of ozone in the stratosphere prevents about 99 percent of the sun's harmful ultraviolet radiation from reaching the earth's surface thus protecting humans from cancer and damage to the immune system. This layer does not have clouds and hence airplanes fly in this layer as it creates less turbulence. Temperature rises with altitude in the stratosphere until there is another reversal. This point is called the stratopause and it marks the end of the stratosphere and the beginning of the atmosphere's next layer, the mesosphere.

In the *mesosphere* the temperature decreases with altitude falling up to  $-110^{\circ}\text{C}$  at the top. Above this is a layer where ionization of the gases is a major phenomenon, thus increasing the temperature. This layer is called the *thermosphere*. Only the lower troposphere is routinely involved in our weather and hence air pollution. The other layers are not significant in determining the level of air pollution.

## Types and sources of Air Pollution

### What is air pollution?

Air pollution occurs due to the presence of undesirable solid or gaseous particles in the air in quantities that are harmful to human health and the environment. Air may get polluted by natu-

ral causes such as volcanoes, which release ash, dust, sulphur and other gases, or by forest fires that are occasionally naturally caused by lightning. However, unlike pollutants from human activity, naturally occurring pollutants tend to remain in the atmosphere for a short time and do not lead to permanent atmospheric change.

Pollutants that are emitted directly from identifiable sources are produced both by natural events (for example, dust storms and volcanic eruptions) and human activities (emission from vehicles, industries, etc.). These are called *primary pollutants*. There are five primary pollutants that together contribute about 90 percent of the global air pollution. These are carbon oxides (CO and CO<sub>2</sub>), nitrogen oxides, sulfur oxides, volatile organic compounds (mostly hydrocarbons) and suspended particulate matter.

Pollutants that are produced in the atmosphere when certain chemical reactions take place among the primary pollutants are called *secondary pollutants*. Eg: sulfuric acid, nitric acid, carbonic acid, etc.

*Carbon monoxide* is a colourless, odorless and toxic gas produced when organic materials such as natural gas, coal or wood are incompletely burnt. Vehicular exhausts are the single largest source of carbon monoxide. The number of vehicles has been increasing over the years all over the world. Vehicles are also poorly maintained and several have inadequate pollution control equipment resulting in release of greater amounts of carbon monoxide. Carbon monoxide is however not a persistent pollutant. Natural processes can convert carbon monoxide to other compounds that are not harmful. Therefore the air can be cleared of its carbon monoxide if no new carbon monoxide is introduced into the atmosphere.

*Sulfur oxides* are produced when sulfur containing fossil fuels are burnt.

*Nitrogen oxides* are found in vehicular exhausts. Nitrogen oxides are significant, as they are involved in the production of secondary air pollutants such as ozone.

*Hydrocarbons* are a group of compounds consisting of carbon and hydrogen atoms. They either evaporate from fuel supplies or are remnants of fuel that did not burn completely. Hydrocarbons are washed out of the air when it rains and run into surface water. They cause an oily film on the surface and do not as such cause a serious issue until they react to form secondary pollutants. Using higher oxygen concentrations in the fuel-air mixture and using valves to prevent the escape of gases, fitting of catalytic converters in automobiles, are some of the modifications that can reduce the release of hydrocarbons into the atmosphere.

*Particulates* are small pieces of solid material (for example, smoke particles from fires, bits of asbestos, dust particles and ash from industries) dispersed into the atmosphere. The effects of particulates range from soot to the carcinogenic (cancer causing) effects of asbestos, dust particles and ash from industrial plants that are dispersed into the atmosphere. Repeated exposure to particulates can cause them to accumulate in the lungs and interfere with the ability of the lungs to exchange gases.

*Lead* is a major air pollutant that remains largely unmonitored and is emitted by vehicles. High lead levels have been reported in the ambient air in metropolitan cities. Leaded petrol is the primary source of airborne lead emissions in Indian cities.

Pollutants are also found indoors from infiltration of polluted outside air and from various chemicals used or produced inside buildings. Both indoor and outdoor air pollution are equally harmful.

Types of particulates

Term	Meaning	Examples
Aerosol	General term for particles suspended in air	Sprays from pressurized cans
Mist	Aerosol consisting of liquid droplets	Sulfuric acid mist
Dust	Aerosol consisting of solid particles that are blown into the air or are produced from larger particles by grinding them down	Dust storm
Smoke	Aerosol consisting of solid particles or a mixture of solid and liquid particles produced by chemical reaction such as fires	Cigarette smoke, smoke from burning garbage
Fume	Generally means the same as smoke but often applies specifically to aerosols produced by condensation of hot vapors of metals.	Zinc/lead fumes
Plume	Geometrical shape or form of the smoke coming out of a chimney	
Fog	Aerosol consisting of water droplets	
Smog	Term used to describe a mixture of smoke and fog.	

What happens to pollutants in the atmosphere?

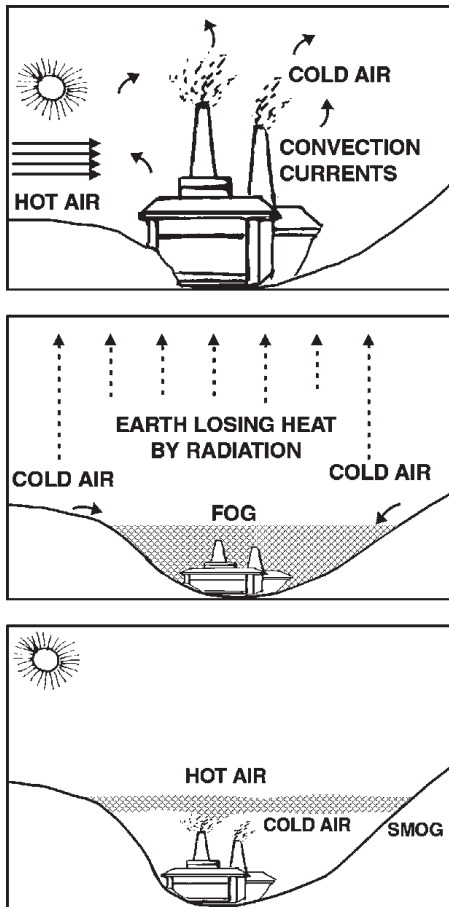
Once pollutants enter the troposphere they are transported downwind, diluted by the large volume of air, transformed through either physical or chemical changes or are removed from the atmosphere by rain during which they are attached to water vapour that subsequently forms rain or snow that falls to the earth’s surface. The atmosphere normally disperses pollutants by mixing them in the very large volume of air that covers the earth. This dilutes the pollutants to acceptable levels. The rate of dispersion however varies in relation to the following aspects:

Topography

Normally as the earth’s surface becomes warmed by sunlight the layer of air in contact with the ground is also heated by convection. This warmer air is less dense than the cold air above it, so it rises. Thus pollutants produced in the surface layer are effectively dispersed.

However on a still evening, the process is reversed. An hour or two before sunset after a sunny day, the ground starts to lose heat and the air near the ground begins to cool rapidly. Due to the absence of wind, a static layer of cold air is produced as the ground cools. This in turn induces condensation of fog. The morning sun cannot initially penetrate this fog layer. The

cold air being dense cannot rise and is trapped by the warm air above. It cannot move out of the area due to the surrounding hills. The topographic features resemble a closed chemical reactor in which the pollutants are trapped. This condition often continues through the cool night and reaches its maximum intensity before sunrise. When the morning sun warms the ground the air near the ground also warms up and rises within an hour or two. This may be broken up by strong winds. In cold regions this situation can persist for several days. Such a situation is known as smog (smoke + fog).

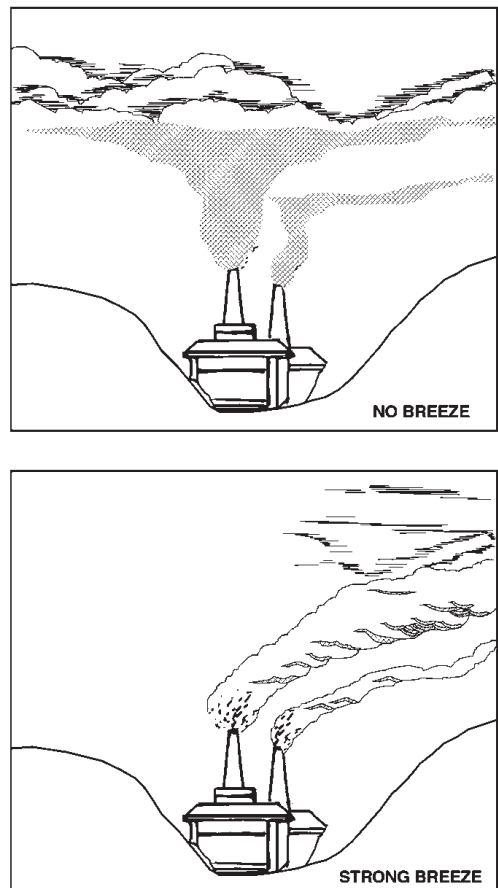


The most well known example is that of the 'London Smog' that occurred in 1952. The city used large quantities of sulphur containing coal for domestic heating that released smoke, along with smoke from thermal power plants and

other industrial establishments. This used to lead to the generation of high levels of smoke containing sulphur oxides. Due to a sudden adverse meteorological condition air pollutants like smoke and sulphur oxides started to build-up in the atmosphere. The white fog accumulated over the city turned black forming a 'pea-soup' smog with almost zero visibility. Within two days of the formation of this smog, people started suffering from acute pulmonary disorders which caused irritation of bronchi, cough, nasal discharges, sore throat, vomiting and burning sensations in the eyes. This event lead to several deaths.

#### *Meteorological conditions*

The velocity of the wind affects the dispersal of pollutants. Strong winds mix polluted air more rapidly with the surrounding air diluting the pollutants rapidly. When wind velocity is low mixing takes place and the concentration of pollutants remains high.





When sulphur dioxide and nitrogen oxides are transported by prevailing winds they form secondary pollutants such as nitric acid vapour, droplets of sulfuric acid and particles of sulphate and nitrate salts. These chemicals descend on the earth's surface in two forms: wet (as acidic rain, snow, fog and cloud vapour) and dry (as acidic particles). The resulting mixture is called acid deposition, commonly called *acid rain*.

Acid deposition has many harmful effects especially when the pH falls below 5.1 for terrestrial systems and below 5.5 for aquatic systems. It contributes to human respiratory diseases such as bronchitis and asthma, which can cause premature death. It also damages statues, buildings, metals and car finishes. Acid deposition can damage tree foliage directly but the most serious effect is weakening of trees so they become more susceptible to other types of damage. The nitric acid and the nitrate salts in acid deposition can lead to excessive soil nitrogen levels. This can over stimulate growth of other plants and intensify depletion of other important soil nutrients such as calcium and magnesium, which in turn can reduce tree growth and vigour.

### **Effects of air pollution on living organisms**

Our respiratory system has a number of mechanisms that help in protecting us from air pollution. The hair in our nose filters out large particles. The sticky mucus in the lining of the upper respiratory tract captures smaller particles and dissolves some gaseous pollutants. When the upper respiratory system is irritated by pollutants sneezing and coughing expel contaminated air and mucus. Prolonged smoking or exposure to air pollutants can overload or breakdown these natural defenses causing or contributing to diseases such as lung cancer, asthma, chronic bronchitis and emphysema. Elderly people, infants, pregnant women and people with heart disease, asthma or other res-

piratory diseases are especially vulnerable to air pollution.

Cigarette smoking is responsible for the greatest exposure to carbon monoxide. Exposure to air containing even 0.001 percent of carbon monoxide for several hours can cause collapse, coma and even death. As carbon monoxide remains attached to hemoglobin in blood for a long time, it accumulates and reduces the oxygen carrying capacity of blood. This impairs perception and thinking, slows reflexes and causes headaches, drowsiness, dizziness and nausea. Carbon monoxide in heavy traffic causes headaches, drowsiness and blurred vision.

Sulfur dioxide irritates respiratory tissues. Chronic exposure causes a condition similar to bronchitis. It also reacts with water, oxygen and other material in the air to form sulfur-containing acids. The acids can become attached to particles which when inhaled are very corrosive to the lung.

Nitrogen oxides especially NO<sub>2</sub> can irritate the lungs, aggravate asthma or chronic bronchitis and also increase susceptibility to respiratory infections such as influenza or common colds.

Suspended particles aggravate bronchitis and asthma. Exposure to these particles over a long period of time damages lung tissue and contributes to the development of chronic respiratory disease and cancer.

Many volatile organic compounds such as (benzene and formaldehyde) and toxic particulates (such as lead, cadmium) can cause mutations, reproductive problems or cancer. Inhaling ozone, a component of photochemical smog causes coughing, chest pain, breathlessness and irritation of the eye, nose and the throat.



## Effects on plants

When some gaseous pollutants enter leaf pores they damage the leaves of crop plants. Chronic exposure of the leaves to air pollutants can break down the waxy coating that helps prevent excessive water loss and leads to damage from diseases, pests, drought and frost. Such exposure interferes with photosynthesis and plant growth, reduces nutrient uptake and causes leaves to turn yellow, brown or drop off altogether. At a higher concentration of sulphur dioxide majority of the flower buds become stiff and hard. They eventually fall from the plants, as they are unable to flower.

Prolonged exposure to high levels of several air pollutants from smelters, coal burning power plants and industrial units as well as from cars and trucks can damage trees and other plants.

## Effects of air pollution on materials

Every year air pollutants cause damage worth billions of rupees. Air pollutants break down exterior paint on cars and houses. All around the world air pollutants have discoloured irreplaceable monuments, historic buildings, marble statues, etc.

## Effects of air pollution on the stratosphere

The upper stratosphere consists of considerable amounts of ozone, which works as an effective screen for ultraviolet light. This region called the ozone layer extends up to 60 kms above the surface of the earth. Though the ozone is present upto 60 kms its greatest density remains in the region between 20 to 25 kms. The ozone layer does not consist of solely ozone but a mixture of other common atmospheric gases. In the most dense ozone layer there will be only one ozone molecule in 100,000 gas molecules. Therefore even small changes in the ozone con-

centration can produce dramatic effects on life on earth.

The total amount of ozone in a 'column' of air from the earth's surface upto an altitude of 50 km is the *total column ozone*. This is recorded in *Dobson Units (DU)*, a measure of the thickness of the ozone layer by an equivalent layer of pure ozone gas at normal temperature and pressure at sea level. This means that 100 DU=1mm of pure ozone gas at normal temperature and pressure at sea level.

Ozone is a form of oxygen with three atoms instead of two. It is produced naturally from the photodissociation of oxygen gas molecules in the atmosphere. The ozone thus formed is constantly broken down by naturally occurring processes that maintain its balance in the ozone layer. In the absence of pollutants the creation and breakdown of ozone are purely governed by natural forces, but the presence of certain pollutants can accelerate the breakdown of ozone. Though it was known earlier that ozone shows fluctuations in its concentrations which may be accompanied sometimes with a little ozone depletion, it was only in 1985 that the large scale destruction of the ozone also called the Ozone Hole came into limelight when some British researchers published measurements about the ozone layer.

Soon after these findings a greater impetus was given to research on the ozone layer, which convincingly established that CFC's were leading to its depletion. These CFCs (chloro-fluorocarbons) are extremely stable, non-flammable, non-toxic and harmless to handle. This makes them ideal for many industrial applications like aerosols, air conditioners, refrigerators and fire extinguishers. Many cans, which give out foams and sprays, use CFCs. (eg: perfumes, room fresheners, etc.) CFCs are also used in making foams for mattresses and cushions, disposable Styrofoam cups, glasses, packaging material for insulation, cold storage etc. However their sta-

bility also gives them a long life span in the atmosphere.

Halons are similar in structure to the CFCs but contain bromine atoms instead of chlorine. They are more dangerous to the ozone layer than CFCs. Halons are used as fire extinguishing agents as they do not pose a harm to people and equipment exposed to them during fire fighting.

The CFCs and the halons migrate into the upper atmosphere after they are released. As they are heavier than air they have to be carried by air currents up to just above the lower atmosphere and then they slowly diffuse into the upper atmosphere. This is a slow process and can take as long as five to fifteen years. In the stratosphere unfiltered UV-radiation severs the chemical bonds releasing chlorine from the rest of the CFC. This attacks the ozone molecule resulting in its splitting into an oxygen molecule and an oxygen atom.

Despite the fact that CFCs are evenly distributed over the globe, the ozone depletion is especially pronounced over the South Pole due to the extreme weather conditions in the Antarctic atmosphere. The presence of the ice crystals makes the Cl-O bonding easier. The ozone layer over countries like Australia, New Zealand, South Africa and parts of South America is also depleted.

India has signed the Montreal Protocol in 1992, which aims to control the production and consumption of Ozone Depleting Substances.

### **Ozone depletion-What does it do?**

Changes in the ozone layer have serious implications for mankind.

**Effects on human health:** Sunburn, cataract, aging of the skin and skin cancer are caused by

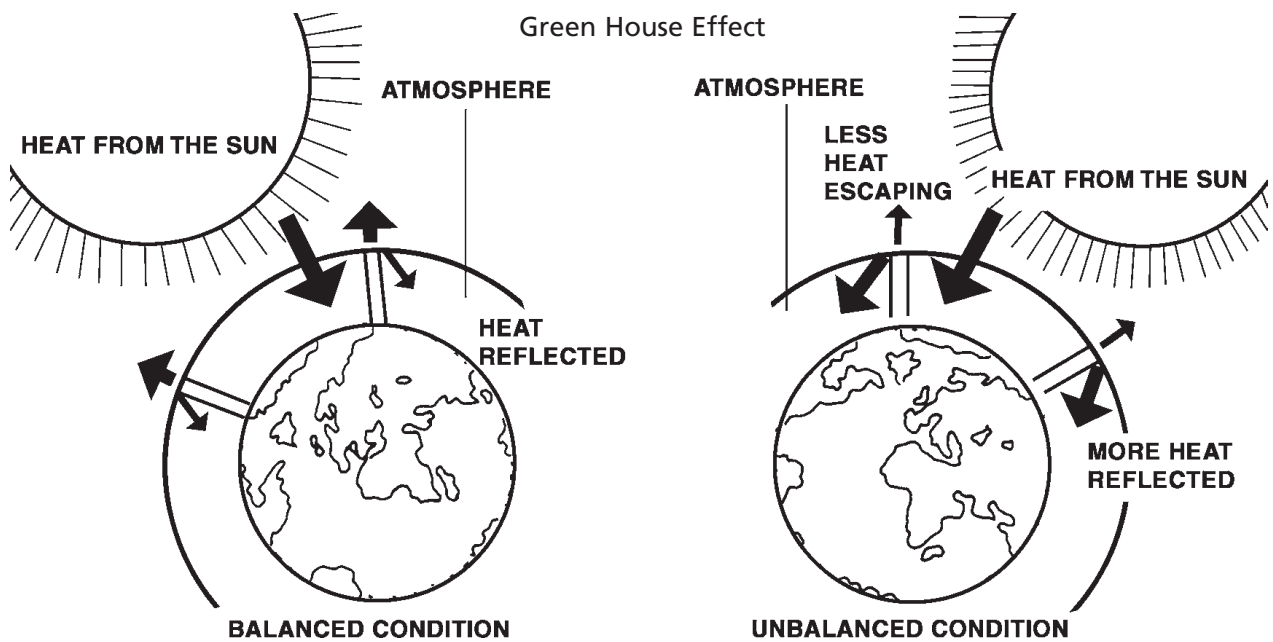
increased ultra-violet radiation. It weakens the immune system by suppressing the resistance of the whole body to certain infections like measles, chicken pox and other viral diseases that elicit rash and parasitic diseases such as malaria introduced through the skin.

**Food production:** Ultra violet radiation affects the ability of plants to capture light energy during the process of photosynthesis. This reduces the nutrient content and the growth of plants. This is seen especially in legumes and cabbage.

Plant and animal planktons are damaged by ultra-violet radiation. In zooplanktons (microscopic animals) the breeding period is shortened by changes in radiation. As planktons form the basis of the marine food chain a change in their number and species composition influences fish and shell fish production.

**Effect on materials:** Increased UV radiation damages paints and fabrics, causing them to fade faster.

**Effect on climate:** Atmospheric changes induced by pollution contribute to global warming, a phenomenon which is caused due to the increase in concentration of certain gases like carbon dioxide, nitrogen oxides, methane and CFCs. Observations of the earth have shown beyond doubt that atmospheric constituents such as water vapour, carbon dioxide, methane, nitrogen oxides and Chloro Fluoro Carbons trap heat in the form of infra-red radiation near the earth's surface. This is known as the '**Greenhouse Effect**'. The phenomenon is similar to what happens in a greenhouse. The glass in a greenhouse allows solar radiation to enter which is absorbed by the objects inside. These objects radiate heat in the form of terrestrial radiation, which does not pass out through the glass. The heat is therefore trapped in the greenhouse increasing the temperature inside and ensuring the luxuriant growth of plants.



There could be several adverse effects of global warming.

- With a warmer earth the polar ice caps will melt causing a rise in ocean levels and flooding of coastal areas.
- In countries like Bangladesh or the Maldives this would be catastrophic. If the sea level rises by 3m., Maldives will disappear completely beneath the waves.
- The rise in temperature will bring about a fall in agricultural produce.
- Changes in the distribution of solar energy can bring about changes in habitats. A previously productive agricultural area will suffer severe droughts while rains will fall in locations that were once deserts. This could bring about changes in the species of natural plants, agricultural crops, insects, livestock and micro-organisms.
- In the polar regions temperature rises caused by global warming would have disastrous effects. Vast quantities of meth-

ane are trapped beneath the frozen soil of Alaska. When the permafrost melts the methane that will be released can accelerate the process of global warming.

### Control measures for air pollution

Air pollution can be controlled by two fundamental approaches: preventive techniques and effluent control.

One of the effective means of controlling air pollution is to have proper equipment in place. This includes devices for removal of pollutants from the flue gases through scrubbers, closed collection recovery systems through which it is possible to collect the pollutants before they escape, use of dry and wet collectors, filters, electrostatic precipitators, etc. Providing a greater height to the stacks can help in facilitating the discharge of pollutants as far away from the ground as possible. Industries should be located in places so as to minimize the effects of pollution after considering the topography and the wind directions. Substitution of raw material that causes more

pollution with those that cause less pollution can be done.

## **Air pollution in India**

The World Health Organization (WHO) which rates only mega cities of the world has rated Delhi the fourth most polluted city in the world. However compared to other cities in India, Delhi is not at the top of the list of polluted cities. Our country has several pollution hotspots. The recent release from the Central Pollution Control Board (CPCB), *Parivesh*, January 2003 states that Ahmedabad's air is most noxious followed by Kanpur, Solapur and Lucknow with small particulate levels (PM<sub>10</sub>) 3-4 times the standard of 60 microgram per cubic meter (mg/m<sup>3</sup>). The report has ranked 29 cities according to Respirable Particulate Matter (RSPM) levels recorded during the year 2000. This report thus confirms the fact that Indian cities show high particulate pollution with 14 cities hitting critical levels.

Nitrogen dioxide levels in most major cities are generally close to the acceptable annual standard of 60 mg/m<sup>3</sup>. However sharp increases have been noticed in a few cities with heavy vehicular traffic and density as in a few locations in Kolkata and Delhi indicating stronger impact of traffic. The CPCB indicates vehicles as one of the predominant sources of air pollution. However the impact of hard measures implemented in Delhi over the last few years such as introduction of Euro II standards, lowering the sulphur content in fuel to 500 ppm and implementing Compressed Natural Gas program has succeeded in improving the quality of air. Rapid urbanization of smaller cities especially those situated near the big commercial centers have an enormous increase in traffic load especially in the most polluted segment such as two and three wheelers and diesel vehicles combined with poor quality fuel contribute to the deteriorating air quality in a big way.

It is alarming to note that residential locations in India are fast outpacing industrial locations in air pollution implying that vehicular fumes are responsible for this trend. The Supreme Court's order of April 5, 2002 has directed the Central Government for an action plan for other polluted cities. Absence of any local initiatives for action and delay in air pollution control measures will only make the situation worse.

The Supreme Court also played a vital role protecting the Taj Mahal. Being exposed to sulphur dioxide and suspended particulate matter, the Taj had contracted 'marble cancer', a fungal growth that corroded its surface giving it a yellowish tinge. The SPM deposits blackened it. Shri MC Mehta an environmental lawyer filed a public interest litigation in 1984 expressing concern over the havoc the polluting units in Agra were wreaking on the Taj Mahal. Twelve years later the Supreme Court ordered 292 industries in the vicinity to either adopt pollution control measures or shut down. It also made it mandatory for these units to either switch over to eco-friendly fuels like natural gas or shift out of the area.

### *Air quality monitoring*

India does not presently have a well established system of monitoring air pollution. When air quality monitoring began in India in the late 1960s planners focused only on a few pollutants namely sulphur dioxide, nitrogen oxides and suspended particulate matter. Other pollutants such as carbon monoxide and lead were monitored only on a limited scale. The threat from other air toxins such as benzene, ozone, other small particulates is not known as these are not monitored at all. A database on ambient air quality in Indian cities has been prepared by the monitoring networks of the National Environmental Engineering Research Institute (NEERI), Nagpur. The Central Pollution Control Board (CPCB) initiated its own national Ambient Air Quality Monitoring (NAAQM) program in 1985.

Ambient air quality standards in India developed by the Central Pollution Control Board

Area Category	SPM µg/m3	SO2 µg/m3	Co µg/m3	NOx µg/m3
Industrial and mixed use	500	120	5000	120
Residential and rural	200	80	2000	80
Sensitive	100	3	1000	30

Data to the NAAQM is supplied by the respective state pollution control boards, which is then transmitted to the CPCB. Experts feel that the present air quality-monitoring network cannot capture the true profile of urban air pollution due to the lack of adequate monitoring stations. Moreover critical toxins have still not been included in the list of pollutants to be monitored.

*Legal aspects of air pollution control in India*  
The Air (Prevention and Control of Pollution) Act was legislated in 1981. The Act provided for prevention, control and abatement of air pollution. In areas notified under this Act no industrial pollution causing activity could come up without the permission of the concerned State Pollution Control Board. But this Act was not strong enough to play a precautionary or a corrective role. After the Bhopal disaster, a more comprehensive Environment Protection Act (EPA) was passed in 1986. This Act for the first time conferred enforcement agencies with necessary punitive powers to restrict any activity that can harm the environment. To regulate vehicular pollution the Central Motor Vehicles Act of 1939 was amended in 1989. Following this amendment the exhaust emission rules for vehicle owners were notified in 1990 and the mass emission standards for vehicle manufacturers were enforced in 1991 for the first time. The mass emission norms have been further revised for 2000.

Air quality management as a well-defined program has yet to emerge in India. We need a much more strengthened air quality management with continuous monitoring of air if we are to have a better quality of air. This would also need an integrated approach with strict air pollution control laws. Some of the suggestions for doing this include:

- Putting a greater emphasis on pollution prevention rather than control
- Reducing the use of fossil fuels
- Improving the quality of vehicular fuel
- Increasing the use of renewable energy

5.2.2 Water Pollution

Our liquid planet glows like a soft blue sapphire in the hard-edged darkness of space. There is nothing else like it in the solar system. It is because of water.

– John Todd

**Introduction:** Water is the essential element that makes life on earth possible. Without water there would be no life. We usually take water for granted. It flows from our taps when they are turned on. Most of us are able to bathe when we want to, swim when we choose and water

our gardens. Like good health we ignore water when we have it.

Although 71% of the earth's surface is covered by water only a tiny fraction of this water is available to us as fresh water. About 97% of the total water available on earth is found in oceans and is too salty for drinking or irrigation. The remaining 3% is fresh water. Of this 2.997% is locked in ice caps or glaciers. Thus only 0.003% of the earth's total volume of water is easily available to us as soil moisture, groundwater, water vapour and water in lakes, streams, rivers and wetlands.

In short if the world's water supply were only 100 litres our usable supply of fresh water would be only about 0.003 litres (one-half teaspoon). This makes water a very precious resource. The future wars in our world may well be fought over water. By the middle of this century, almost twice as many people will be trying to share the same amount of fresh water the earth has today. As freshwater becomes more scarce access to water resources will be a major factor in determining the economic growth of several countries around the world.

**Water availability on the planet:** Water that is found in streams, rivers, lakes, wetlands and artificial reservoirs is called surface water. Water that percolates into the ground and fills the pores in soil and rock is called groundwater. Porous water-saturated layers of sand, gravel or bedrock through which ground water flows are called aquifers. Most aquifers are replenished naturally by rainfall that percolates downward through the soil and rock. This process is called natural recharge. If the withdrawal rate of an aquifer exceeds its natural recharge rate, the water table is lowered. Any pollutant that is discharged onto the land above is also pulled into the aquifer and pollutes the groundwater resulting in polluted water in the nearby wells.

India receives most of her rainfall during the months of June to September due to the seasonal winds and the temperature differences between the land and the sea. These winds blow from the opposite directions in the different seasons. They blow into India from the surrounding oceans during the summer season and blow out from the subcontinent to the oceans during the winter. The monsoon in India is usually reasonably stable but varies geographically. In some years the commencement of the rains may be delayed considerably over the entire country or a part of it. The rains may also terminate earlier than usual. They may be heavier than usual over one part than over another. All these may cause local floods or drought. However in India even areas that receive adequate rainfall during the monsoon suffer from water shortages in the post monsoon period due to lack of storage facilities.

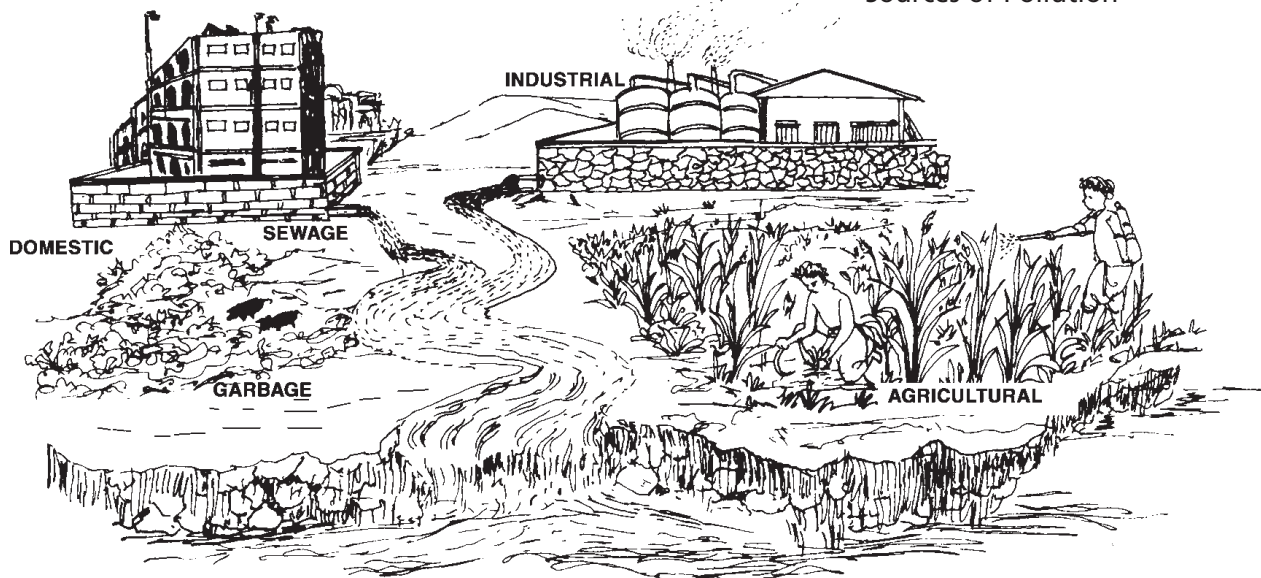
**When the quality or composition of water changes directly or indirectly as a result of man's activities such that it becomes unfit for any purpose it is said to be polluted.**

**Point sources of pollution:** When a source of pollution can be readily identified because it has a definite source and place where it enters the water it is said to come from a **point source**. Eg. Municipal and Industrial Discharge Pipes.

When a source of pollution cannot be readily identified, such as agricultural runoff, acid rain, etc, they are said to be **non-point sources** of pollution.



## Sources of Pollution



### Causes of water pollution

There are several classes of common water pollutants. These are **disease-causing agents** (pathogens) which include bacteria, viruses, protozoa and parasitic worms that enter water from domestic sewage and untreated human and animal wastes. Human wastes contain concentrated populations of coliform bacteria such as *Escherichia coli* and *Streptococcus faecalis*. These bacteria normally grow in the large intestine of humans where they are responsible for some food digestion and for the production of vitamin K. These bacteria are not harmful in low numbers. Large amounts of human waste in water, increases the number of these bacteria which cause gastrointestinal diseases. Other potentially harmful bacteria from human wastes may also be present in smaller numbers. Thus the greater the amount of wastes in the water the greater are the chances of contracting diseases from them.

Another category of water pollutants is **oxygen depleting wastes**. These are organic wastes that can be decomposed by aerobic (oxygen requiring) bacteria. Large populations of bacteria use up the oxygen present in water to

degrade these wastes. In the process this degrades water quality. The amount of oxygen required to break down a certain amount of organic matter is called the biological oxygen demand (BOD). The amount of BOD in the water is an indicator of the level of pollution. If too much organic matter is added to the water all the available oxygen is used up. This causes fish and other forms of oxygen dependent aquatic life to die. Thus anaerobic bacteria (those that do not require oxygen) begin to break down the wastes. Their anaerobic respiration produces chemicals that have a foul odour and an unpleasant taste that is harmful to human health.

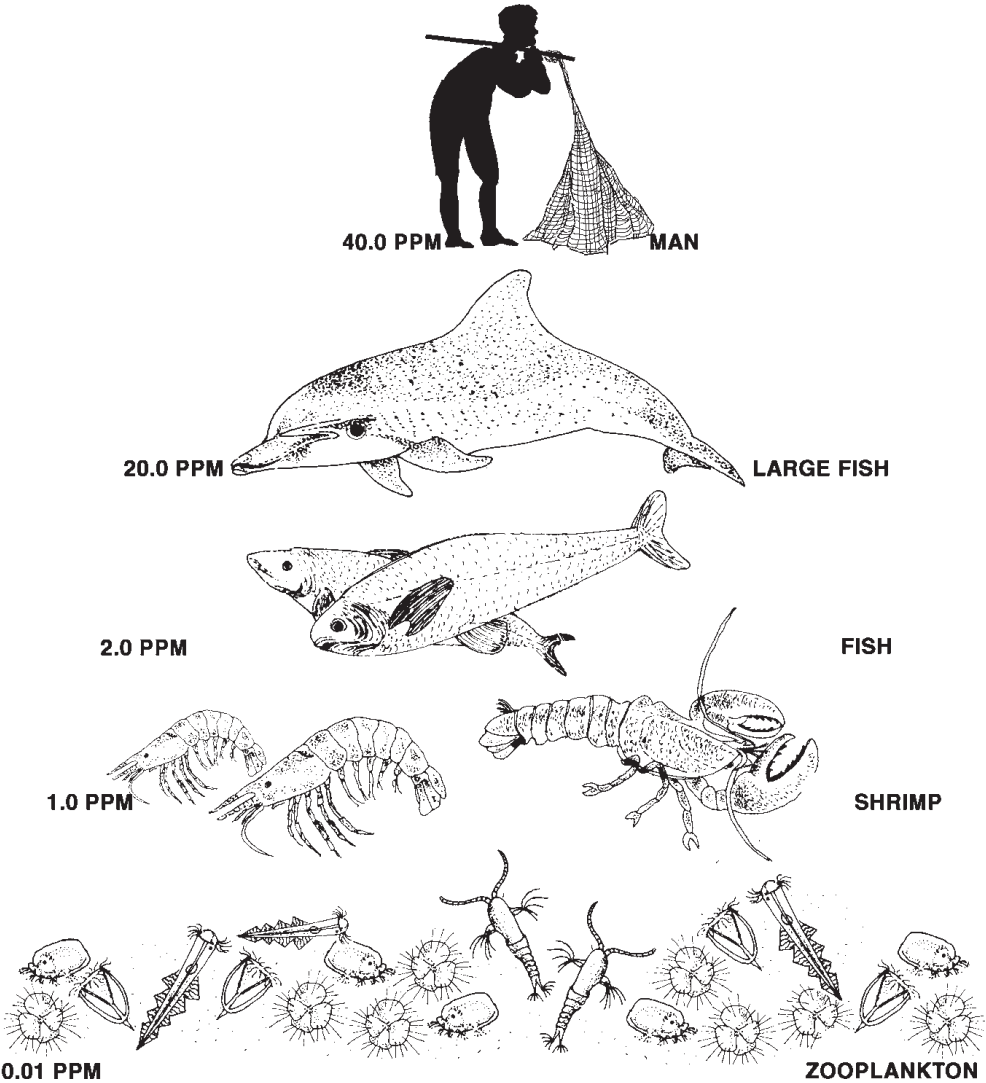
A third class of pollutants are **inorganic plant nutrients**. These are water soluble nitrates and phosphates that cause excessive growth of algae and other aquatic plants. The excessive growth of algae and aquatic plants due to added nutrients is called eutrophication. They may interfere with the use of the water by clogging water intake pipes, changing the taste and odour of water and cause a buildup of organic matter. As the organic matter decays, oxygen levels decrease and fish and other aquatic species die.



The quantity of fertilizers applied in a field is often many times more than is actually required by the plants. The chemicals in fertilizers and pesticides pollute soil and water. While excess fertilizers cause eutrophication, pesticides cause bioaccumulation and biomagnification. Pesticides which enter water bodies are introduced into the aquatic food chain. They are then absorbed by the phytoplanktons and aquatic plants. These plants are eaten by the herbivorous fish which are in turn eaten by the carnivorous fish which are in turn eaten by the water birds. At each link in the food chain these chemicals which do not pass out of the body are accumulated and increasingly concentrated resulting in biomagnification of these harmful substances.

One of the effects of accumulation of high levels of pesticides such as DDT is that birds lay eggs with shells that are much thinner than normal. This results in the premature breaking of these eggs, killing the chicks inside. Birds of prey such as hawks, eagles and other fish eating birds are affected by such pollution. Although DDT has been banned in India for agricultural use and is to be used only for malaria eradication, it is still used in the fields as it is cheap.

A fourth class of water pollutants is **water soluble inorganic chemicals** which are acids, salts and compounds of toxic metals such as mercury and lead. High levels of these chemicals can make the water unfit to drink, harm



fish and other aquatic life, reduce crop yields and accelerate corrosion of equipment that use this water.

Another cause of water pollution is a variety of **organic chemicals**, which include oil, gasoline, plastics, pesticides, cleaning solvents, detergent and many other chemicals. These are harmful to aquatic life and human health. They get into the water directly from industrial activity either from improper handling of the chemicals in industries and more often from improper and illegal disposal of chemical wastes.

**Sediment of suspended matter** is another class of water pollutants. These are insoluble particles of soil and other solids that become suspended in water. This occurs when soil is eroded from the land. High levels of soil particles suspended in water, interferes with the penetration of sunlight. This reduces the photosynthetic activity of aquatic plants and algae disrupting the ecological balance of the aquatic bodies. When the velocity of water in streams and rivers decreases the suspended particles settle down at the bottom as sediments. Excessive sediments that settle down destroys feeding and spawning grounds of fish, clogs and fills lakes, artificial reservoirs etc.

**Water soluble radioactive isotopes** are yet another source of water pollution. These can be concentrated in various tissues and organs as they pass through food chains and food webs. Ionizing radiation emitted by such isotopes can cause birth defects, cancer and genetic damage.

**Hot water** let out by power plants and industries that use large volumes of water to cool the plant result in rise in temperature of the local water bodies. Thermal pollution occurs when industry returns the heated water to a water source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity. For efficient functioning of the steam

turbines, the steam is condensed into water after it leaves the turbines. This condensation is done by taking water from a water body to absorb the heat. This heated water, which is at least 15oC higher than the normal is discharged back into the water body. The warm water not only decreases the solubility of oxygen but changes the breeding cycles of various aquatic organisms.

**Oil** is washed into surface water in runoff from roads and parking lots which also pollutes groundwater. Leakage from underground tanks

### CASE STUDY

One of the worst oil spill disasters that have occurred is that of the Exxon Valdez. On 24<sup>th</sup> march 1989 the Exxon Valdez, a tanker more than three football fields wide went off course in a 16 kilometer wide channel in Prince William Sound near Valdez in Alaska. It hit submerged rocks, creating an environmental disaster. The rapidly spreading oil slick coated more than 1600 kilometers of shoreline killing between 300,000 and 645,000 water birds and a large number of sea otters, harbor seals, whales and fishes. Exxon spent \$ 2.2. billion directly on the clean-up operations. However some results of the cleanup effort showed that where high pressure jets of hot water were used to clean beaches coastal plants and animals that had survived the spill were killed. Thus it did more harm than good. Exxon pleaded guilty in 1991 and agreed to pay the Federal Government and the state of Alaska \$ 1 billion in fines and civil damages. This \$8.5 billion accident might have been prevented if Exxon had spent only \$22.5 million to fit the tanker with a double hull-one inside the other. Such double hulled vessels would be less likely to rupture and spill their contents. The spill highlighted the need for marine pollution prevention.

is another source of pollution. Accidental oil spills from large transport tankers at sea have been causing significant environmental damage.

Though accidents such as the *Exxon Valdez* get worldwide attention, much more oil is released as a result of small, regular releases from other less visible sources. Nearly two thirds of all marine oil pollution comes from three sources: run-off from streets, improper discharge of lubricating oil from machines or automobile crankcases and intentional oil discharges that occur during the loading and unloading of tankers. Oil tankers often use sea water as ballast to stabilize the ship after they have discharged their oil. This oil contaminated water is then discharged back into the sea when the tanker is refilled.

**Groundwater pollution:** While oil spills are highly visible and often get a lot of media attention, a much greater threat to human life comes from our groundwater being polluted which is used for drinking and irrigation. While groundwater is easy to deplete and pollute it gets renewed very slowly and hence must be used judiciously. Groundwater flows are slow and not turbulent hence the contaminants are not effectively diluted and dispersed as compared to surface water. Moreover pumping groundwater and treating it is very slow and costly. Hence it is extremely essential to prevent the pollution of groundwater in the first place. Ground water is polluted due to:

- Urban run-off of untreated or poorly treated waste water and garbage
- Industrial waste storage located above or near aquifers
- Agricultural practices such as the application of large amounts of fertilizers and pesticides, animal feeding operations, etc. in the rural sector

- Leakage from underground storage tanks containing gasoline and other hazardous substances
- Leachate from landfills
- Poorly designed and inadequately maintained septic tanks
- Mining wastes

Severe cases of arsenic poisoning from contaminated groundwater have been reported from West Bengal in what is known today as the worst case of groundwater pollution. The School of Environmental Sciences, Jadavpur University, West Bengal has been involved in the task of surveying the magnitude of the arsenic problem in West Bengal for the last fourteen years. According to a report in the Down to Earth (Vol. 11, No.22), arsenic poisoning was first noticed by K C Saha, former professor of dermatology at the School of Tropical Medicine, Kolkata when he began to receive patients with skin lesions that resembled the symptoms of leprosy which was in reality not leprosy. Since all the patients were from the district of 24-Parganas, Saha along with others began to look for the cause and found it to be arsenic toxicity. Thus groundwater arsenic contamination in West Bengal was first reported in a local daily newspaper in December 1983 when 63 people from three villages located in different districts were identified by health officials as suffering from arsenic poisoning.

There are two theories that have been put forth to explain this unusually high content of arsenic in groundwater. One group of researchers suggested that the cause is natural while the other stated that the cause is man-made.

According to the first hypothesis, arsenic probably originates in the Himalayan headwaters of the Ganga and the Brahmaputra rivers and has been lying undisturbed beneath the surface of

the region's deltas for thousands of years in the thick layers of fine alluvial mud across the banks of these rivers. Most of the arsenic affected areas of West Bengal lie in the alluvial plains formed in the quaternary period (last 1.6 million years). The Purulia district of West Bengal is part of the extensive area of the Precambrian era (last 570 million year) having metamorphic rocks and granites with widespread sulphide mineralisation. Researchers from the UK based British Geological Survey (BGS) suggested that their position close to where the river Ganga enters Bangladesh (geologically) may be the primary source of arsenic in the Bengal alluvium. According to David Kinniburgh project leader with BGS the main factor is time. The mud in these areas is thicker, wider and flatter than almost anywhere else on earth. It can thus take hundreds or thousands of years for underground water to percolate through the mud before reaching the sea and thus it absorbs arsenic for a long period.

Other researchers feel that the excess amount of arsenic in groundwater can be contributed to by the high rate of groundwater extraction. Their hypothesis called the pyrite oxidation thesis describes how arsenic can get mobilized in the groundwater. In this hypothesis arsenic is assumed to be present in certain minerals (pyrites) that are deposited within the aquifer sediments. Due to the lowering of the water table below the deposits, arseno-pyrite which is oxidized in a zone of the aquifer called the Vadose zone releases arsenic as arsenic adsorbed on iron hydroxide. During the subsequent recharge period, iron hydroxide releases arsenic into groundwater. This theory is supported by two arguments. The first is the intensive irrigation development in West Bengal using deep tube wells and shallow tube wells. This method of extraction, which was exactly in the 20m to 100m below ground level ensured, increased contribution of groundwater to irrigation. The other argument that supports the pyrite oxidation theory is that prior to irrigation develop-

ment and drinking water supply schemes based on groundwater there were no reported cases of arsenic poisoning.

Arsenicosis or arsenic toxicity develops after two to five years of exposure to arsenic contaminated drinking water depending on the amount of water consumption and the arsenic concentration in water. Initially the skin begins to darken (called diffuse melanosis) which later leads to spotted melanosis when darkened spots begin to appear on the chest, back and limbs. At a later stage leucomelanosis sets in and the body begins to show black and white spots. In the middle stage of arsenicosis the skin in parts becomes hard and fibrous. Rough, dry skin with nodules on hands or the soles of feet indicate severe toxicity. This can lead to the formation of gangrene and cancer. Arsenic poisoning brings with it other complications such as liver and spleen enlargement, cirrhosis of the liver, diabetes, goiter and skin cancers.

### **The state of India's rivers**

India has always had a tradition of worshipping rivers. Most of the rivers in India are named after gods, goddesses or saints. However a large majority of the Indian population including those who worship the rivers do not think twice before polluting a river. Urbanization, industrialization, excess withdrawal of water, agricultural run-off, improper agricultural practices and various religious and social practices all contribute to river pollution in India. Every single river in India be it the Ganga, Yamuna, Cauvery or the Krishna have their own share of problems due to pollution. Waters from the Ganga and the Yamuna are drawn for irrigation through the network of canals as soon as these rivers reach the plains reducing the amount of water that flows downstream. What flows in the river is water from small nalas, and streams that carry with them sewage and industrial effluents. The residual freshwater, is unable to dilute the pol-

lutants and the rivers turn into stinking sewers. In spite of data from scientifically competent studies conducted by the Central Pollution Control Board (CPCB), the Government has not been able to tackle this issue. Sewage and municipal effluents account for 75% of the pollution load in rivers while the remaining 25% is from industrial effluents and non-point pollution sources.

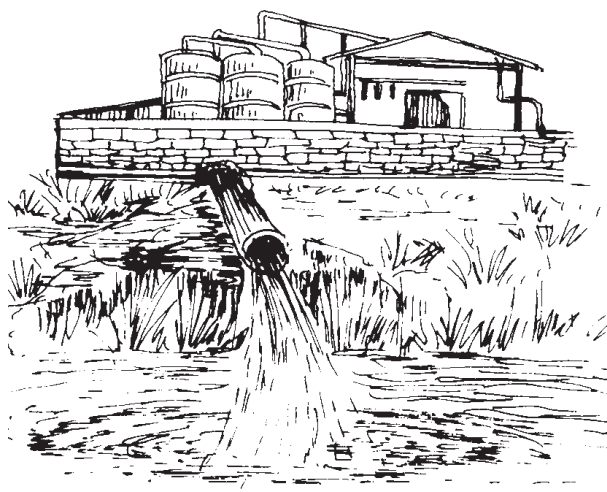
In 1985, India launched the Ganga Action plan (GAP) the largest ever river clean-up operation in the country. The plan has been criticized for, overspending and slow progress. The GAP Phase II in 1991 included cleaning operations for the tributaries of the Ganga, ie; the Yamuna, Gomti and the Damodar. Thus the Yamuna Action Plan (YAP), Gomti Action Plan and the Damodar Action plan were added.

In 1995 the National River Conservation plan was launched. Under this all the rivers in India were taken up for clean-up operations. In most of these plans, attempts have been made to tap drains, divert sewage to sewage treatment plants before letting out the sewage into the rivers. The biggest drawback of these river cleaning programs was that they failed to pin responsibilities as to who would pay for running the treatment facilities in the long run. With the power supply being erratic and these plants being heavily dependent on power, most of these facilities lie underutilized. Moreover the problem of river pollution due to agricultural run-off has not been addressed in these programs. NRCP is scheduled to be completed by March 2005. The approved cost for the plan is Rs. 772.08 crores covering 18 rivers in 10 states including 46 towns. The cost is borne entirely by the Central Government and the Ministry of Environment and Forests is the nodal agency that co-ordinates and monitors the plan. Under this plan the major activities include treating the pollution load from sewer systems of towns and cities, setting up of Sewage treatment plants, electric crematoria, low cost sanitation facilities,

riverfront development, afforestation and solid waste management.

### **Control measures for preventing water pollution**

While the foremost necessity is prevention, setting up effluent treatment plants and treating waste through these can reduce the pollution load in the recipient water. The treated effluent can be reused for either gardening or cooling purposes wherever possible. A few years ago a new technology called the Root Zone Process has been developed by Thermax. This system involves running contaminated water through the root zones of specially designed reed beds. The reeds, which are essentially wetland plants have the capacity to absorb oxygen from the surrounding air through their stomatal openings. The oxygen is pushed through the porous stem of the reeds into the hollow roots where it enters the root zone and creates conditions suitable for the growth of numerous bacteria and fungi. These micro-organisms oxidize impurities in the wastewaters, so that the water which finally comes out is clean.



**Water Pollution**



### 5.2.3 Soil Pollution

**Introduction:** We can no more manufacture a soil with a tank of chemicals than we can invent a rain forest or produce a single bird. We may enhance the soil by helping its processes along, but we can never recreate what we destroy. The soil is a resource for which there is no substitute. (Environmental historian Donald Worster reminds us that fertilizers are not a substitute for fertile soil).

Soil is a thin covering over the land consisting of a mixture of minerals, organic material, living organisms, air and water that together support the growth of plant life. Several factors contribute to the formation of soil from the parent material. This includes mechanical weathering of rocks due to temperature changes and abrasion, wind, moving water, glaciers, chemical weathering activities and lichens. Climate and time are also important in the development of soils. Extremely dry or cold climates develop soils very slowly while humid and warm climates develop them more rapidly. Under ideal climatic conditions soft parent material may develop into a centimeter of soil within 15 years. Under poor climatic conditions a hard parent material may require hundreds of years to develop into soil.

Mature soils are arranged in a series of zones called soil horizons. Each horizon has a distinct texture and composition that varies with different types of soils. A cross sectional view of the horizons in a soil is called a soil profile.

The top layer or the surface litter layer called the O horizon consists mostly of freshly fallen and partially decomposed leaves, twigs, animal waste, fungi and other organic materials. Normally it is brown or black.

The uppermost layer of the soil called the A horizon consists of partially decomposed organic matter (humus) and some inorganic mineral particles. It is usually darker and looser than the

deeper layers. The roots of most plants are found in these two upper layers. As long as these layers are anchored by vegetation soil stores water and releases it in a trickle throughout the year instead of in a force like a flood. These two top layers also contain a large amount of bacteria, fungi, earthworms and other small insects that form complex food webs in the soil that help recycle soil nutrients and contribute to soil fertility.

The B horizon often called the subsoil contains less organic material and fewer organisms than the A horizon. The area below the subsoil is called the C horizon and consists of weathered parent material. This parent material does not contain any organic materials. The chemical composition of the C-horizon helps to determine the pH of the soil and also influences the soil's rate of water absorption and retention.

Soils vary in their content of clay (very fine particles), silt (fine particles), sand (medium size particles) and gravel (coarse to very coarse particles). The relative amounts of the different sizes and types of mineral particles determine soil texture. Soils with approximately equal mixtures of clay, sand, silt and humus are called loams.

### Causes of soil degradation

#### Erosion

Soil erosion can be defined as the movement of surface litter and topsoil from one place to another. While erosion is a natural process often caused by wind and flowing water it is greatly accelerated by human activities such as farming, construction, overgrazing by livestock, burning of grass cover and deforestation.

Loss of the topsoil makes a soil less fertile and reduces its water holding capacity. The topsoil, which is washed away, also contributes to water pollution clogging lakes, increasing turbidity of the water and also leads to loss of aquatic

life. For one inch of topsoil to be formed it normally requires 200-1000 years depending upon the climate and soil type. Thus if the topsoil erodes faster than it is formed the soil becomes a non-renewable resource.

Thus it is essential that proper soil conservation measures are used to minimize the loss of top soil. There are several techniques that can protect soil from erosion. Today both water and soil are conserved through integrated treatment methods. Some of the most commonly employed methods include the two types of treatment that are generally used.

- Area treatment which involves treating the land
- Drainage line treatment which involves treating the natural water courses (nalas)

*Continuous contour trenches* can be used to enhance infiltration of water reduce the run-off and check soil erosion. These are actually shallow trenches dug across the slope of the land and along the contour lines basically for

the purpose of soil and water conservation. They are most effective on gentle slopes and in areas of low to medium rainfall. These bunds are stabilized by fast growing tree species and grasses. In areas of steep slopes where the bunds are not possible, continuous contour benches (CCBs) made of stones are used for the same purpose.

Gradonies can also be used to convert wastelands into agricultural lands. In this narrow trenches with bunds on the downstream side are built along contours in the upper reaches of the catchment to collect run-off and to conserve moisture from the trees or tree crops. The area between the two bunds is use for cultivation of crops after development of fertile soil cover.

Some of the ways in which this can be achieved are:

**Live check dams** which barriers created by planting grass, shrubs and trees across the gullies can be used for this purpose.

A **bund constructed out of stones** across the stream can also be used for conserving soil and water.

Area Treatment

Purpose	Treatment Measure	Effect
Reduces the impact of rain drops on the soil	Develop vegetative cover on the non arable land	Minimum disturbance and displacement of soil particles
Infiltration of water where it falls	Apply water infiltration measures on the area	In situ soil and moisture conservation
Minimum surface run off	Store surplus rain water by constructing bunds, ponds in the area	Increased soil moisture in the area, facilitate ground water recharge
Ridge to valley sequencing	Treat the upper catchment first and then proceed towards the outlet	Economically viable, less risk of damage and longer life of structures of the lower catchments



## Drainage line treatment

Purpose	Treatment measure	Effect
Stop further deepening of gullies and retain sediment run-off	Plug the gullies at formation	Stops erosion, recharges groundwater at the upper level.
Reduce run-off velocity, pass cleaner water to the downstream side	Crate temporary barriers in nalas	Delayed flow and increased groundwater recharge
Minimum sedimentation in the storage basins	Use various methods to treat the catchments	
Low construction cost	Use local material and skills for constructing the structures	Structures are locally maintained

**An Earthen checkbund** is constructed out of local soil across the stream to check soil erosion and flow of water.

A **Gabion structure** is a bund constructed of stone and wrapped in galvanized chainlink.

**A Gabion structure with ferrocement impervious barrier** has a one inch thick impervious wall of ferrocement at the center of the structure which goes below the ground level upto the hard strata. This ferrocement partition supported by the gabion portion is able to retain the water and withstand the force of the runoff water.

**An Underground bandhara** is an underground structure across a nalla bed to function as a barrier to check the ground water movement.

**Excess use of fertilizers:** Approximately 25 percent of the world's crop yield is estimated to be directly attributed to the use of chemical fertilizers. The use of chemical fertilizes has increased significantly over the last few decades

and is expected to rise even higher. Fertilizers are very valuable as they replace the soil nutrients used up by plants. The three primary soil nutrients often in short supply are potassium, phosphorus and nitrogen compounds. These are commonly referred to as macronutrients. Certain other elements like boron, zinc and manganese are necessary in extremely small amounts and are known as micronutrients. When crops are harvested a large amount of macronutrients and a small amount of micronutrients are removed with the crops. If the same crop is grown again depleted levels of thee nutrients can result in decreased yields. These necessary nutrients can be returned to the soil through the application of fertilizers. In addition to fertilizers a large amount of pesticides (chemicals used to kill or control populations of unwanted fungi, animals or plants often called pests) are also used to ensure a good yield. Pesticides can be subdivided into several categories based on the kinds of organisms they are used to control. *Insecticides* are used to control insect populations while *fungicides* are used to control unwanted fungal growth. Mice and rats are killed by *rodenticides* while plant pests are controlled by *herbicides*.

## Problems with pesticide use

Pesticides not only kill the pests but also a large variety of living things including humans. They may be persistent or non-persistent. Persistent pesticides once applied are effective for a long time. However as they do not break down easily they tend to accumulate in the soil and in the bodies of animals in the food chain.

For example, DDT which was one of the first synthetic organic insecticide to be used was thought to be the perfect insecticide. During the first ten years of its use (1942-1952) DDT is estimated to have saved about five million lives primarily because of its use to control disease carrying mosquitoes. However after a period of use many mosquitoes and insects became tolerant of DDT, thus making it lose its effectiveness. DDT in temperate regions of the world has a half life (the amount of time required for half of the chemical to decompose) of 10 to 15 years. This means that if 100 kilograms of DDT were to be sprayed over an area, 50 kilograms would still be present in the area 10 to 15 years later. The half-life of DDT varies according to the soil type, temperature, kind of soil organisms present and other factors. In tropical parts of the world the half life may be as short as six months. The use of DDT has been banned in some countries. India still however permits the use of DDT though for purposes of mosquito control only. Persistent pesticides become attached to small soil particles which are easily moved by wind and water to different parts thus affecting soils elsewhere. Persistent pesticides may also accumulate in the bodies of animals, and over a period of time increase in concentration if the animal is unable to flush them out of its system thus leading to the phenomenon called bioaccumulation. When an affected animal is eaten by another carnivore these pesticides are further concentrated in the body of the carnivore. This phenomenon of acquiring increasing levels of a substance in the bodies of higher trophic level organisms is known as biomagnification. This process especially in the

case of insecticides like DDT have been proved to be disastrous. DDT is a well known case of biomagnification in ecosystems. DDT interferes with the production of normal eggshells in birds making them fragile.

Other problems associated with insecticides is the ability of insect populations to become resistant to them thus rendering them useless in a couple of generations. Most pesticides kill beneficial as well as pest species. They kill the predator as well as the parasitic insects that control the pests. Thus the pest species increase rapidly following the use of a pesticide as there are no natural checks to their population growth. The short term and the long-term health effects to the persons using the pesticide and the public that consumes the food grown by using the pesticides are also major concerns. Exposure to small quantities of pesticides over several years can cause mutations, produce cancers, etc.

Thus the question that comes to mind is that if pesticides have so many drawbacks then why are they used so extensively and what are the substitutes for them? There are three main reasons for the use of pesticides. Firstly the use of pesticides in the short term has increased the amount of food that can be grown in many parts of the world as the damage by pests is decreased. The second reason for its extensive use is based on an economic consideration. The increased yields more than compensates the farmer for cost of pesticides. Thirdly current health problems especially in developing countries due to mosquitoes are impossible to control without insecticides.

However more and more farmers are increasingly opting to replace chemical fertilizers and use different methods of controlling pests without affecting their yield. Thus several different approaches that have slightly varying and overlapping goals have been developed. Alternative agriculture is the broadest term that is used that includes all non-traditional agricultural methods

and encompasses sustainable agriculture, organic agriculture, alternative uses of traditional crops, alternative methods for raising crops, etc.

Sustainable agriculture advocates the use of methods to produce adequate safe food in an economically viable manner while maintaining the state of the ecosystem. Organic agriculture advocates avoiding the use of chemical fertilizers and pesticides. A wide variety of techniques can be used to reduce this negative impact of agriculture. Leaving crop residue on the soil and incorporating it into the soil reduces erosion and increase soil organic matter. Introduction of organic matter into the soil also makes compaction less likely. Crop rotation is an effective way to enhance soil fertility, reduce erosion and control pests. There have been arguments both for and against organic farming. Critics argue that organic farming cannot produce the amount of food required for today's population and it is economically viable only in certain conditions. However supporters for organic farming feel that of the hidden costs of soil erosion and pollution are taken into account it is a viable approach. Besides organic farmers do not have to spend on fertilizers and pesticides and also get a premium price for their products thus making it financially viable for them.

Another way to reduce these impacts is through the use of *integrated pest management*. This is a technique that uses a complete understanding of all ecological aspects of a crop and the particular pests to which it is susceptible to establish pest control strategies that uses no or few pesticides. IPM promotes the use of biopesticides. Biopesticides are derived from three sources: microbial, botanical and biochemical. Microbial pesticides are micro-organisms such as bacteria, fungus, virus or protozoa that fight pests through a variety of ways. They produce toxins specific to the pests and produce diseases in them. Biochemical pesticides contain several chemicals that affect the reproductive and digestive mechanisms of the pests. The most

commonly used biopesticides are *Bacillus thuringiensis* (Bt), neem (*Azadirachta indica*) and trichogramma. Although they are available in the market they are yet to become market favourites.

### **Excess salts and water**

Irrigated lands can produce crop yields much higher than those that only use rainwater. However this has its own set of ill effects. Irrigation water contains dissolved salts and in dry climates much of the water in the saline solution evaporates leaving its salts such as sodium chloride in the topsoil. The accumulation of these salts is called salinization, which can stunt plant growth, lower yields and eventually kill the crop and render the land useless for agriculture. These salts can be flushed out of the soil by using more water. This practice however increases the cost of crop production and also wastes enormous amounts of water. Flushing salts can also make the downstream irrigation water saltier.

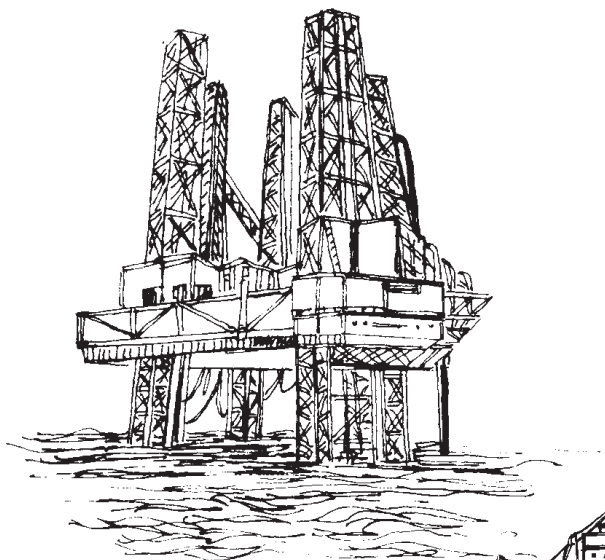
Another problem with irrigation is water logging. This occurs when large amounts of water is used to leach the salts deeper into the soil. However if the drainage is poor this water accumulates underground gradually raising the water table. The roots of the plants then get enveloped in this saline water and eventually die.

Thus in the long run it is better for us to adopt sustainable farming practices so as to prevent the degradation of soil.

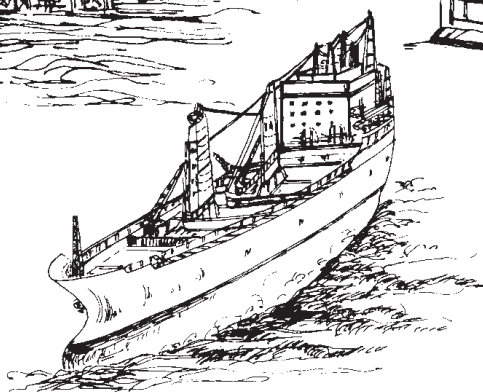
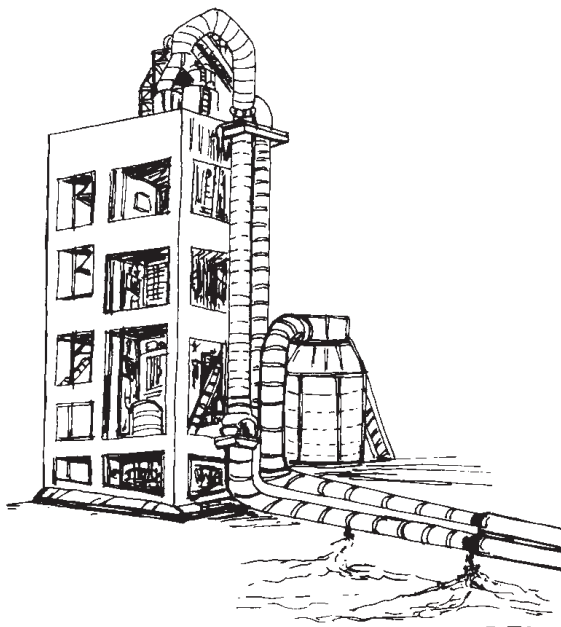
### **5.2.4 Marine Pollution**

Marine pollution can be defined as the introduction of substances to the marine environment directly or indirectly by man resulting in adverse effects such as hazards to human health, obstruction of marine activities and lowering the quality of sea water. While the causes of ma-

### SPILLAGE FROM OIL RIGS



### SPILLAGE FROM OIL PIPELINES



### SPILLAGE FROM TANKERS

rine pollution may be similar to that of general water pollution there are some very specific causes that pollute marine waters.

- The most obvious inputs of waste is through pipes directly discharging wastes into the sea. Very often municipal waste and sewage from residences and hotels in coastal towns are directly discharged into the sea.
- Pesticides and fertilizers from agriculture which are washed off the land by rain, enter water courses and eventually reach the sea.
- Petroleum and oils washed off from the roads normally enter the sewage system but stormwater overflows carry these materials into rivers and eventually into the seas.
- Ships carry many toxic substances such as oil, liquefied natural gas, pesticides, industrial chemicals, etc. in huge quantities sometimes to the capacity of 350,000 tonnes. Ship accidents and accidental spillages at sea therefore can be very damaging to the marine environment. Shipping channels in estuaries and at the entrances to ports often require frequent dredging to keep them open. This dredged material that may contain heavy metals and other contaminants are often dumped out to sea.
- Offshore oil exploration and extraction also pollute the seawater to a large extent.

## Pollution due to organic wastes

The amount of oxygen dissolved in the water is vital for the plants and animals living in it. Wastes, which directly or indirectly affect the oxygen concentration, play an important role in determining the quality of the water. Normally the greatest volume of waste discharged to watercourses, estuaries and the sea is sewage, which is primarily organic in nature and is degraded by bacterial activity. Using the oxygen present in the water these wastes are broken down into stable inorganic compounds. However as a result of this bacterial activity the oxygen concentration in the water is reduced. When the oxygen concentration falls below 1.5 mg/lit, the rate of aerobic oxidation is reduced and their place is taken over by the anaerobic bacteria that can oxidize the organic molecules without the use of oxygen. This results in end products such as hydrogen sulphide, ammonia and methane, which are toxic to many organisms. This process results in the formation of an anoxic zone which is low in its oxygen content from which most life disappears except for anaerobic bacteria, fungi, yeasts and some protozoa. This makes the water foul smelling.

**Control measures:** One way of reducing the pollution load on marine waters is through the introduction of sewage treatment plants. This will reduce the biological oxygen demand (BOD) of the final product before it is discharged to the receiving waters.

Various stages of treatment such as primary, secondary or advanced can be used depending on the quality of the effluent that is required to be treated.

**Primary treatment:** These treatment plants use physical processes such as screening and sedimentation to remove pollutants that will settle, float or, that are too large to pass through simple screening devices. This includes, stones, sticks, rags, and all such material that can clog pipes. A *screen* consists of parallel bars spaced 2 to 7cms apart followed by a wire mesh with smaller

openings. One way of avoiding the problem of disposal of materials collected on the screens is to use a device called a comminuter which grinds the coarse material into small pieces that can then be left in the waste water. After screening the wastewater passes into a *grit chamber*. The detention time is chosen to be long enough to allow lighter, organic material to settle. From the grit chamber the sewage passes into a *primary settling tank* (also called as sedimentation tank) where the flow speed is reduced sufficiently to allow most of the suspended solids to settle out by gravity. If the waste is to undergo only primary treatment it is then chlorinated to destroy bacteria and control odours after which the effluent is released. Primary treatment normally removes about 35 percent of the BOD and 60 percent of the suspended solids.

**Secondary treatment:** The main objective of secondary treatment is to remove most of the BOD. There are three commonly used approaches: trickling filters, activated sludge process and oxidation ponds. Secondary treatment can remove at least 85 percent of the BOD.

A *trickling filter* consists of a rotating distribution arm that sprays liquid wastewater over a circular bed of 'fist size' rocks or other coarse materials. The spaces between the rocks allow air to circulate easily so that aerobic conditions can be maintained. The individual rocks in the bed are covered with a layer of slime, which consists of bacteria, fungi, algae, etc. which degrade the waste trickling through the bed. This slime periodically slides off individual rocks and is collected at the bottom of the filter along with the treated wastewater and is then passed on to the secondary settling tank where it is removed.

In the *activated sludge process* the sewage is pumped into a large tank and mixed for several hours with bacteria rich sludge and air bubbles to facilitate degradation by micro-organisms. The water then goes into a sedimentation tank



where most of the microorganisms settle out as sludge. This sludge is then broken down in an anaerobic digester where methane-forming bacteria slowly convert the organic matter into carbon dioxide, methane and other stable end products. The gas produced in the digester is 60 percent methane, which is a valuable fuel and can be put to many uses within the treatment plant itself. The digested sludge, which is still liquid, is normally pumped out onto sludge drying beds where evaporation and seepage remove the water. This dried sludge is potentially a good source of manure. Activated sludge tanks use less land area than trickling filters with equivalent performance. They are also less expensive to construct than trickling filters and have fewer problems with flies and odour and can also achieve higher rates of BOD removal. Thus although the operating costs are a little higher due to the expenses incurred on energy for running pumps and blowers they are preferred over trickling filters.

*Oxidation ponds* are large shallow ponds approximately 1 to 2 metres deep where raw or partially treated sewage is decomposed by microorganisms. They are easy to build and manage and accommodate large fluctuations in flow and can provide treatment at a much lower cost. They however require a large amount of land and hence can be used where land is not a limitation.

**Advanced sewage treatment:** This involves a series of chemical and physical process that removes specific pollutants left in the water after primary and secondary treatment. Sewage treatment plant effluents contain nitrates and phosphates in large amounts. These contribute to eutrophication. Thus advanced treatment plants are designed to specifically remove these contaminants. Advanced treatment plants are very expensive to build and operate and hence are rarely used.

**Pollution due to oil:** Oil pollution of the sea normally attracts the greatest attention because of its visibility. There are several sources though which the oil can reach the sea.

#### *Tanker operations*

Half the world production of crude oil which is close to three billion tones a year is transported by sea. After a tanker has unloaded its cargo of oil it has to take on seawater as ballast for the return journey. This ballast water is stored in the cargo compartments that previously contained the oil. During the unloading of the cargo a certain amount of oil remains clinging to the walls of the container and this may amount to 800 tonnes in a 200,000 tonne tanker. The ballast water thus becomes contaminated with this oil. When a fresh cargo of oil is to be loaded, these compartments are cleaned with water, which discharges the dirty ballast along with the oil into the sea. Two techniques have substantially reduced this oil pollution. In the *load-on-top* system, the compartments are cleaned by high pressure jets of water. The oily water is retained in the compartment until the oil floats to the top. The water underneath that contains only a little oil is then discharged into the sea and the oil is transferred to a slop tank. At the loading terminal, fresh oil is loaded on top of the oil in the tank and hence the name of the technique. In the second method called '*crude oil washing*', the clingage is removed by jets of crude oil while the cargo is being unloaded. Some modern tankers have *segregated ballast* where the ballast water does not come in contact with the oil. Thus with the introduction of these new methods of deballasting, the amount of oil entering the sea has been considerably reduced.

#### *Dry docking*

All ships need periodic dry docking for servicing, repairs, cleaning the hull, etc. During this period when the cargo compartments are to

completely emptied, residual oil finds its way into the sea.

#### *Bilge and fuel oils*

As ballast tanks take up valuable space, additional ballast is sometimes carried in empty fuel tanks. While being pumped overboard it carries oil into the sea. Individually the quantity of oil released may be small but it becomes a considerable amount when all the shipping operations are taken into consideration.

#### *Tanker accidents*

A large number of oil tanker accidents happen every year. Sometimes this can result in major disasters such as that of the Exxon Valdez described in the section on water pollution.

#### *Offshore oil production*

Oil that is extracted from the seabed contains some water. Even after it is passed through oil separators the water that is discharged contains some oil, which adds to marine pollution. Drilling muds which are pumped down oil wells when it is being drilled normally contain 70 to 80 percent of oil. They are dumped on the seabed beneath the platform thus heavily contaminating the water. Uncontrolled release of oil from the wells can be catastrophic events resulting in oil pollution.

**Control measures for oil pollution:** Cleaning oil from surface waters and contaminated beaches is a time consuming labour intensive process. The natural process of emulsification of oil in the water can be accelerated through the use of *chemical dispersants* which can be sprayed on the oil. A variety of *slick-lickers* in which a continuous belt of absorbent material dips through the oil slick and is passed through rollers to extract the oil have been designed. Rocks, harbour walls can be cleaned with high-

pressure steam or dispersants after which the surface must be hosed down.

**Effects of marine pollution:** Apart from causing eutrophication a large amount of organic wastes can also result in the development of red tides. These are phytoplankton blooms of such intensity that the area is discolored. Many important commercially important marine species are also killed due to clogging of gills or other structures.

When liquid oil is spilled on the sea it spreads over the surface of the water to form a thin film called an *oil slick*. The rate of spreading and the thickness of the film depends on the sea temperature and the nature of the oil.

Oil slicks damage marine life to a large extent. Salt marshes, mangrove swamps are likely to trap oil and the plants, which form the basis for these ecosystems thus suffer. For salt marsh plants, oil slicks can affect the flowering, fruiting and germination.

If liquid oil contaminates a bird's plumage its water repellent properties are lost. Water thus penetrates the plumage and displaces the air trapped between the feathers and the skin. This air layer is necessary as it provides buoyancy and thermal insulation. With this loss the plumage becomes water logged and the birds may sink and drown. Even if this does not happen loss of thermal insulation results in exhaustion of food reserves in an attempt to maintain body temperature often followed by death. Birds often clean their plumage by preening and in the process consume oil which depending on its toxicity can lead to intestinal, renal or liver failure.

Drill cuttings dumped on the seabed create anoxic conditions and result in the production of toxic sulphides in the bottom sediment thus eliminating the benthic fauna.



Fish and shellfish production facilities can also be affected by oil slicks. The most important commercial damage can however also come from tainting which imparts an unpleasant flavour to fish and seafood and is detectable at extremely low levels of contamination. This reduces the market value of seafood.

5.2.5 Noise Pollution

Noise may not seem as harmful as the contamination of air or water but it is a pollution problem that affects human health and can contribute to a general deterioration of environmental quality.

Noise is undesirable and unwanted sound. Not all sound is noise. What may be considered as music to one person may be noise to another. It is not a substance that can accumulate in the environment like most other pollutants. Sound is measured in a unit called the ‘Decibel’.

Decibel levels of common sounds

dB	Environmental Condition
0	Threshold of hearing
10	Rustle of leaves
20	Broadcasting studio
30	Bedroom at night
40	Library
50	Quiet office
60	Conversational speech (at 1m)
70	Average radio
74	Light traffic noise
90	Subway train
100	Symphony orchestra
110	Rock band
120	Aircraft takeoff
146	Threshold of pain

There are several sources of noise pollution that contribute to both indoor and outdoor noise pollution. Noise emanating from factories, vehicles, playing of loudspeakers during various festivals can contribute to outdoor noise pollution while loudly played radio or music systems, and other electronic gadgets can contribute to indoor noise pollution. A study conducted by researchers from the New Delhi based National Physical Laboratory show that noise generated by firecrackers (presently available in the market) is much higher than the prescribed levels. The permitted noise level is 125 decibels, as per the Environment (Protection) (second amendment) Rules, 1999.

The differences between sound and noise is often subjective and a matter of personal opinion. There are however some very harmful effects caused by exposure to high sound levels. These effects can range in severity from being extremely annoying to being extremely painful and hazardous.

Effects of noise pollution on physical health

The most direct harmful effect of excessive noise is physical damage to the ear and the temporary or permanent hearing loss often called a temporary threshold shift (TTS). People suffering from this condition are unable to detect weak sounds. However hearing ability is usually recovered within a month of exposure. In Maharashtra people living in close vicinity of Ganesh mandals that play blaring music for ten days of the Ganesh festival are usually known to suffer from this phenomenon. Permanent loss, usually called noise induced permanent threshold shift (NIPTS) represents a loss of hearing ability from which there is no recovery.

Below a sound level of 80 dBA hearing loss does not occur at all. However temporary effects are noticed at sound levels between 80 and 130 dBA. About 50 percent of the people exposed

to 95 dBA sound levels at work will develop NIPTS and most people exposed to more than 105 dBA will experience permanent hearing loss to some degree. A sound level of 150 dBA or more can physically rupture the human eardrum.

The degree of hearing loss depends on the duration as well as the intensity of the noise. For example, 1hour of exposure to a 100 dBA sound level can produce a TTS that may last for about one day. However in factories with noisy machinery workers are subjected to high sound levels for several hours a day. Exposure to 95 dBA for 8 hours everyday for over a period of 10 years may cause about 15 dBA of NIPTS. In addition to hearing losses excessive sound levels can cause harmful effects on the circulatory system by raising blood pressure and altering pulse rates.

**Effects of noise pollution on mental health:**

Noise can also cause emotional or psychological effects such as irritability, anxiety and stress. Lack of concentration and mental fatigue are significant health effects of noise. It has been observed that the performance of school children is poor in comprehension tasks when schools are situated in busy areas of a city and suffer from noise pollution.

As noise interferes with normal auditory communication, it may mask auditory warning signals and hence increases the rate of accidents especially in industries. It can also lead to lowered worker efficiency and productivity and higher accident rates on the job.

Thus noise is just more than a mere nuisance or annoyance. It definitely affects the quality of life. It is thus important to ensure mitigation or control of noise pollution.

**Permitted noise levels**

**Ambient Noise Levels dB**

<i>Zone</i>	<i>Day-time</i>	<i>Night-time</i>
Silent Zone	50	40
Residential Zone	55	45
Commercial Zone	65	55
Industrial Zone	70	70

A standard safe time limit has been set for exposure to various noise levels. Beyond this ‘safe’ time continuing exposure over a period of a year will lead to hearing loss.

<b>Duration</b>	<b>dBA</b>
8 hours	90
4 hours	93
2 hours	96
1 hour	99
30 minutes	102
15 minutes	105
7 minutes	108
4 minutes	111
2 minutes	114
1 minute	117
30 seconds	120
Instantaneous rupture of membrane	150

**Noise Control techniques**

There are four fundamental ways in which noise can be controlled: Reduce noise at the source, block the path of noise, increase the path length and protect the recipient. In general, the best control method is to reduce noise levels at the source.

Source reduction can be done by effectively muffling vehicles and machinery to reduce the noise. In industries noise reduction can be done by using rigid sealed enclosures around machinery lined with acoustic absorbing material. Isolating machines and their enclosures from the floor using special spring mounts or absorbent mounts and pads and using flexible couplings for interior pipelines also contribute to reducing noise pollution at the source.

However one of the best methods of noise source reduction is regular and thorough maintenance of operating machinery. Noise levels at construction sites can be controlled using proper construction planning and scheduling techniques. Locating noisy air compressors and other equipment away from the site boundary along with creation of temporary barriers to physically block the noise can help contribute to reducing noise pollution. Most of the vehicular noise comes from movement of the vehicle tires on the pavement and wind resistance. However poorly maintained vehicles can add to the noise levels. Traffic volume and speed also have significant effects on the overall sound. For example doubling the speed increases the sound levels by about 9 dBA and doubling the traffic volume (number of vehicles per hour) increases sound levels by about 3 dBA. A smooth flow of traffic also causes less noise than does a stop-and-go traffic pattern. Proper highway planning and design are essential for controlling traffic noise. Establishing lower speed limits for highways that pass through residential areas, limiting traffic volume and providing alternative routes for truck traffic are effective noise control measures. The path of traffic noise can also be blocked by construction of vertical barriers alongside the highway. Planting of trees around houses can also act as effective noise barriers. In industries different types of absorptive material can be used to control interior noise. Highly absorptive interior finish material for walls, ceilings and floors can decrease indoor noise levels significantly. Sound levels drop significantly with increasing

distance from the noise source. Increasing the path length between the source and the recipient offers a passive means of control. Municipal land-use ordinances pertaining to the location of airports make use of the attenuating effect of distance on sound levels. Use of earplugs and earmuffs can protect individuals effectively from excessive noise levels. Specially designed earmuffs can reduce the sound level reaching the eardrum by as much as 40 dBA. However very often workers tend not to wear them on a regular basis despite company requirements for their use.

### 5.2.6 Thermal Pollution

**Sources:** The discharge of warm water into a river is usually called a **thermal pollution**. It occurs when an industry removes water from a source, uses the water for cooling purposes and then returns the heated water to its source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity. For efficient functioning of the steam turbines, the steam is condensed into water after it leaves the turbines. This condensation is done by taking water from a water body to absorb the heat. This heated water, which is at least 15°C higher than the normal is discharged back into the water body.

**Effects:** The warmer temperature decreases the solubility of oxygen and increases the metabolism of fish. This changes the ecological balance of the river. Within certain limits thermal additions can promote the growth of certain fish and the fish catch may be high in the vicinity of a power plant. However sudden changes in temperature caused by periodic plant shutdowns both planned and unintentional can change result in death of these fish that are acclimatized to living in warmer waters.

Tropical marine animals are generally unable to withstand a temperature increase of 2 to 3°C

and most sponges, mollusks and crustaceans are eliminated at temperatures above 37°C. This results in a change in the diversity of fauna as only those species that can live in warmer water survive.

**Control measures:** Thermal pollution can be controlled by passing the heated water through a cooling pond or a cooling tower after it leaves the condenser. The heat is dissipated into the air and the water can then be discharged into the river or pumped back to the plant for reuse as cooling water. There are several ways in which thermal pollution can be reduced. One method is to construct a large shallow pond. Hot water is pumped into one end of the pond and cooler water is removed from the other end. The heat gets dissipated from the pond into the atmosphere. A second method is to use a cooling tower. These structures take up less land area than the ponds. Here most of the heat transfer occurs through evaporation. Here warm waters coming from the condenser is sprayed downward over vertical sheets or baffles where the water flows in thin films. Cool air enters the tower through the water inlet that encircles the base of the tower and rises upwards causing evaporative cooling. A natural draft is maintained because of the density difference between the cool air outside and the warmer air inside the tower. The waste heat is dissipated into the atmosphere about 100 m above the base of the tower. The cooled water is collected at the floor of the tower and recycled back to the power plant condensers. The disadvantage in both these methods is however that large amounts of water are lost by evaporation.

### 5.2.7 Nuclear Hazards

Nuclear energy can be both beneficial and harmful depending on the way in which it is used. We routinely use X-rays to examine bones for fractures, treat cancer with radiation and diagnose diseases with the help of radioactive iso-

topes. Approximately 17 % of the electrical energy generated in the world comes from nuclear power plants. However on the other hand it is impossible to forget the destruction that nuclear bombs caused the cities of Hiroshima and Nagasaki. The radioactive wastes from nuclear energy have caused serious environmental damage.

Nuclear fission is the splitting of the nucleus of the atom. The resulting energy can be used for a variety of purposes. The first controlled fission of an atom was carried out in Germany in 1938. However the United States was the first country to develop an atomic bomb which was subsequently dropped on the Japanese cities of Hiroshima and Nagasaki. The world's first electricity generating reactor was constructed in the United States in 1951 and the Soviet Union built its first reactor in 1954. In December 1953, President Dwight D. Eisenhower in his 'Atoms for Peace' speech made the following prediction: *'Nuclear reactors will produce electricity so cheaply that it will not be necessary to meter it. The users will pay a fee and use as much electricity as they want. Atoms will provide a safe, clean and dependable source of electricity.'*

Today however though nuclear power is being used as a reliable source of electricity the above statement sounds highly optimistic. Several serious accidents have caused worldwide concern about safety and disposal of radioactive wastes.

In order to appreciate the consequences of using nuclear fuels to generate energy it is important to understand how the fuel is processed. Low-grade uranium ore, which contains 0.2 percent uranium by weight, is obtained by surface or underground mining. After it is mined the ore goes through a milling process where it is crushed and treated with a solvent to concentrate the uranium and produces yellow cake a material containing 70 to 90 percent uranium oxide. Naturally occurring uranium contains only 0.7 percent of fissionable U-235, which is not

high enough for most types of reactors. Hence it is necessary to increase the amount of U-235 by enrichment though it is a difficult and expensive process. The enrichment process increases the U-235 content from 0.7 to 3 percent. Fuel fabrication then converts the enriched material into a powder, which is then compacted into pellets. These pellets are sealed in metal fuel rods about 4 meters in length which is then loaded into the reactor. As fission occurs the concentration of U-235 atoms decreases. After about three years, a fuel rod does not have enough radioactive material to sustain a chain reaction and hence the spent fuel rods must be replaced by new ones. The spent rods are however still very radioactive containing about one percent U-235 and one percent plutonium. These rods are a major source of radioactive waste material produced by a nuclear reactor.

Initially it was thought that spent fuel rods could be reprocessed to not only provide new fuel but also to reduce the amount of nuclear waste. However the cost of producing fuel rods by reprocessing was found to be greater than the cost of producing fuel rods from ore. Presently India does operate reprocessing plants to reprocess spent fuel as an alternative to storing them as nuclear waste. At each step in the cycle there is a danger of exposure and poses several health and environmental concerns.

Although nuclear power has significant benefits an incident which changed people's attitudes towards nuclear power plants was the Chernobyl disaster that occurred in 1986. Chernobyl is a small city in Ukraine near the border with Belarus north of Kiev. At 1.00 am April 25, 1986 a test to measure the amount of electricity that the still spinning turbine would produce if steam were shut off was being conducted at the Chernobyl Nuclear Power Station-4. This was important information since the emergency core cooling system required energy for its operation and the coasting turbine could provide some of that energy until another source

became available. The amount of steam being produced was reduced by lowering the control rods into the reactor. But the test was delayed because of a demand for electricity and a new shift of workers came on duty. The operators failed to program the computer to maintain power at 700 megawatts and the output dropped to 30 megawatts. This presented an immediate need to rapidly increase the power and many of the control rods were withdrawn. Meanwhile an inert gas (xenon) had accumulated on the fuel rods. The gas absorbed the neutrons and slowed the rate of power increase. In an attempt to obtain more power the operators withdrew all the control rods. This was a second serious safety violation.

At 1.00am, the operators shut off most of the emergency warning signals and turned on all the eight pumps to provide adequate cooling for the reactor following the completion of the test. Just as the final stages for the test were beginning a signal indicated excessive reaction in the reactor. In spite of the warning the operators blocked the automatic reactor shutdown and began the test. As the test continued the power output of the reactor rose beyond its normal level and continued to rise. The operators activated the emergency system designed to put the control rods back into the reactor and stop the fission. But it was already too late. The core had already been deformed and the rods would not fit properly thus the reaction could not be stopped. In 4.5 seconds the energy level of the reactor increased two thousand times. The fuel rods ruptured the cooling water turned into steam and a steam explosion occurred. The lack of cooling water allowed the reactor to explode. The explosion blew the 1000 metric ton concrete roof from the reactor and the reactor caught fire. This resulted in the world's worst nuclear accident and it took ten days to bring the runaway reaction under control.



There were of course immediate fatalities, but the long-term consequences were devastating. 116,000 people were evacuated of which 24,000 had received high doses of radiation. Even today many people suffer from illnesses they feel are related to their exposure to the fallout from Chernobyl. In 1996 ten years after the accident it was clear that one of the long-term effects was the increased frequency of thyroid cancer in children.

The degree and the kind of damage from nuclear accidents vary with the kind of radiation, the amount of radiation, the duration of exposure and the types of cells irradiated. Radiation can also cause mutations which are changes in the genetic makeup of the cells. Mutations can occur in the ovaries or the testes leading to the formation of mutated eggs or sperms which in turn can lead to abnormal offspring. Mutations can also occur in the tissues of the body and may manifest themselves as abnormal tissue growths known as cancer. Two common cancers that are linked to increased radiation exposure are leukemia and breast cancer.

### **5.3 SOLID WASTE MANAGEMENT: CAUSES, EFFECTS AND CONTROL MEASURES OF URBAN AND INDUSTRIAL WASTE**

In ancient cities, food scraps and other wastes were simply thrown into the unpaved streets where they accumulated. Around 320 B.C. in Athens, the first known law forbidding this practice was established and a system of waste removal began to evolve in several eastern Mediterranean cities. Disposal methods were very crude and often were just open pits outside the city walls. As populations increased, efforts were made to transport the wastes out further thus creating city dumps. Until recently the disposal of municipal solid waste did not attract much public attention. The favoured

means of disposal was to dump solid wastes outside the city or village limits.

Around most towns and cities in India the approach roads are littered with multi-coloured plastic bags and other garbage. Waste is also burnt to reduce its volume. Modern methods of disposal such as incineration and the development of sanitary landfills, etc. are now attempting to solve these problems. Lack of space for dumping solid waste has become a serious problem in several cities and towns all over the world. Dumping and burning wastes is not an acceptable practice today from either an environmental or a health perspective. Today disposal of solid waste should be part of an integrated waste management plan. The method of collection, processing, resource recovery and the final disposal should mesh with one another to achieve a common objective.

### **Characteristics of municipal solid waste**

Solid wastes are grouped or classified in several different ways. These different classifications are necessary to address the complex challenges of solid waste management in an effective manner. The term municipal solid waste (MSW) is generally used to describe most of the non-hazardous solid waste from a city, town or village that requires routine collection and transport to a processing or disposal site. Sources of MSW include private homes, commercial establishments and institutions as well as industrial facilities. However MSW does not include wastes from industrial processes, construction and demolition debris, sewage sludge, mining wastes or agricultural wastes.

Municipal solid waste contains a wide variety of materials. It can contain food waste such as vegetable and meat material, left over food, egg shells, etc which is classified as wet garbage as well as paper, plastic, tetrapacks, plastic cans, newspaper, glass bottles, cardboard boxes, alu-

minum foil, metal items, wood pieces, etc. which is classified as dry garbage.

### **Control measures of urban and industrial wastes:**

An integrated waste management strategy includes three main components:

1. Source reduction
2. Recycling
3. Disposal

**Source reduction** is one of the fundamental ways to reduce waste. This can be done by using less material when making a product, reuse of products on site, designing products or packaging to reduce their quantity. On an individual level we can reduce the use of unnecessary items while shopping, buy items with minimal packaging, avoid buying disposable items and also avoid asking for plastic carry bags.

**Recycling** is reusing some components of the waste that may have some economic value. Recycling has readily visible benefits such as conservation of resources reduction in energy used during manufacture and reducing pollution levels. Some materials such as aluminum and steel can be recycled many times. Metal, paper, glass and plastics are recyclable. Mining of new aluminum is expensive and hence recycled aluminum has a strong market and plays a significant role in the aluminum industry. Paper recycling can also help preserve forests as it takes about 17 trees to make one ton of paper. Crushed glass (cullet) reduces the energy required to manufacture new glass by 50 percent. Cullet lowers the temperature requirement of the glassmaking process thus conserving energy and reducing air pollution. However even if recycling is a viable alternative, it presents several problems.

The problems associated with recycling are either technical or economical. Plastics are difficult to recycle because of the different types of polymer resins used in their production. Since each type has its own chemical makeup differ-

ent plastics cannot be recycled together. Thus separation of different plastics before recycling is necessary. Similarly in recycled paper the fibers are weakened and it is difficult to control the colour of the recycled product. Recycled paper is banned for use in food containers to prevent the possibility of contamination. It very often costs less to transport raw paper pulp than scrap paper. Collection, sorting and transport account for about 90 percent of the cost of paper recycling. The processes of pulping, deinking and screening wastepaper are generally more expensive than making paper from virgin wood or cellulose fibers. Very often thus recycled paper is more expensive than virgin paper. However as technology improves the cost will come down.

**Disposal** of solid waste is done most commonly through a sanitary landfill or through incineration. A modern sanitary landfill is a depression in an impermeable soil layer that is lined with an impermeable membrane. The three key characteristics of a municipal sanitary landfill that distinguish it from an open dump are:

- Solid waste is placed in a suitably selected and prepared landfill site in a carefully prescribed manner.
- The waste material is spread out and compacted with appropriate heavy machinery.
- The waste is covered each day with a layer of compacted soil.

The problem with older landfills are associated with groundwater pollution. Pollutants seeping out from the bottom of a sanitary landfill (leachates) very often percolate down to the groundwater aquifer no matter how thick the underlying soil layer. Today it is essential to have suitable bottom liners and leachate collection systems along with the installation of monitoring systems to detect groundwater pollution. The organic material in the buried solid waste



will decompose due to the action of microorganisms. At first the waste decomposes aerobically until the oxygen that was present in the freshly placed fill is used up by the aerobic microorganisms. The anerobes take over producing methane which is poisonous and highly explosive when mixed with air in concentrations between 5 and 15 percent. The movement of gas can be controlled by providing impermeable barriers in the landfill. A venting system to collect the blocked gas and vent it to the surface where it can be safely diluted and dispersed into the atmosphere is thus a necessary component of the design of sanitary landfills.

Even though landfilling is an economic alternative for solid waste disposal, it has become increasingly difficult to find suitable landfilling sites that are within economic hauling distance and very often citizens do not want landfills in their vicinity. Another reason is that no matter how well engineered the design and operation may be, there is always the danger of some environmental damage in the form of leakage of leachates.

**Incineration** is the process of burning municipal solid waste in a properly designed furnace under suitable temperature and operating conditions. Incineration is a chemical process in which the combustible portion of the waste is combined with oxygen forming carbon dioxide and water, which are released into the atmosphere. This chemical reaction called oxidation results in the release of heat. For complete oxidation the waste must be mixed with appropriate volumes of air at a temperature of about 815o C for about one hour. Incineration can reduce the municipal solid waste by about 90 percent in volume and 75 percent in weight. The risks of incineration however involve air-quality problems and toxicity and disposal of the fly and bottom ash produced during the incineration process. Fly ash consists of finely divided particulate matter, including cinders, mineral dust and soot. Most of the incinerator ash is

bottom ash while the remainder is fly ash. The possible presence of heavy metals in incinerator ash can be harmful. Thus toxic products and materials containing heavy metals (for example batteries and plastics) should be segregated. Thus extensive air pollution control equipment and high-level technical supervision and skilled employees for proper operation and maintenance is required.

Thus while sanitary landfills and incinerators have their own advantages and disadvantages, the most effective method of solid waste management is source reduction and recycling.

### **Vermi – Composting**

Nature has perfect solutions for managing the waste it creates, if left undisturbed. The biogeochemical cycles are designed to clear the waste material produced by animals and plants. We can mimic the same methods that are present in nature. All dead and dry leaves and twigs decompose and are broken down by organisms such as worms and insects, and is finally broken down by bacteria and fungi, to form a dark rich soil-like material called compost.

These organisms in the soil use the organic material as food, which provides them with nutrients for their growth and activities. These nutrients are returned to the soil to be used again by trees and other plants. This process recycles nutrients in nature.

This soil can be used as a manure for farms and gardens.

### *Steps for Vermi-Compost*

- Dig a pit about half a meter square, one meter deep.
- Line it with straw or dried leaves and grass.
- Organize the disposal of organic waste into the pit as and when generated.
- Introduce a culture of worms that is now produced commercially.
- Ensure that the contents are covered with a sprinkling of dried leaves and soil everyday.
- Water the pit once or twice a week to keep it moist.
- Turn over the contents of the pit ever 15 days.
- In about 45 days the waste will be decomposed by the action of the microorganisms.
- The soil derived is fertile and rich in nutrients.

## **Hazardous wastes**

Modern society produces large quantities of hazardous waste which are generated by chemical manufacturing companies, petroleum refineries, paper mills, smelters and other industries. Hazardous wastes are those that can cause harm to humans or the environment. Wastes are normally classified as hazardous waste when they cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or pose a sub-

stantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of.

## **Characteristics of hazardous wastes**

A waste is classified as a hazardous waste if it exhibits any of the four primary characteristics based on the physical or chemical properties of toxicity, reactivity, ignitability and corrosivity. In addition to this waste products that are either infectious or radioactive are also classified as hazardous

*Toxic wastes* are those substances that are poisonous even in very small or trace amounts. Some may have an acute or immediate effect on humans or animals causing death or violent illness. Others may have a chronic or long term effect slowly causing irreparable harm to exposed persons. Acute toxicity is readily apparent because organisms respond to the toxin shortly after being exposed. Chronic toxicity is much more difficult to determine because the effects may not be seen for years. Certain toxic wastes are known to be carcinogenic, causing cancer and others may be mutagenic causing biological changes in the children of exposed people and animals.

*Reactive wastes* are those that have a tendency to react vigorously with air or water, are unstable to shock or heat, generate toxic gases or explode during routine management. For example, gunpowder, nitroglycerine, etc.

*Ignitable wastes* are those that burn at relatively low temperatures (less than 60 C) and are capable of spontaneous combustion during storage, transport or disposal. For example, gasoline, paint thinners, and alcohol.

*Corrosive wastes* are those that destroy materials and living tissue by chemical reaction. For example, acids and bases.

*Infectious wastes* include human tissue from surgery, used bandages and hypodermic needles, microbiological materials, etc.

*Radioactive waste* is basically an output from the nuclear power plants and can persist in the environment for thousands of years before it decays appreciably.

### **Environmental problems and health risks caused by hazardous wastes.**

As most of the hazardous wastes are disposed of on or in land the most serious environmental effect is contaminated groundwater. Once groundwater is polluted with hazardous wastes it is very often not possible to reverse the damage.

Pesticides are used increasingly to protect and increase food production. They form residues in the soil which are washed into streams which then carry them forwards. The residues may persist in the soil or in the bottom of lakes and rivers. Exposure can occur through ingestion, inhalation and skin contact resulting in acute or chronic poisoning. Today we have an alternative to the excess use of pesticides through the use of Integrated Pest Management (IPM). The IPM system uses a wide variety of plants and insects to create a more natural process. The natural balance between climate, soil and insect populations can help to prevent an insect from overpopulating an area and destroying a particular crop.

Lead, mercury and arsenic are hazardous substances which are often referred to as heavy metals. Lead is an abundant heavy metal and is relatively easy to obtain. It is used in batteries, fuel, pesticides, paints, pipes and other places where resistance to corrosion is required. Most of the lead taken up by people and wildlife is stored in bones. Lead can affect red blood cells by reducing their ability to carry oxygen and

shortening their life span. Lead may also damage nerve tissue which can result in brain disease.

Mercury occurs in several different forms. Mercury is used in the production of chlorine. It is also used as a catalyst in the production of some plastics. Industrial processes such as the production of chlorine and plastics are responsible for most of the environmental damage resulting from mercury. Our body has a limited ability to eliminate mercury. In the food web mercury becomes more concentrated as it is taken up by various organisms. In an aquatic environment, mercury can be absorbed by the plankton which are then consumed by fish. In addition, fish take up mercury through their gills and by eating

#### **Minamata-An important lesson about mercury**

A case of human mercury poisoning which occurred about forty years ago in the Minamata bay in Japan taught the world an important lesson about the dangers of mercury poisoning. A large plastics plant located near the Minamata bay used a mercury containing compound in a reaction to produce vinyl chloride a common plastic material. The left over mercury was dumped into the Bay along with other wastes from the plant. Though the mercury was in its less toxic inorganic state when dumped microorganisms at the bottom of the bay converted the mercury into its organic form. This organic mercury then entered into the tissues of fish which were in turn consumed by the people living in the area. The contaminated fish thus caused an outbreak of poisoning killing and affecting several people. Mothers who had eaten the contaminated fish gave birth to infants who showed signs of mercury poisoning. Mercury poisoning is thus called Minamata Disease.

other fish contaminated with mercury. Generally older the fish greater is the mercury concentration in its body. Birds that eat the fish concentrate even more mercury in their bodies. It is a cumulative poison ( it builds up in the body over long periods of time) and is known to cause brain damage.

Thousands of chemicals are used in industry everyday. When used incorrectly or inappropriately they can become health hazards. PCBs (Polychlorinated biphenyls) are resistant to fire and do not conduct electricity very well which makes them excellent materials for several industrial purposes. Rainwater can wash PCBs out of disposal areas in dumps and landfills thus contaminating water. PCBs do not break down very rapidly in the environment and thus retain their toxic characteristics. They cause long term exposure problems to both humans and wildlife. PCBs are concentrated in the kidneys and liver and thus cause damage. They cause reproductive failure in birds and mammals.

Vinyl chloride is a chemical that is widely used in the manufacture of plastic. Usually people are only exposed to high levels of vinyl chloride if they work with it or near it but exposure can also occur from vinyl chloride gas leaks. After a long continuous exposure (one to three years) in humans, vinyl chloride can cause deafness, vision problems, circulation disorders and bone deformities. Vinyl chloride can also cause birth defects.

It is essential to substitute the use of PCBs and vinyl chloride with chemicals that are less toxic. Polyvinyl chloride use can be lowered by reducing our use of plastics. Thus by reducing waste, encouraging recycling and using products that are well made and durable we can greatly reduce our consumption of these chemicals thus curtailing our exposure to these substances.

We may not realize it but many household chemicals can be quite toxic to humans as well

as wildlife. Most of the dangerous substances in our homes are found in various kinds of cleaners, solvents and products used in automotive care. When these products are used incorrectly they have the potential to be harmful.

Today the most common methods for disposing off hazardous wastes are land disposal and incineration. In countries where there is abundant land available for disposal for example, North America land disposal is the most widely used method. In countries like Europe and Japan where land is not readily available and is expensive, incineration is the preferred method for disposal. In spite of strong laws however illegal dumping of these wastes continues. Hazardous waste management must move beyond burying and burning. Industries need to be encouraged to generate less hazardous waste in their manufacturing processes. Although toxic wastes cannot be entirely eliminated, technologies are available for minimizing, recycling and treating wastes. An informed public can also contribute in a big way towards this end. It is essential for us to understand the ill effects of chemical substances so that we can make informed decisions about its use. We might decide that the benefits of the use of a toxic substance do not outweigh the risks and choose not to use it at all or we may decide that it is acceptable to use a substance under certain specific circumstances where it is adequately controlled and exposure to toxic levels is prevented.

## **5.4 ROLE OF AN INDIVIDUAL IN PREVENTION OF POLLUTION**

There are a host of environmental problems caused by human actions on the environment. If we are to respond to these problems we have to recognize that each of us is individually responsible for the quality of the environment we live in. Our personal actions can either worsen or improve our environmental quality. Several

people may feel that environmental problems can be solved with quick technological fixes. While a majority of individuals would want a cleaner environment, not many of them want to make major changes in their lifestyle that could contribute to a cleaner environment. Decisions and actions taken by individuals to a very large extent determine the quality of life for everyone. This necessitates that individuals should not only be aware of various environmental issues and the consequences of their actions on the environment but should also make a firm resolve to develop environmentally ethical lifestyles.

With the help of solar energy, natural processes developed over billions of years can indefinitely renew the topsoil, water, air, forests, grasslands and wildlife on which all forms of life depend, but only as long as we do not use these potentially renewable resources faster than they are replenished. Some of our wastes can be diluted, decomposed and recycled by natural processes indefinitely as long as these processes are not overloaded. Natural processes also provide services of flood prevention, erosion control at no costs at all. We must therefore learn to value these resources and use them sustainably.

Concepts that help individuals contribute towards a better quality of our environment and human life.

- Develop respect or reverence for all forms of life.
- Each individual must try to answer four basic questions:  
     Where do the things that I consume come from?  
     What do I know about the place where I live?  
     How am I connected to the earth and other living things?  
     What is my purpose and responsibility as a human being?

- Try to plant trees wherever you can and more importantly take care of them. They reduce air pollution.
- Reduce the use of wood and paper products wherever possible. Manufacturing paper leads to pollution and loss of forests which releases oxygen and takes up carbon dioxide. Try to recycle paper products and use recycled paper wherever possible.
- From the mail you receive reuse as many envelopes that you can.
- Do not buy furniture, doors, window frames made from tropical hardwoods such as teak and mahogany. These are forest based.
- Help in restoring a degraded area near your home or join in an afforestation program.
- Use pesticides in your home only when absolutely necessary and use them in as small amounts as necessary. Some insect species help to keep a check on the populations of pest species.
- Advocate organic farming by asking your grocery store to stock vegetables and fruits grown by an organic method. This will automatically help to reduce the use of pesticides.
- Reduce the use of fossil fuels by either walking up a short distance using a car pool, sharing a bike or using public transport. This reduces air pollution.
- Shut off the lights and fans when not needed.
- Don't use aerosol spray products and commercial room air fresheners. They damage the ozone layer.

- Do not pour pesticides, paints, solvents, oil or other products containing harmful chemicals down the drain or on the ground.
- Buy consumer goods that last, keep them as long as possible and have them repaired as far as possible instead of disposing them off. Such products end up in landfills that could pollute ground water.
- Buy consumer goods in refillable glass containers instead of cans or throwaway bottles.
- Use rechargeable batteries.
- Try to avoid asking for plastic carry bags when you buy groceries or vegetables or any other items. Use your own cloth bag instead.
- Use sponges and washable cloth napkins, dish towels and handkerchiefs instead of paper ones.
- Don't use throwaway paper and plastic plates and cups when reusable versions are available.
- Recycle all newspaper, glass, aluminum and other items accepted for recycling in your area. You might have to take a little trouble to locate such dealers.
- Set up a compost bin in your garden or terrace and use it to produce manure for your plants to reduce use of fertilizers.
- Try to lobby and push for setting up garbage separation and recycling programs in your localities.
- Choose items that have the least packaging or no packaging.
- Start individual or community composting or vermicomposting plants in your neighborhood and motivate people to join in.
- Do not litter the roads and surroundings just because the sweeper from the Municipal Corporation will clean it up. Take care to put trash into dustbins or bring it back home with you where it can be appropriately disposed.
- You must realize that you cannot do everything and have solutions for every problem in the world. You can however concentrate on issues that you feel strongly about and can do something about. Focusing your energy on a particular issue will help you get better results.
- You could join any of the several NGOs that exist in our country or become volunteers. Organize small local community meetings to discuss positive approaches of pollution prevention.
- Learn about the biodiversity of your own area. Understand the natural and cultural assets. This would help you to develop a sense of pride in your city/town/village and will also help you understand the problems facing their survival.
- You cannot improve your world by not voting. You have the option to make a choice rather than complain later on.
- It is important that you do not get discouraged at the first sign of trouble. Do not dwell on the negative aspects. But take positive actions wherever you can to make the world a better place to live in.
- When talking to elected officials always be courteous and reasonable. You may disagree with a particular position but be re-



spectful in doing so as you will gain little by being hostile and brash.

- Take care to put into practice what you preach. Remember environment protection begins with YOU.

## 5.5 POLLUTION CASE STUDIES

### A case study of groundwater pollution in India

An example of groundwater pollution caused by excessive extraction is that fluoride contamination. Fluorosis is not a localized problem. It has spread across 19 states and across a variety of ecological regions ranging from the Thar desert, the Gangetic plains and the Deccan plateau. Each of these regions are distinct in terms of rainfall, soil type, groundwater recharge regime, climatic conditions and hydrology. High fluoride concentration in groundwater is a natural phenomenon in several countries such as China, Sri Lanka, West Indies, Spain, Holland, Italy and Mexico. Experts claim that a fluoride belt stretches across the Middle East across Pakistan and India and then into Southeast Asia and the South of China. According to a report of the Rajiv Gandhi National Drinking Water mission, the bedrock of the Indian peninsula consists of a number of fluoride bearing minerals. When the bedrock weathers the fluoride leaches into water and the soil. Although the Indian peninsular bedrock has always been the same, this problem has only surfaced during the last three decades. This is related to the over extraction of groundwater which has resulted in the tapping of aquifers with high fluoride concentrations.

The beginnings of this phenomenon can be traced back to the 1970s and the 1980s when there was massive state investment in rural water development for irrigation as well as for drinking. Encouraged by state subsidies on diesel and electricity, people invested in diesel and

submersible pumps in a bid to extract groundwater through borewells. This policy aggravated the fluoride problem.

Fluoride mainly enters the human body through drinking water where 96 to 99 percent of it combines with the bones as it has an affinity for calcium phosphate in the bones. Excess intake of fluoride can lead to dental fluorosis, skeletal fluorosis or non-skeletal fluorosis. Dental fluorosis is characterized by discoloured, blackened, mottled or chalky white teeth. Skeletal fluorosis leads to severe and permanent bone and joint deformities. Non-skeletal fluorosis leads to gastro-intestinal problems and neurological disorders. Fluoride can damage the foetus and adversely affect the IQ of children.

Once fluoride is detected in water, the only solution is to defluoridate it. Various technologies are available for this process. However the type of technology to be selected depends upon the fluoride levels in the water and the volume of water to be defluoridated. None of the Indian technologies are however fool-proof. Defluoridation plants and household water treatment kits are stop-gap solutions.

### A case study of pesticide pollution in India

One of the most terrifying effects of pesticide contamination of ground water came to light when pesticide residues were found in bottled water. Between July and December 2002, the Pollution Monitoring Laboratory of the New Delhi based Center for Science and Environment (CSE) analysed 17 brands of bottled water both packaged drinking water and packaged natural mineral water commonly sold in areas that fall within the national capital region of Delhi. Pesticide residues of organochlorine and organophosphorus pesticides which are most commonly used in India were found in all the samples. Among organochlorines, gamma-hexachlorocyclohexane (lindane) and DDT were

prevalent while among organophosphorus pesticides, Malathion and Chlorpyrifos were most common. All these were present above permissible limits specified by the European Economic Community, which is the norm, used all over Europe.

One may wonder as to how these pesticide residues get into bottled water that is manufactured by several big companies. This can be traced to several facts. There is no regulation that the bottled water industry must be located in 'clean' zones. Currently the manufacturing plants of most brands are situated in the dirtiest industrial estates or in the midst of agricultural fields. Most companies use bore wells to pump out water from the ground from depths varying from 24m to even 152 m below the ground. The raw water samples collected from the plants also revealed the presence of pesticide residues. This clearly indicated that the source of pesticide residues in the polluted groundwater are used to manufacture the bottled water. This is despite the fact that all bottled water plants use a range of purification methods. Thus obviously the fault lies in the treatment methods used.

These plants use the membrane technology where the water is filtered using membranes with ultra-small pores to remove fine suspended solids and all bacteria and protozoa and even viruses. While nanofiltration can remove insecticides and herbicides it is expensive and thus rarely used. Most industries also use an activated charcoal adsorption process, which is effective in removing organic pesticides but not heavy metals. To remove pesticides the plants use reverse osmosis and granular activated charcoal methods. Thus even though manufacturers claim to use these process the presence of pesticide residues points to the fact that either manufacturers do not use the treatment process effectively or only treat a part of the raw water.

The low concentration of pesticide residues in bottled water do not cause acute or immediate effect. However repeated exposure even to extremely miniscule amounts can result in chronic effects like cancer, liver and kidney damage, disorders of the nervous system, damage to the immune system and birth defects.

Similarly six months after CSE reported pesticide residues in bottled water it also found these pesticides in popular cold drink brands sold across the country. This is because the main ingredient in a cold drink or a carbonated non-alcoholic beverage is water and there are no standards specified for water to be used in these beverages in India.

There were no standards for bottled water in India till on September 29, 2000 the Union Ministry of Health and Family Welfare issued a notification (no759(E)) amending the Prevention of Food Adulteration Rules, 1954. The BIS (Bureau of Indian Standards) certification mark became mandatory for bottled water from March 29, 2001. However the parameters for pesticide residues remained ambiguous. Following the report published by CSE in *Down to Earth*, Vol 11, no. 18, a series of Committees were established and eventually on 18<sup>th</sup> July 2003 amendments were made in the Prevention of Food Adulteration Rules stating that pesticide residues considered individually should not exceed 0.0001mg.lit and the total pesticide residues will not be more than 0.0005 mg/lit that the analysis shall be conducted by using internationally established test methods meeting the residue limits specified herein. This notification came into force from January 1, 2004.

### **A case study of river pollution in India**

Almost all the rivers in India are polluted. The causes of pollution may also be more or less similar. This is a case study of the river Damodar as reported in *Down to Earth*. The 563 km long

Damodar river originates near Chandwa village in the Chhotanagpur hills in Bihar's Palamau district. It flows through one of the richest mineral belts in the world before draining into the Hooghly, about 50 km south of Calcutta. Indian industry depends heavily on this region as 60 percent of the coal consumed in our country comes from the Chhotanagpur belt. Coal based industries of all types dot the area because of locational advantages and the easy availability of water and power. In addition various industries such as the steel, cement, fertilizer and explosive plants are also located here. The river Damodar is polluted with minerals, mine rejects and toxic effluents. Both its water and its sand are infested by coal dust and waste from these industries. There are seven thermal power plants in the Damodar valley. The states of Bihar and West Bengal depend almost entirely on this area for their power requirements. These power plants not only consume a lot of water but also dump ash in the valley.

### *Mining*

As underground mines cannot keep pace with the rising demand, 60 percent of the coal extracted from the area comes from open cast mines which are responsible for serious land degradation. The disposal of rock and soil extracted along with the coal only adds to the problem.

### *Industries*

The industries in the area do not have proper effluent treatment plants. Among the big coal based industries the washeries account for the bulk of the pollution in terms of the total suspended solids (TSS), oil and grease. About 20 percent of the coal handled goes out in the form of slurry which is deposited in the ponds outside. After the slurry settles, coalfine (the sediment) is collected manually. Due to inadequate retrieval methods very often the water discharges into the river from the pond carries high

amounts of fine coal particles and oil thus polluting the river. The other major coal based polluters are the coke oven plants that heat coal to temperatures as high as 1100°C in the absence of oxygen to prepare it for use in blast furnaces and foundries. The volatile components in the coal are removed, leaving hot, non-volatile coke in the oven which is washed with huge quantities of water. This water that contains oil and suspended particles is then discharged into the river.

### *Flyash from the thermal power plants*

Only one of the thermal power plants has an electrostatic precipitator to collect the fly ash while the other just make do with mechanical dust collectors. As most of these plants are located on the banks of the river the fly ash eventually finds its way into the river. The bottom ash from the boilers is mixed with water to form a slurry which is then drained into ash ponds. Most of the ponds are full and in several cases the drainage pipes are choked. The slurry is therefore directly discharged into the river.

### *Effects*

The river and its tributaries are the largest source of drinking water for the huge population that lives in the valley. On April 2, 1990 about 200,000 litres of furnace oil spilled into the river from the Bokaro Steel Plant. This oil traveled 150 km downstream to Durgapur. For a week after the incident five million people drank contaminated water in which the oil levels were 40 to 80 times higher than the permissible value of 0.03 mg/l.

The Damodar Action Plan an end-of-the pipe pollution treatment scheme seeks to tackle effluents. One viable option could be to switch to less polluting industries and cleaner technology. This would need strong Government initiative and also a mass movement by people.

### *Pollution*

## 5.6 DISASTER MANAGEMENT: FLOODS, EARTHQUAKES, CYCLONES, LANDSLIDES

The Indian subcontinent is very vulnerable to droughts, floods, cyclones, earthquakes, landslides, avalanches and forest fires. Among the 36 states and Union territories in the country, 22 are prone to disasters.

Among all the disasters that occur in the country, floods are the most frequently occurring natural disasters, due to the irregularities of the Indian monsoon. About 75 percent of the annual rainfall in India is concentrated in three to four months of the monsoon season. As a result there is a very heavy discharge from the rivers during this period causing widespread floods. Approximately 40 million hectares of land in the country has been identified as being prone to floods. Major floods are mainly caused in the Ganga-Brahmaputra-Meghna basin which carries 60 percent of the total river flow of our country.

India has a long coastline of 5700 kms, which is exposed to tropical cyclones arising in the Bay of Bengal and the Arabian sea. The Indian Ocean is one of the six major cyclone prone regions of the world. In India, cyclones occur usually between April and May and also between October and December. The eastern coastline is more prone to cyclones as it is hit by about 80 percent of the total cyclones generated in the region.

Droughts are a perennial feature in some states of India. Sixteen percent of the country's total area is drought prone. Drought is a significant environmental problem as it is caused by a lower than average rainfall over a long period of time. Most of the drought prone areas identified by the Government lie in the arid and semi-arid areas of the country.

Earthquakes are considered to be one of the most destructive natural hazards. The impact of

this phenomenon occurs with so little warning that it is almost impossible to make preparations against damages and collapse of buildings. About 50 to 60 percent of India is vulnerable to seismic activity of varying intensities. Most of the vulnerable areas are located in the Himalayan and sub-Himalayan regions.

### From management to mitigation of disasters

Till very recently the approach towards dealing with natural disasters has been post disaster management involving problems such as evacuation, warnings, communications, search and rescue, fire-fighting, medical and psychiatric assistance, provision of relief, shelter, etc. After the initial trauma and the occurrence of the natural disaster is over and reconstruction and rehabilitation is done by people, NGOs and the Government, its memories are relegated to history.

It is evident today that human activities are responsible for accelerating the frequency and severity of natural disasters. Natural occurrences such as floods, earthquakes, cyclones, etc. will always occur. They are a part of the environment that we live in. However destruction from natural hazards can be minimized by the presence of a well functioning warning system combined with preparedness on part of the community that will be affected. Thus though traditionally disaster management consisted primarily of reactive mechanisms, the past few years have witnessed a gradual shift towards a more proactive, mitigation based approach.

Disaster management is a multidisciplinary area in which a wide range of issues that range from forecasting, warning, evacuation, search and rescue, relief, reconstruction and rehabilitation are included. It is also multi-sectoral as it involves administrators, scientists, planners, volunteers and communities. These roles and activities span

the pre-disaster, during disaster and post disaster plans. Since their activities are complementary as well as supplementary to each other there is a critical need for coordinating these activities.

In order to transfer the benefits of scientific research and development to the communities links must be developed between scientific communities and field agencies. Coordination between Government agencies and NGOs needs to be built up so that overlap of activities may be avoided and linkages between the Government and communities are established.

Today we have a range of early warning systems for a range of natural hazards. Although they are more accurate than before and can help in prediction it is not enough to ensure communities are safe from disasters. This is where disaster mitigation can play an important role. Mitigation means lessening the negative impact of the natural hazards. It is defined as sustained action taken to reduce long term vulnerability of human life and property to natural hazards. While the preparatory, response and the recovery phases of emergency management relate to specific events, mitigation activities have the potential to produce repetitive benefits over time.

Certain guidelines if followed can result in an effective mitigation program.

- Pre-disaster mitigation can help in ensuring faster recovery from the impacts of disasters.
- Mitigation measures must ensure protection of the natural and cultural assets of the community.
- Hazard reduction methods must take into account the various hazards faced by the affected community and their desires and priorities.

- Any mitigation program must also ensure effective partnership between Government, scientific, private sector, NGOs and the community.

The main elements of a mitigation strategy are as follows:

#### *Risk assessment and Vulnerability analysis*

This involves identification of hot spot areas of prime concern, collection of information on past natural hazards, information of the natural ecosystems and information on the population and infrastructure. Once this information is collected a risk assessment should be done to determine the frequency, intensity, impact and the time taken to return to normalcy after the disaster. The assessment of risk and vulnerabilities will need to be revised periodically. A regular mechanism will therefore have to be established for this. The use of Geographical Information Systems (GIS) a computer program can be a valuable tool in this process as the primary data can be easily updated and the corresponding assessments can be made.

#### *Applied research and technology transfer*

There is a need to establish or upgrade observation equipment and networks, monitor the hazards properly, improve the quality of forecasting and warning, disseminate information quickly through the warning systems and undertake disaster simulation exercises.

Thus space technologies such as remote sensing, satellite communications and Global Positioning Systems have a very important role to play. Government organizations like ISRO (Indian Space Research Organization) can play a vital role. Similarly Government organizations the National Building Research Organization, the Meteorological Department, Irrigation Department, etc. can undertake applied research for devising locale specific mitigation strategies in

collaboration with educational institutions or Universities.

Such steps could lead to the formulation of locale specific mitigation measures. A combination of scientific knowledge and expertise with the community based mitigation measures would not only enhance the database but would also form the basis of a successful mitigation strategy.

#### *Public awareness and training*

One of the most critical components of a mitigation strategy is the training to be imparted to the officials and staff of the various departments involved at the state and the district level. This enables sharing of information and methodology. The success of a mitigation strategy will depend to a large extent on the inter-sectional, inter-departmental coordination and efficient teamwork. Thus a training program that is designed after assessment of gaps in knowledge, skills and attitude with respect to the various tasks that need to be undertaken is a vital component.

#### *Institutional mechanisms*

The most important need at the National level is to strengthen or develop the capacity to undertake disaster mitigation strategies. There is a need to emphasize on proactive and pre-disaster measures rather than post disaster response. It is thus essential to have a permanent administrative structure which can monitor the developmental activities across departments and provides suggestions for necessary mitigation measures. The National Disaster Management Center (NDMC) can perform such a task. Professionals like architects, structural engineers, doctors, chemical engineers who are involved with management of hazardous chemicals can be asked to form groups that can design specific mitigation measures.

#### *Incentives and resources for mitigation*

To a very large extent the success of mitigation programs will depend upon the availability of continued funding. There is thus a need to develop mechanisms to provide stable sources of funding for all mitigation programs. This will include incentives for relocation of commercial and residential activities outside the disaster prone areas. Housing finance companies should make it mandatory for structures in such hazard prone areas to follow special building specifications. The introduction of disaster linked insurance should be explored and should cover not only life but also household goods, cattle, structures and crops.

#### *Landuse planning and regulations*

Long term disaster reduction efforts should aim at promoting appropriate land-use in the disaster prone areas. Separation of industrial areas from residential areas, maintaining wetlands as buffer zones for floods, creation of public awareness of proper land practices and formation of land-use policies for long term sustainable development is imperative.

#### *Hazard resistant design and construction*

In areas that are prone to disasters protection can be enhanced by careful selection of sites and the way the buildings are built. Thus it is essential to promote the knowledge of disaster resistant construction techniques and practices among engineers, architects and technical personnel.

#### *Structural and Constructional reinforcement of existing buildings*

It is also possible to reduce the vulnerability of existing buildings through minor adaptations or alterations thereby ensuring their safety. This can be done by insertion of walls on the outside of the building, buttresses, walls in the interior of the building, portico fill-in-walls, specially an-



chored frames, covering of columns and beams, construction of new frame system, placing residential electrical equipment above flood level, designing water storage tanks to be able to withstand cyclonic winds, earthquakes and floods, etc.

## **Floods and mitigation measures**

The lower plain regions of India in particular Bihar, Uttar Pradesh and West Bengal in respect of the Ganga and Assam in respect of the Brahmaputra suffer from the adverse effects of floods every year. The Ganga Brahmaputra basin receives maximum run off within the three monsoon months. Based on hydrological studies carried out, it is estimated that only 18 percent of the rainwater can be stored in dams, reservoirs, etc. while 82 percent of the rainwater flows through rivers ultimately into the sea. Floods are therefore a recurring phenomenon in our country.

Floods can be caused by natural, ecological or anthropogenic factors either individually or as a combined result. Anthropogenic activities such as deforestation and shifting cultivation can also contribute to floods. Forests on the hill slopes normally exert a sponge effect soaking up the abundant rainfall and storing it before releasing it in small amounts over a period of time. However when the forests are cleared the rivers turn muddy and swollen during the wet monsoon season and run dry later on in the year during the drier periods. An increasing proportion of the rainfall is therefore released shortly after precipitation in the form of floods.

The mitigation measures for floods include both structural and non-structural measures. The structural measures include:

- Reservoirs for impounding monsoon flows to be released in a regulated manner after the peak flood flow passes.

- Prevention of over-bank spilling by the construction of embankments and floodwalls.
- Improvement of flow conditions in the channel and anti-erosion measures.
- Improved drainage.

The non-structural measures include:

- Flood plain management such as Flood Plain Zoning and Flood Proofing including Disaster Preparedness
- Maintaining wetlands
- Flood forecasting and warning services
- Disaster relief, flood fighting and public health measures
- Flood insurance

## **Earthquakes and mitigation measures**

It has been several years since the earthquake struck Gujarat on January 26, 2001. In these years rehabilitation has been done on a massive scale. Gujarat's experience has taught that building shelters with less vulnerability to earthquakes should also take into consideration the specific needs of the victims instead of being a top down approach. The role of NGOs in this is very important. Their strength lies in their manpower, informality in operations and valuable human resources. Their ability to reach out to the community and sensitivity to local traditions is an asset in such situations. A report on the various initiatives in Gujarat reported in Down to Earth (Vol 12, No. 2) by Mihir Bhatt throws light on the various developments that have taken place after the earthquake. According to the report the initiatives of the International Fund for

Agriculture Development in supporting the Self Employed Women's Association and the Government's initiative in community based livelihood security for earthquakes and drought victims have the potential to shape future disaster response and development projects in Gujarat. Similarly the Gujarat Woman's Economic Development Corporation initiative in reviving women's businesses after the calamity also provides many practical lessons in regenerating local economies and artisan markets. This project supported by the Asian Development Bank, puts premium on investments in income generation and asset building after a natural disaster. The farming kits provided to affected farmers by Gujarat's agriculture ministry is also showing promising results after two seasons. The author however states that coordination between Government, local NGOs and local community initiatives both for rescue as well as rehabilitation needs to be strengthened as this can cause delays, overlaps and waste of relief material and efforts.

## Cyclones and mitigation measures

Tropical cyclones are the worst natural hazards in the tropics. They are large revolving vortices in the atmosphere extending horizontally from 150 to 1000 km and vertically from the surface to 12 to 14 km. These are intense low-pressure areas. Strong winds spiraling anti clockwise in the Northern Hemisphere blow around the cyclone center at the lower level. At the higher levels the sense of rotation is just opposite to that at the lower level. They generally move 300 to 5000 km per day over the ocean. While moving over the ocean they pick up energy from the warm water of the ocean and some of them grow into a devastating intensity. On an average about 5 to 6 tropical cyclones form in the Bay of Bengal and the Arabian Sea every year out of which 2 to 3 may be severe. More cyclones form in the Bay of Bengal than in the Arabian Sea. The main dangers from cyclones

are very strong winds, torrential rains and high storm tides. Most of the casualties are caused by coastal inundation by storm tides. This is often followed by heavy rainfall and floods. Storm surges cause the greatest destruction.

Although one cannot control cyclones, the effects of cyclones can be mitigated through effective and efficient mitigation policies and strategies. A brief description of the same is given below.

*Installation of early warning systems:* Such systems fitted along the coastlines can greatly assist forecasting techniques thus helping in early evacuation of people in the storm surge areas.

*Developing communication infrastructure:* Communication plays a vital role in cyclone disaster mitigation and yet this is one of the first services that gets disrupted during cyclones. Amateur Radio has today emerged as a second line unconventional communications systems and is an important tool for disaster mitigation.

*Developing shelter belts:* Shelter belts with plantations of trees can act as effective wind and tide breakers. Apart from acting as effective windbreakers and protecting soil crops from being damaged they prevent soil erosion.

*Developing community cyclone shelters:* Cyclone shelters at strategic locations can help minimizing the loss of human life. In the normal course these shelters can be used as public utility buildings.

*Construction of permanent houses:* There is a need to build appropriately designed concrete houses that can withstand high winds and tidal waves.

*Training and education:* Public awareness programs that inform the population about their response to cyclone warnings and preparedness can go a long way in reducing casualties.

*Landuse control and settlement planning:* No residential and industrial units should be ideally permitted in the coastal belt of 5 km from the sea as it is the most vulnerable belt. No further growth of settlements in this region should allowed. Major settlements and other important establishments should be located beyond 10 km from the sea.

## **Landslides and mitigation measures**

Landslides are recurring phenomena in the Himalayan region. In the recent years however intensive construction activity and the destabilizing forces of nature have aggravated the problem. Landslides occur as a result of changes on a slope, sudden or gradual, either in its composition, structure, hydrology or vegetation. The changes can be due to geology, climate, weathering, land-use and earthquakes.

A significant reduction in the hazards caused by landslides can be achieved by preventing the exposure of population and facilities to landslides and by physically controlling the landslides. Developmental programs that involve modification of the topography, exploitation of natural resources and change in the balance load on the ground should not be permitted. Some critical measures that could be undertaken to prevent further landslides are drainage measures, erosion control measures such a bamboo check dams, terracing, jute and coir netting and rock-fall control measures such as grass plantation, vegetated dry masonry wall, retaining wall and most importantly preventing deforestation and improving afforestation.

Disasters cannot be totally prevented. However early warning systems, careful planning and preparedness on part of the vulnerable community would help in minimizing the loss of life and property due to these disasters.

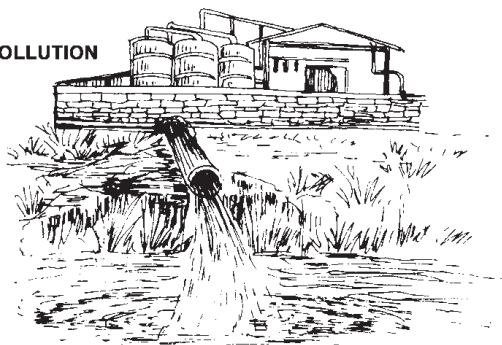
**UNIT 5:**  
**Pollution**

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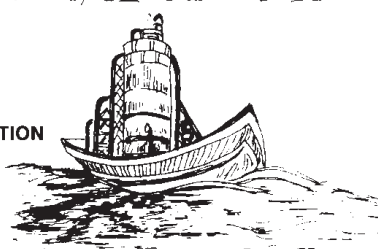
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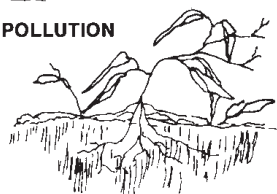
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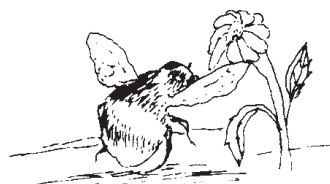
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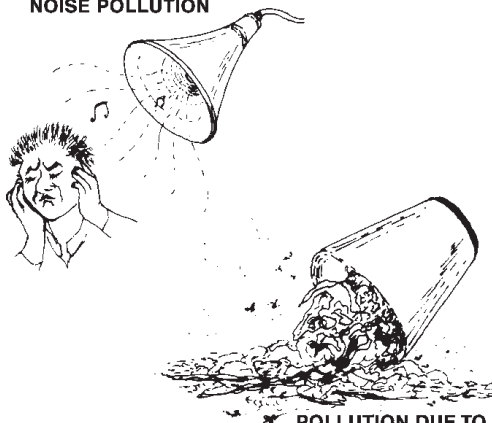
**SOIL POLLUTION**



**LOSS OF RENEWABLE RESOURCES**



**NOISE POLLUTION**



**POLLUTION DUE TO GARBAGE**

'We spray our elms, and the following spring, trees are silent of robin song, not because we sprayed the robins directly but because the poison traveled step by step through the now familiar elm-earthworm-robin cycle'

– Rachael Carson

book has inspired controversy and has initiated a major change in thinking about the safety of using pesticides and other toxic chemicals.

## 5.1 DEFINITION

*Pollution* is the effect of undesirable changes in our surroundings that have harmful effects on plants, animals and human beings. This occurs

This quotation appeared in Rachael Carson's book entitled *Silent Spring*. In the years following the publication of *Silent Spring* in 1962, the

when only short-term economic gains are made at the cost of the long-term ecological benefits for humanity. No natural phenomenon has led to greater ecological changes than have been made by mankind. During the last few decades we have contaminated our air, water and land on which life itself depends with a variety of waste products.

Pollutants include solid, liquid or gaseous substances present in greater than natural abundance produced due to human activity, which have a detrimental effect on our environment. The nature and concentration of a pollutant determines the severity of detrimental effects on human health. An average human requires about 12 kg of air each day, which is nearly 12 to 15 times greater than the amount of food we eat. Thus even a small concentration of pollutants in the air becomes more significant in comparison to the similar levels present in food. Pollutants that enter water have the ability to spread to distant places especially in the marine ecosystem.

From an ecological perspective pollutants can be classified as follows:

**Degradable or non-persistent pollutants:** These can be rapidly broken down by natural processes. Eg: domestic sewage, discarded vegetables, etc.

**Slowly degradable or persistent pollutants:** Pollutants that remain in the environment for many years in an unchanged condition and take decades or longer to degrade. Eg: DDT and most plastics.

**Non-degradable pollutants:** These cannot be degraded by natural processes. Once they are released into the environment they are difficult to eradicate and continue to accumulate. Eg: toxic elements like lead or mercury.

## 5.2 CAUSES, EFFECTS AND CONTROL MEASURES OF POLLUTION

### 5.2.1 Air Pollution

**History of air pollution:** The origin of air pollution on the earth can be traced from the times when man started using firewood as a means of cooking and heating. Hippocrates has mentioned air pollution in 400 BC. With the discovery and increasing use of coal, air pollution became more pronounced especially in urban areas. It was recognized as a problem 700 years ago in London in the form of smoke pollution, which prompted King Edward I to make the first antipollution law to restrict people from using coal for domestic heating in the year 1273. In the year 1300 another Act banning the use of coal was passed. Defying the law led to imposition of capital punishment. In spite of this air pollution became a serious problem in London during the industrial revolution due to the use of coal in industries. The earliest recorded major disaster was the 'London Smog' that occurred in 1952 that resulted in more than 4000 deaths due to the accumulation of air pollutants over the city for five days.

In Europe, around the middle of the 19<sup>th</sup> century, a black form of the Peppered moth was noticed in industrial areas. Usually the normal Peppered moth is well camouflaged on a clean lichen covered tree. However the peppered pattern was easily spotted and picked up by birds on the smoke blackened bark of trees in the industrial area, while the black form remained well camouflaged. Thus while the peppered patterned moths were successful in surviving in clean non-industrial areas, the black coloured moths were successful in industrial areas. With the spread of industrialization, it has been observed that the black forms are not only seen in Peppered moth, but also in many other moths. This is a classic case of pollution leading to adaptation.



Air pollution began to increase in the beginning of the twentieth century with the development of the transportation systems and large-scale use of petrol and diesel. The severe air quality problems due to the formation of photochemical smog from the combustion residues of diesel and petrol engines were felt for the first time in Los Angeles. Pollution due to auto-exhaust remains a serious environmental issue in many developed and developing countries including India.

The Air Pollution Control Act in India was passed in 1981 and the Motor Vehicle Act for controlling the air pollution, very recently. These laws are intended to prevent air from being polluted.

The greatest industrial disaster leading to serious air pollution took place in Bhopal where extremely poisonous methyl isocyanide gas was accidentally released from the Union Carbide's pesticide manufacturing plant on the night of December 3<sup>rd</sup> 1984. The effects of this disaster on human health and the soil are felt even today.

## Structure of the atmosphere

The atmosphere is normally composed of 79 percent nitrogen, 20 percent oxygen and one percent as a mixture of carbon dioxide, water vapour and trace amounts of several other gases such as neon, helium, methane, krypton, hydrogen and xenon. The general structure of the atmosphere has several important features that have relevance to environmental problems. The atmosphere is divided into several layers.

The innermost layer the *troposphere* extends 17 kilometers above sea level at the equator and about 8 kilometers over the poles. It contains about 75 percent of the mass of the earth's air. The fragility of this layer is obvious from the fact that if the earth were an apple this particular layer would be no thicker than an apple's skin.

Temperature declines with altitude in the troposphere. At the top of the troposphere temperatures abruptly begin to rise. This boundary where this temperature reversal occurs is called the tropopause.

The tropopause marks the end of the troposphere and the beginning of the *stratosphere*, the second layer of the atmosphere. The stratosphere extends from 17 to 48 kilometers above the earth's surface. While the composition of the stratosphere is similar to that of the troposphere it has two major differences. The volume of water vapour here is about 1000 times less while the volume of ozone is about 1000 times greater. The presence of ozone in the stratosphere prevents about 99 percent of the sun's harmful ultraviolet radiation from reaching the earth's surface thus protecting humans from cancer and damage to the immune system. This layer does not have clouds and hence airplanes fly in this layer as it creates less turbulence. Temperature rises with altitude in the stratosphere until there is another reversal. This point is called the stratopause and it marks the end of the stratosphere and the beginning of the atmosphere's next layer, the mesosphere.

In the *mesosphere* the temperature decreases with altitude falling up to  $-110^{\circ}\text{C}$  at the top. Above this is a layer where ionization of the gases is a major phenomenon, thus increasing the temperature. This layer is called the *thermosphere*. Only the lower troposphere is routinely involved in our weather and hence air pollution. The other layers are not significant in determining the level of air pollution.

## Types and sources of Air Pollution

### What is air pollution?

Air pollution occurs due to the presence of undesirable solid or gaseous particles in the air in quantities that are harmful to human health and the environment. Air may get polluted by natu-

ral causes such as volcanoes, which release ash, dust, sulphur and other gases, or by forest fires that are occasionally naturally caused by lightning. However, unlike pollutants from human activity, naturally occurring pollutants tend to remain in the atmosphere for a short time and do not lead to permanent atmospheric change.

Pollutants that are emitted directly from identifiable sources are produced both by natural events (for example, dust storms and volcanic eruptions) and human activities (emission from vehicles, industries, etc.). These are called *primary pollutants*. There are five primary pollutants that together contribute about 90 percent of the global air pollution. These are carbon oxides (CO and CO<sub>2</sub>), nitrogen oxides, sulfur oxides, volatile organic compounds (mostly hydrocarbons) and suspended particulate matter.

Pollutants that are produced in the atmosphere when certain chemical reactions take place among the primary pollutants are called *secondary pollutants*. Eg: sulfuric acid, nitric acid, carbonic acid, etc.

*Carbon monoxide* is a colourless, odorless and toxic gas produced when organic materials such as natural gas, coal or wood are incompletely burnt. Vehicular exhausts are the single largest source of carbon monoxide. The number of vehicles has been increasing over the years all over the world. Vehicles are also poorly maintained and several have inadequate pollution control equipment resulting in release of greater amounts of carbon monoxide. Carbon monoxide is however not a persistent pollutant. Natural processes can convert carbon monoxide to other compounds that are not harmful. Therefore the air can be cleared of its carbon monoxide if no new carbon monoxide is introduced into the atmosphere.

*Sulfur oxides* are produced when sulfur containing fossil fuels are burnt.

*Nitrogen oxides* are found in vehicular exhausts. Nitrogen oxides are significant, as they are involved in the production of secondary air pollutants such as ozone.

*Hydrocarbons* are a group of compounds consisting of carbon and hydrogen atoms. They either evaporate from fuel supplies or are remnants of fuel that did not burn completely. Hydrocarbons are washed out of the air when it rains and run into surface water. They cause an oily film on the surface and do not as such cause a serious issue until they react to form secondary pollutants. Using higher oxygen concentrations in the fuel-air mixture and using valves to prevent the escape of gases, fitting of catalytic converters in automobiles, are some of the modifications that can reduce the release of hydrocarbons into the atmosphere.

*Particulates* are small pieces of solid material (for example, smoke particles from fires, bits of asbestos, dust particles and ash from industries) dispersed into the atmosphere. The effects of particulates range from soot to the carcinogenic (cancer causing) effects of asbestos, dust particles and ash from industrial plants that are dispersed into the atmosphere. Repeated exposure to particulates can cause them to accumulate in the lungs and interfere with the ability of the lungs to exchange gases.

*Lead* is a major air pollutant that remains largely unmonitored and is emitted by vehicles. High lead levels have been reported in the ambient air in metropolitan cities. Leaded petrol is the primary source of airborne lead emissions in Indian cities.

Pollutants are also found indoors from infiltration of polluted outside air and from various chemicals used or produced inside buildings. Both indoor and outdoor air pollution are equally harmful.

Types of particulates

Term	Meaning	Examples
Aerosol	General term for particles suspended in air	Sprays from pressurized cans
Mist	Aerosol consisting of liquid droplets	Sulfuric acid mist
Dust	Aerosol consisting of solid particles that are blown into the air or are produced from larger particles by grinding them down	Dust storm
Smoke	Aerosol consisting of solid particles or a mixture of solid and liquid particles produced by chemical reaction such as fires	Cigarette smoke, smoke from burning garbage
Fume	Generally means the same as smoke but often applies specifically to aerosols produced by condensation of hot vapors of metals.	Zinc/lead fumes
Plume	Geometrical shape or form of the smoke coming out of a chimney	
Fog	Aerosol consisting of water droplets	
Smog	Term used to describe a mixture of smoke and fog.	

What happens to pollutants in the atmosphere?

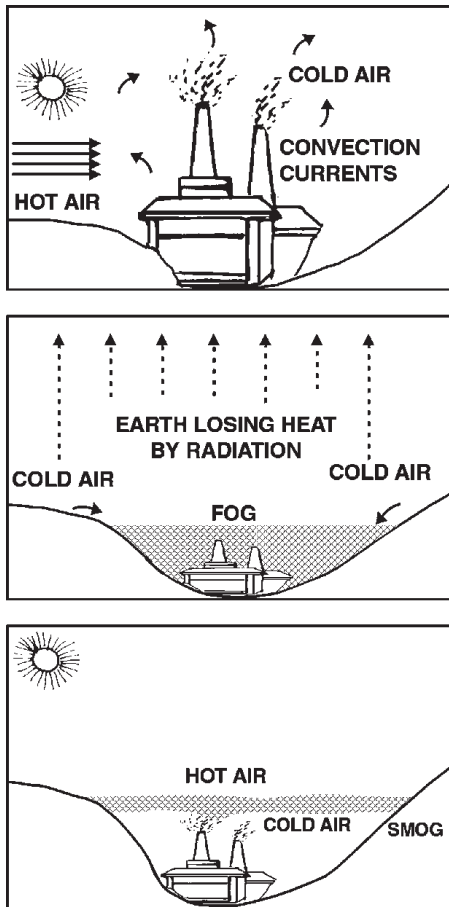
Once pollutants enter the troposphere they are transported downwind, diluted by the large volume of air, transformed through either physical or chemical changes or are removed from the atmosphere by rain during which they are attached to water vapour that subsequently forms rain or snow that falls to the earth’s surface. The atmosphere normally disperses pollutants by mixing them in the very large volume of air that covers the earth. This dilutes the pollutants to acceptable levels. The rate of dispersion however varies in relation to the following aspects:

Topography

Normally as the earth’s surface becomes warmed by sunlight the layer of air in contact with the ground is also heated by convection. This warmer air is less dense than the cold air above it, so it rises. Thus pollutants produced in the surface layer are effectively dispersed.

However on a still evening, the process is reversed. An hour or two before sunset after a sunny day, the ground starts to lose heat and the air near the ground begins to cool rapidly. Due to the absence of wind, a static layer of cold air is produced as the ground cools. This in turn induces condensation of fog. The morning sun cannot initially penetrate this fog layer. The

cold air being dense cannot rise and is trapped by the warm air above. It cannot move out of the area due to the surrounding hills. The topographic features resemble a closed chemical reactor in which the pollutants are trapped. This condition often continues through the cool night and reaches its maximum intensity before sunrise. When the morning sun warms the ground the air near the ground also warms up and rises within an hour or two. This may be broken up by strong winds. In cold regions this situation can persist for several days. Such a situation is known as smog (smoke + fog).

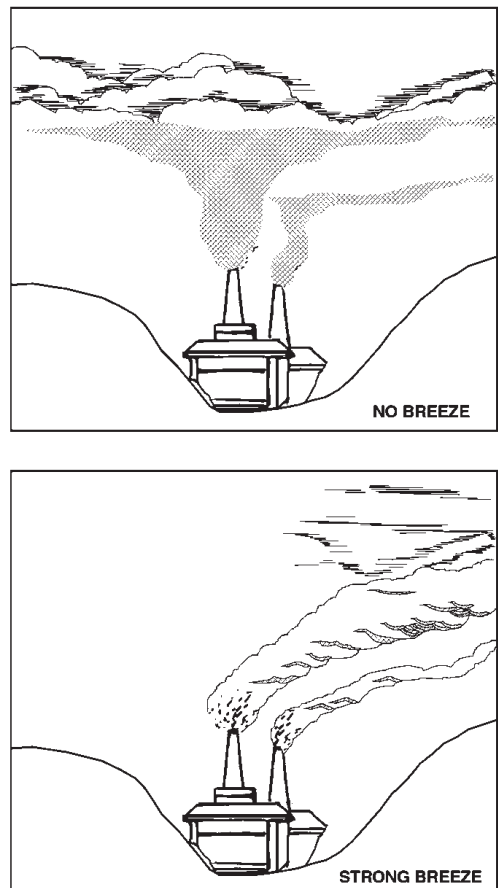


The most well known example is that of the 'London Smog' that occurred in 1952. The city used large quantities of sulphur containing coal for domestic heating that released smoke, along with smoke from thermal power plants and

other industrial establishments. This used to lead to the generation of high levels of smoke containing sulphur oxides. Due to a sudden adverse meteorological condition air pollutants like smoke and sulphur oxides started to build-up in the atmosphere. The white fog accumulated over the city turned black forming a 'pea-soup' smog with almost zero visibility. Within two days of the formation of this smog, people started suffering from acute pulmonary disorders which caused irritation of bronchi, cough, nasal discharges, sore throat, vomiting and burning sensations in the eyes. This event led to several deaths.

#### *Meteorological conditions*

The velocity of the wind affects the dispersal of pollutants. Strong winds mix polluted air more rapidly with the surrounding air diluting the pollutants rapidly. When wind velocity is low mixing takes place and the concentration of pollutants remains high.



When sulphur dioxide and nitrogen oxides are transported by prevailing winds they form secondary pollutants such as nitric acid vapour, droplets of sulfuric acid and particles of sulphate and nitrate salts. These chemicals descend on the earth's surface in two forms: wet (as acidic rain, snow, fog and cloud vapour) and dry (as acidic particles). The resulting mixture is called acid deposition, commonly called *acid rain*.

Acid deposition has many harmful effects especially when the pH falls below 5.1 for terrestrial systems and below 5.5 for aquatic systems. It contributes to human respiratory diseases such as bronchitis and asthma, which can cause premature death. It also damages statues, buildings, metals and car finishes. Acid deposition can damage tree foliage directly but the most serious effect is weakening of trees so they become more susceptible to other types of damage. The nitric acid and the nitrate salts in acid deposition can lead to excessive soil nitrogen levels. This can over stimulate growth of other plants and intensify depletion of other important soil nutrients such as calcium and magnesium, which in turn can reduce tree growth and vigour.

### **Effects of air pollution on living organisms**

Our respiratory system has a number of mechanisms that help in protecting us from air pollution. The hair in our nose filters out large particles. The sticky mucus in the lining of the upper respiratory tract captures smaller particles and dissolves some gaseous pollutants. When the upper respiratory system is irritated by pollutants sneezing and coughing expel contaminated air and mucus. Prolonged smoking or exposure to air pollutants can overload or breakdown these natural defenses causing or contributing to diseases such as lung cancer, asthma, chronic bronchitis and emphysema. Elderly people, infants, pregnant women and people with heart disease, asthma or other res-

piratory diseases are especially vulnerable to air pollution.

Cigarette smoking is responsible for the greatest exposure to carbon monoxide. Exposure to air containing even 0.001 percent of carbon monoxide for several hours can cause collapse, coma and even death. As carbon monoxide remains attached to hemoglobin in blood for a long time, it accumulates and reduces the oxygen carrying capacity of blood. This impairs perception and thinking, slows reflexes and causes headaches, drowsiness, dizziness and nausea. Carbon monoxide in heavy traffic causes headaches, drowsiness and blurred vision.

Sulfur dioxide irritates respiratory tissues. Chronic exposure causes a condition similar to bronchitis. It also reacts with water, oxygen and other material in the air to form sulfur-containing acids. The acids can become attached to particles which when inhaled are very corrosive to the lung.

Nitrogen oxides especially NO<sub>2</sub> can irritate the lungs, aggravate asthma or chronic bronchitis and also increase susceptibility to respiratory infections such as influenza or common colds.

Suspended particles aggravate bronchitis and asthma. Exposure to these particles over a long period of time damages lung tissue and contributes to the development of chronic respiratory disease and cancer.

Many volatile organic compounds such as (benzene and formaldehyde) and toxic particulates (such as lead, cadmium) can cause mutations, reproductive problems or cancer. Inhaling ozone, a component of photochemical smog causes coughing, chest pain, breathlessness and irritation of the eye, nose and the throat.

## Effects on plants

When some gaseous pollutants enter leaf pores they damage the leaves of crop plants. Chronic exposure of the leaves to air pollutants can break down the waxy coating that helps prevent excessive water loss and leads to damage from diseases, pests, drought and frost. Such exposure interferes with photosynthesis and plant growth, reduces nutrient uptake and causes leaves to turn yellow, brown or drop off altogether. At a higher concentration of sulphur dioxide majority of the flower buds become stiff and hard. They eventually fall from the plants, as they are unable to flower.

Prolonged exposure to high levels of several air pollutants from smelters, coal burning power plants and industrial units as well as from cars and trucks can damage trees and other plants.

## Effects of air pollution on materials

Every year air pollutants cause damage worth billions of rupees. Air pollutants break down exterior paint on cars and houses. All around the world air pollutants have discoloured irreplaceable monuments, historic buildings, marble statues, etc.

## Effects of air pollution on the stratosphere

The upper stratosphere consists of considerable amounts of ozone, which works as an effective screen for ultraviolet light. This region called the ozone layer extends up to 60 kms above the surface of the earth. Though the ozone is present upto 60 kms its greatest density remains in the region between 20 to 25 kms. The ozone layer does not consist of solely ozone but a mixture of other common atmospheric gases. In the most dense ozone layer there will be only one ozone molecule in 100,000 gas molecules. Therefore even small changes in the ozone con-

centration can produce dramatic effects on life on earth.

The total amount of ozone in a 'column' of air from the earth's surface upto an altitude of 50 km is the *total column ozone*. This is recorded in *Dobson Units (DU)*, a measure of the thickness of the ozone layer by an equivalent layer of pure ozone gas at normal temperature and pressure at sea level. This means that 100 DU=1mm of pure ozone gas at normal temperature and pressure at sea level.

Ozone is a form of oxygen with three atoms instead of two. It is produced naturally from the photodissociation of oxygen gas molecules in the atmosphere. The ozone thus formed is constantly broken down by naturally occurring processes that maintain its balance in the ozone layer. In the absence of pollutants the creation and breakdown of ozone are purely governed by natural forces, but the presence of certain pollutants can accelerate the breakdown of ozone. Though it was known earlier that ozone shows fluctuations in its concentrations which may be accompanied sometimes with a little ozone depletion, it was only in 1985 that the large scale destruction of the ozone also called the Ozone Hole came into limelight when some British researchers published measurements about the ozone layer.

Soon after these findings a greater impetus was given to research on the ozone layer, which convincingly established that CFC's were leading to its depletion. These CFCs (chloro-fluorocarbons) are extremely stable, non-flammable, non-toxic and harmless to handle. This makes them ideal for many industrial applications like aerosols, air conditioners, refrigerators and fire extinguishers. Many cans, which give out foams and sprays, use CFCs. (eg: perfumes, room fresheners, etc.) CFCs are also used in making foams for mattresses and cushions, disposable Styrofoam cups, glasses, packaging material for insulation, cold storage etc. However their sta-



bility also gives them a long life span in the atmosphere.

Halons are similar in structure to the CFCs but contain bromine atoms instead of chlorine. They are more dangerous to the ozone layer than CFCs. Halons are used as fire extinguishing agents as they do not pose a harm to people and equipment exposed to them during fire fighting.

The CFCs and the halons migrate into the upper atmosphere after they are released. As they are heavier than air they have to be carried by air currents up to just above the lower atmosphere and then they slowly diffuse into the upper atmosphere. This is a slow process and can take as long as five to fifteen years. In the stratosphere unfiltered UV-radiation severs the chemical bonds releasing chlorine from the rest of the CFC. This attacks the ozone molecule resulting in its splitting into an oxygen molecule and an oxygen atom.

Despite the fact that CFCs are evenly distributed over the globe, the ozone depletion is especially pronounced over the South Pole due to the extreme weather conditions in the Antarctic atmosphere. The presence of the ice crystals makes the Cl-O bonding easier. The ozone layer over countries like Australia, New Zealand, South Africa and parts of South America is also depleted.

India has signed the Montreal Protocol in 1992, which aims to control the production and consumption of Ozone Depleting Substances.

### **Ozone depletion-What does it do?**

Changes in the ozone layer have serious implications for mankind.

**Effects on human health:** Sunburn, cataract, aging of the skin and skin cancer are caused by

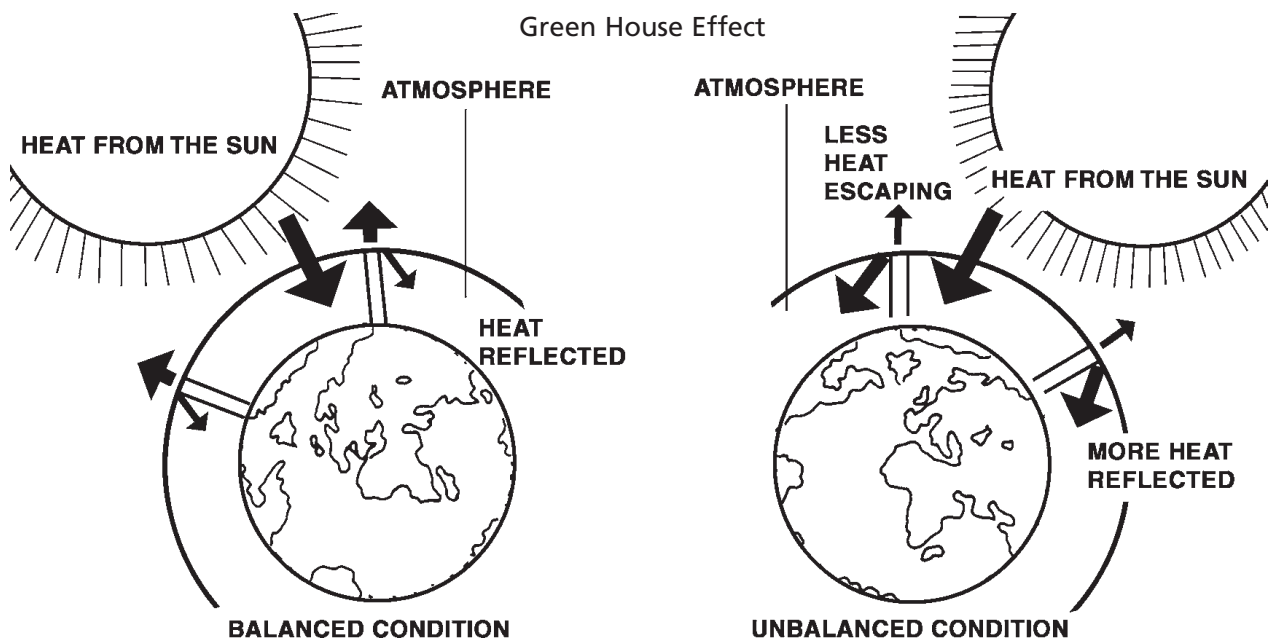
increased ultra-violet radiation. It weakens the immune system by suppressing the resistance of the whole body to certain infections like measles, chicken pox and other viral diseases that elicit rash and parasitic diseases such as malaria introduced through the skin.

**Food production:** Ultra violet radiation affects the ability of plants to capture light energy during the process of photosynthesis. This reduces the nutrient content and the growth of plants. This is seen especially in legumes and cabbage.

Plant and animal planktons are damaged by ultra-violet radiation. In zooplanktons (microscopic animals) the breeding period is shortened by changes in radiation. As planktons form the basis of the marine food chain a change in their number and species composition influences fish and shell fish production.

**Effect on materials:** Increased UV radiation damages paints and fabrics, causing them to fade faster.

**Effect on climate:** Atmospheric changes induced by pollution contribute to global warming, a phenomenon which is caused due to the increase in concentration of certain gases like carbon dioxide, nitrogen oxides, methane and CFCs. Observations of the earth have shown beyond doubt that atmospheric constituents such as water vapour, carbon dioxide, methane, nitrogen oxides and Chloro Fluoro Carbons trap heat in the form of infra-red radiation near the earth's surface. This is known as the '**Greenhouse Effect**'. The phenomenon is similar to what happens in a greenhouse. The glass in a greenhouse allows solar radiation to enter which is absorbed by the objects inside. These objects radiate heat in the form of terrestrial radiation, which does not pass out through the glass. The heat is therefore trapped in the greenhouse increasing the temperature inside and ensuring the luxuriant growth of plants.



There could be several adverse effects of global warming.

- With a warmer earth the polar ice caps will melt causing a rise in ocean levels and flooding of coastal areas.
- In countries like Bangladesh or the Maldives this would be catastrophic. If the sea level rises by 3m., Maldives will disappear completely beneath the waves.
- The rise in temperature will bring about a fall in agricultural produce.
- Changes in the distribution of solar energy can bring about changes in habitats. A previously productive agricultural area will suffer severe droughts while rains will fall in locations that were once deserts. This could bring about changes in the species of natural plants, agricultural crops, insects, livestock and micro-organisms.
- In the polar regions temperature rises caused by global warming would have disastrous effects. Vast quantities of meth-

ane are trapped beneath the frozen soil of Alaska. When the permafrost melts the methane that will be released can accelerate the process of global warming.

### Control measures for air pollution

Air pollution can be controlled by two fundamental approaches: preventive techniques and effluent control.

One of the effective means of controlling air pollution is to have proper equipment in place. This includes devices for removal of pollutants from the flue gases though scrubbers, closed collection recovery systems through which it is possible to collect the pollutants before they escape, use of dry and wet collectors, filters, electrostatic precipitators, etc. Providing a greater height to the stacks can help in facilitating the discharge of pollutants as far away from the ground as possible. Industries should be located in places so as to minimize the effects of pollution after considering the topography and the wind directions. Substitution of raw material that causes more

pollution with those that cause less pollution can be done.

## **Air pollution in India**

The World Health Organization (WHO) which rates only mega cities of the world has rated Delhi the fourth most polluted city in the world. However compared to other cities in India, Delhi is not at the top of the list of polluted cities. Our country has several pollution hotspots. The recent release from the Central Pollution Control Board (CPCB), *Parivesh*, January 2003 states that Ahmedabad's air is most noxious followed by Kanpur, Solapur and Lucknow with small particulate levels (PM<sub>10</sub>) 3-4 times the standard of 60 microgram per cubic meter (mg/m<sup>3</sup>). The report has ranked 29 cities according to Respirable Particulate Matter (RSPM) levels recorded during the year 2000. This report thus confirms the fact that Indian cities show high particulate pollution with 14 cities hitting critical levels.

Nitrogen dioxide levels in most major cities are generally close to the acceptable annual standard of 60 mg/m<sup>3</sup>. However sharp increases have been noticed in a few cities with heavy vehicular traffic and density as in a few locations in Kolkata and Delhi indicating stronger impact of traffic. The CPCB indicates vehicles as one of the predominant sources of air pollution. However the impact of hard measures implemented in Delhi over the last few years such as introduction of Euro II standards, lowering the sulphur content in fuel to 500 ppm and implementing Compressed Natural Gas program has succeeded in improving the quality of air. Rapid urbanization of smaller cities especially those situated near the big commercial centers have an enormous increase in traffic load especially in the most polluted segment such as two and three wheelers and diesel vehicles combined with poor quality fuel contribute to the deteriorating air quality in a big way.

It is alarming to note that residential locations in India are fast outpacing industrial locations in air pollution implying that vehicular fumes are responsible for this trend. The Supreme Court's order of April 5, 2002 has directed the Central Government for an action plan for other polluted cities. Absence of any local initiatives for action and delay in air pollution control measures will only make the situation worse.

The Supreme Court also played a vital role protecting the Taj Mahal. Being exposed to sulphur dioxide and suspended particulate matter, the Taj had contracted 'marble cancer', a fungal growth that corroded its surface giving it a yellowish tinge. The SPM deposits blackened it. Shri MC Mehta an environmental lawyer filed a public interest litigation in 1984 expressing concern over the havoc the polluting units in Agra were wreaking on the Taj Mahal. Twelve years later the Supreme Court ordered 292 industries in the vicinity to either adopt pollution control measures or shut down. It also made it mandatory for these units to either switch over to eco-friendly fuels like natural gas or shift out of the area.

### *Air quality monitoring*

India does not presently have a well established system of monitoring air pollution. When air quality monitoring began in India in the late 1960s planners focused only on a few pollutants namely sulphur dioxide, nitrogen oxides and suspended particulate matter. Other pollutants such as carbon monoxide and lead were monitored only on a limited scale. The threat from other air toxins such as benzene, ozone, other small particulates is not known as these are not monitored at all. A database on ambient air quality in Indian cities has been prepared by the monitoring networks of the National Environmental Engineering Research Institute (NEERI), Nagpur. The Central Pollution Control Board (CPCB) initiated its own national Ambient Air Quality Monitoring (NAAQM) program in 1985.

Ambient air quality standards in India developed by the Central Pollution Control Board

Area Category	SPM µg/m3	SO2 µg/m3	Co µg/m3	NOx µg/m3
Industrial and mixed use	500	120	5000	120
Residential and rural	200	80	2000	80
Sensitive	100	3	1000	30

Data to the NAAQM is supplied by the respective state pollution control boards, which is then transmitted to the CPCB. Experts feel that the present air quality-monitoring network cannot capture the true profile of urban air pollution due to the lack of adequate monitoring stations. Moreover critical toxins have still not been included in the list of pollutants to be monitored.

*Legal aspects of air pollution control in India*  
The Air (Prevention and Control of Pollution) Act was legislated in 1981. The Act provided for prevention, control and abatement of air pollution. In areas notified under this Act no industrial pollution causing activity could come up without the permission of the concerned State Pollution Control Board. But this Act was not strong enough to play a precautionary or a corrective role. After the Bhopal disaster, a more comprehensive Environment Protection Act (EPA) was passed in 1986. This Act for the first time conferred enforcement agencies with necessary punitive powers to restrict any activity that can harm the environment. To regulate vehicular pollution the Central Motor Vehicles Act of 1939 was amended in 1989. Following this amendment the exhaust emission rules for vehicle owners were notified in 1990 and the mass emission standards for vehicle manufacturers were enforced in 1991 for the first time. The mass emission norms have been further revised for 2000.

Air quality management as a well-defined program has yet to emerge in India. We need a much more strengthened air quality management with continuous monitoring of air if we are to have a better quality of air. This would also need an integrated approach with strict air pollution control laws. Some of the suggestions for doing this include:

- Putting a greater emphasis on pollution prevention rather than control
- Reducing the use of fossil fuels
- Improving the quality of vehicular fuel
- Increasing the use of renewable energy

5.2.2 Water Pollution

Our liquid planet glows like a soft blue sapphire in the hard-edged darkness of space. There is nothing else like it in the solar system. It is because of water.

– John Todd

**Introduction:** Water is the essential element that makes life on earth possible. Without water there would be no life. We usually take water for granted. It flows from our taps when they are turned on. Most of us are able to bathe when we want to, swim when we choose and water

our gardens. Like good health we ignore water when we have it.

Although 71% of the earth's surface is covered by water only a tiny fraction of this water is available to us as fresh water. About 97% of the total water available on earth is found in oceans and is too salty for drinking or irrigation. The remaining 3% is fresh water. Of this 2.997% is locked in ice caps or glaciers. Thus only 0.003% of the earth's total volume of water is easily available to us as soil moisture, groundwater, water vapour and water in lakes, streams, rivers and wetlands.

In short if the world's water supply were only 100 litres our usable supply of fresh water would be only about 0.003 litres (one-half teaspoon). This makes water a very precious resource. The future wars in our world may well be fought over water. By the middle of this century, almost twice as many people will be trying to share the same amount of fresh water the earth has today. As freshwater becomes more scarce access to water resources will be a major factor in determining the economic growth of several countries around the world.

**Water availability on the planet:** Water that is found in streams, rivers, lakes, wetlands and artificial reservoirs is called surface water. Water that percolates into the ground and fills the pores in soil and rock is called groundwater. Porous water-saturated layers of sand, gravel or bedrock through which ground water flows are called aquifers. Most aquifers are replenished naturally by rainfall that percolates downward through the soil and rock. This process is called natural recharge. If the withdrawal rate of an aquifer exceeds its natural recharge rate, the water table is lowered. Any pollutant that is discharged onto the land above is also pulled into the aquifer and pollutes the groundwater resulting in polluted water in the nearby wells.

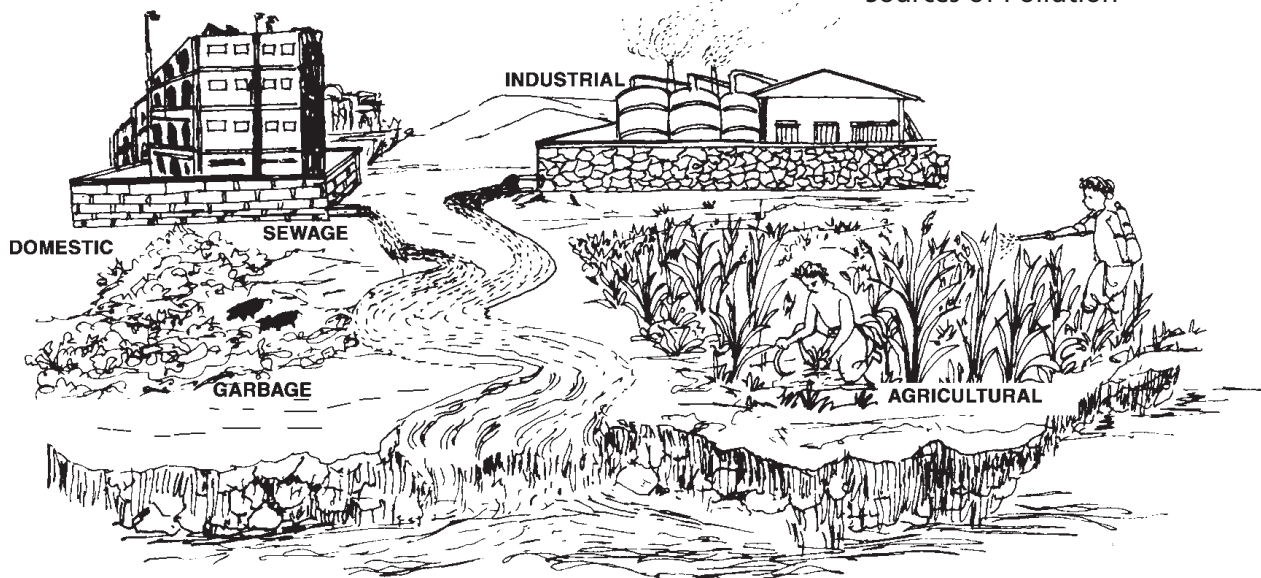
India receives most of her rainfall during the months of June to September due to the seasonal winds and the temperature differences between the land and the sea. These winds blow from the opposite directions in the different seasons. They blow into India from the surrounding oceans during the summer season and blow out from the subcontinent to the oceans during the winter. The monsoon in India is usually reasonably stable but varies geographically. In some years the commencement of the rains may be delayed considerably over the entire country or a part of it. The rains may also terminate earlier than usual. They may be heavier than usual over one part than over another. All these may cause local floods or drought. However in India even areas that receive adequate rainfall during the monsoon suffer from water shortages in the post monsoon period due to lack of storage facilities.

**When the quality or composition of water changes directly or indirectly as a result of man's activities such that it becomes unfit for any purpose it is said to be polluted.**

**Point sources of pollution:** When a source of pollution can be readily identified because it has a definite source and place where it enters the water it is said to come from a **point source**. Eg. Municipal and Industrial Discharge Pipes.

When a source of pollution cannot be readily identified, such as agricultural runoff, acid rain, etc, they are said to be **non-point sources** of pollution.

## Sources of Pollution



### Causes of water pollution

There are several classes of common water pollutants. These are **disease-causing agents** (pathogens) which include bacteria, viruses, protozoa and parasitic worms that enter water from domestic sewage and untreated human and animal wastes. Human wastes contain concentrated populations of coliform bacteria such as *Escherichia coli* and *Streptococcus faecalis*. These bacteria normally grow in the large intestine of humans where they are responsible for some food digestion and for the production of vitamin K. These bacteria are not harmful in low numbers. Large amounts of human waste in water, increases the number of these bacteria which cause gastrointestinal diseases. Other potentially harmful bacteria from human wastes may also be present in smaller numbers. Thus the greater the amount of wastes in the water the greater are the chances of contracting diseases from them.

Another category of water pollutants is **oxygen depleting wastes**. These are organic wastes that can be decomposed by aerobic (oxygen requiring) bacteria. Large populations of bacteria use up the oxygen present in water to

degrade these wastes. In the process this degrades water quality. The amount of oxygen required to break down a certain amount of organic matter is called the biological oxygen demand (BOD). The amount of BOD in the water is an indicator of the level of pollution. If too much organic matter is added to the water all the available oxygen is used up. This causes fish and other forms of oxygen dependent aquatic life to die. Thus anaerobic bacteria (those that do not require oxygen) begin to break down the wastes. Their anaerobic respiration produces chemicals that have a foul odour and an unpleasant taste that is harmful to human health.

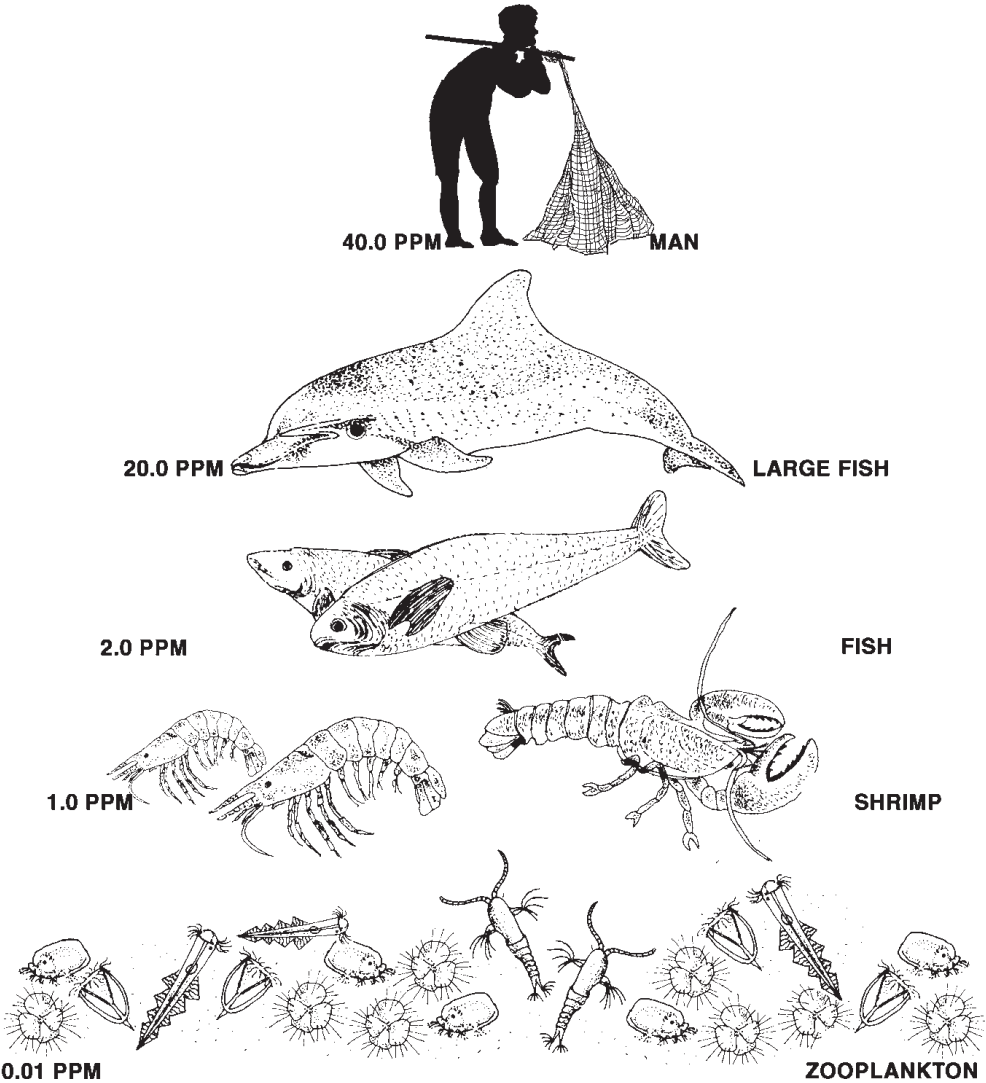
A third class of pollutants are **inorganic plant nutrients**. These are water soluble nitrates and phosphates that cause excessive growth of algae and other aquatic plants. The excessive growth of algae and aquatic plants due to added nutrients is called eutrophication. They may interfere with the use of the water by clogging water intake pipes, changing the taste and odour of water and cause a buildup of organic matter. As the organic matter decays, oxygen levels decrease and fish and other aquatic species die.



The quantity of fertilizers applied in a field is often many times more than is actually required by the plants. The chemicals in fertilizers and pesticides pollute soil and water. While excess fertilizers cause eutrophication, pesticides cause bioaccumulation and biomagnification. Pesticides which enter water bodies are introduced into the aquatic food chain. They are then absorbed by the phytoplanktons and aquatic plants. These plants are eaten by the herbivorous fish which are in turn eaten by the carnivorous fish which are in turn eaten by the water birds. At each link in the food chain these chemicals which do not pass out of the body are accumulated and increasingly concentrated resulting in biomagnification of these harmful substances.

One of the effects of accumulation of high levels of pesticides such as DDT is that birds lay eggs with shells that are much thinner than normal. This results in the premature breaking of these eggs, killing the chicks inside. Birds of prey such as hawks, eagles and other fish eating birds are affected by such pollution. Although DDT has been banned in India for agricultural use and is to be used only for malaria eradication, it is still used in the fields as it is cheap.

A fourth class of water pollutants is **water soluble inorganic chemicals** which are acids, salts and compounds of toxic metals such as mercury and lead. High levels of these chemicals can make the water unfit to drink, harm



fish and other aquatic life, reduce crop yields and accelerate corrosion of equipment that use this water.

Another cause of water pollution is a variety of **organic chemicals**, which include oil, gasoline, plastics, pesticides, cleaning solvents, detergent and many other chemicals. These are harmful to aquatic life and human health. They get into the water directly from industrial activity either from improper handling of the chemicals in industries and more often from improper and illegal disposal of chemical wastes.

**Sediment of suspended matter** is another class of water pollutants. These are insoluble particles of soil and other solids that become suspended in water. This occurs when soil is eroded from the land. High levels of soil particles suspended in water, interferes with the penetration of sunlight. This reduces the photosynthetic activity of aquatic plants and algae disrupting the ecological balance of the aquatic bodies. When the velocity of water in streams and rivers decreases the suspended particles settle down at the bottom as sediments. Excessive sediments that settle down destroys feeding and spawning grounds of fish, clogs and fills lakes, artificial reservoirs etc.

**Water soluble radioactive isotopes** are yet another source of water pollution. These can be concentrated in various tissues and organs as they pass through food chains and food webs. Ionizing radiation emitted by such isotopes can cause birth defects, cancer and genetic damage.

**Hot water** let out by power plants and industries that use large volumes of water to cool the plant result in rise in temperature of the local water bodies. Thermal pollution occurs when industry returns the heated water to a water source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity. For efficient functioning of the steam

turbines, the steam is condensed into water after it leaves the turbines. This condensation is done by taking water from a water body to absorb the heat. This heated water, which is at least 15oC higher than the normal is discharged back into the water body. The warm water not only decreases the solubility of oxygen but changes the breeding cycles of various aquatic organisms.

**Oil** is washed into surface water in runoff from roads and parking lots which also pollutes groundwater. Leakage from underground tanks

### CASE STUDY

One of the worst oil spill disasters that have occurred is that of the Exxon Valdez. On 24<sup>th</sup> march 1989 the Exxon Valdez, a tanker more than three football fields wide went off course in a 16 kilometer wide channel in Prince William Sound near Valdez in Alaska. It hit submerged rocks, creating an environmental disaster. The rapidly spreading oil slick coated more than 1600 kilometers of shoreline killing between 300,000 and 645,000 water birds and a large number of sea otters, harbor seals, whales and fishes. Exxon spent \$ 2.2. billion directly on the clean-up operations. However some results of the cleanup effort showed that where high pressure jets of hot water were used to clean beaches coastal plants and animals that had survived the spill were killed. Thus it did more harm than good. Exxon pleaded guilty in 1991 and agreed to pay the Federal Government and the state of Alaska \$ 1 billion in fines and civil damages. This \$8.5 billion accident might have been prevented if Exxon had spent only \$22.5 million to fit the tanker with a double hull-one inside the other. Such double hulled vessels would be less likely to rupture and spill their contents. The spill highlighted the need for marine pollution prevention.

is another source of pollution. Accidental oil spills from large transport tankers at sea have been causing significant environmental damage.

Though accidents such as the *Exxon Valdez* get worldwide attention, much more oil is released as a result of small, regular releases from other less visible sources. Nearly two thirds of all marine oil pollution comes from three sources: run-off from streets, improper discharge of lubricating oil from machines or automobile crankcases and intentional oil discharges that occur during the loading and unloading of tankers. Oil tankers often use sea water as ballast to stabilize the ship after they have discharged their oil. This oil contaminated water is then discharged back into the sea when the tanker is refilled.

**Groundwater pollution:** While oil spills are highly visible and often get a lot of media attention, a much greater threat to human life comes from our groundwater being polluted which is used for drinking and irrigation. While groundwater is easy to deplete and pollute it gets renewed very slowly and hence must be used judiciously. Groundwater flows are slow and not turbulent hence the contaminants are not effectively diluted and dispersed as compared to surface water. Moreover pumping groundwater and treating it is very slow and costly. Hence it is extremely essential to prevent the pollution of groundwater in the first place. Ground water is polluted due to:

- Urban run-off of untreated or poorly treated waste water and garbage
- Industrial waste storage located above or near aquifers
- Agricultural practices such as the application of large amounts of fertilizers and pesticides, animal feeding operations, etc. in the rural sector

- Leakage from underground storage tanks containing gasoline and other hazardous substances
- Leachate from landfills
- Poorly designed and inadequately maintained septic tanks
- Mining wastes

Severe cases of arsenic poisoning from contaminated groundwater have been reported from West Bengal in what is known today as the worst case of groundwater pollution. The School of Environmental Sciences, Jadavpur University, West Bengal has been involved in the task of surveying the magnitude of the arsenic problem in West Bengal for the last fourteen years. According to a report in the Down to Earth (Vol. 11, No.22), arsenic poisoning was first noticed by K C Saha, former professor of dermatology at the School of Tropical Medicine, Kolkata when he began to receive patients with skin lesions that resembled the symptoms of leprosy which was in reality not leprosy. Since all the patients were from the district of 24-Parganas, Saha along with others began to look for the cause and found it to be arsenic toxicity. Thus groundwater arsenic contamination in West Bengal was first reported in a local daily newspaper in December 1983 when 63 people from three villages located in different districts were identified by health officials as suffering from arsenic poisoning.

There are two theories that have been put forth to explain this unusually high content of arsenic in groundwater. One group of researchers suggested that the cause is natural while the other stated that the cause is man-made.

According to the first hypothesis, arsenic probably originates in the Himalayan headwaters of the Ganga and the Brahmaputra rivers and has been lying undisturbed beneath the surface of

the region's deltas for thousands of years in the thick layers of fine alluvial mud across the banks of these rivers. Most of the arsenic affected areas of West Bengal lie in the alluvial plains formed in the quaternary period (last 1.6 million years). The Purulia district of West Bengal is part of the extensive area of the Precambrian era (last 570 million years) having metamorphic rocks and granites with widespread sulphide mineralisation. Researchers from the UK based British Geological Survey (BGS) suggested that their position close to where the river Ganga enters Bangladesh (geologically) may be the primary source of arsenic in the Bengal alluvium. According to David Kinniburgh project leader with BGS the main factor is time. The mud in these areas is thicker, wider and flatter than almost anywhere else on earth. It can thus take hundreds or thousands of years for underground water to percolate through the mud before reaching the sea and thus it absorbs arsenic for a long period.

Other researchers feel that the excess amount of arsenic in groundwater can be contributed to by the high rate of groundwater extraction. Their hypothesis called the pyrite oxidation thesis describes how arsenic can get mobilized in the groundwater. In this hypothesis arsenic is assumed to be present in certain minerals (pyrites) that are deposited within the aquifer sediments. Due to the lowering of the water table below the deposits, arsenopyrite which is oxidized in a zone of the aquifer called the Vadose zone releases arsenic as arsenic adsorbed on iron hydroxide. During the subsequent recharge period, iron hydroxide releases arsenic into groundwater. This theory is supported by two arguments. The first is the intensive irrigation development in West Bengal using deep tube wells and shallow tube wells. This method of extraction, which was exactly in the 20m to 100m below ground level ensured, increased contribution of groundwater to irrigation. The other argument that supports the pyrite oxidation theory is that prior to irrigation develop-

ment and drinking water supply schemes based on groundwater there were no reported cases of arsenic poisoning.

Arsenicosis or arsenic toxicity develops after two to five years of exposure to arsenic contaminated drinking water depending on the amount of water consumption and the arsenic concentration in water. Initially the skin begins to darken (called diffuse melanosis) which later leads to spotted melanosis when darkened spots begin to appear on the chest, back and limbs. At a later stage leucomelanosis sets in and the body begins to show black and white spots. In the middle stage of arsenicosis the skin in parts becomes hard and fibrous. Rough, dry skin with nodules on hands or the soles of feet indicate severe toxicity. This can lead to the formation of gangrene and cancer. Arsenic poisoning brings with it other complications such as liver and spleen enlargement, cirrhosis of the liver, diabetes, goiter and skin cancers.

### **The state of India's rivers**

India has always had a tradition of worshipping rivers. Most of the rivers in India are named after gods, goddesses or saints. However a large majority of the Indian population including those who worship the rivers do not think twice before polluting a river. Urbanization, industrialization, excess withdrawal of water, agricultural run-off, improper agricultural practices and various religious and social practices all contribute to river pollution in India. Every single river in India be it the Ganga, Yamuna, Cauvery or the Krishna have their own share of problems due to pollution. Waters from the Ganga and the Yamuna are drawn for irrigation through the network of canals as soon as these rivers reach the plains reducing the amount of water that flows downstream. What flows in the river is water from small nalas, and streams that carry with them sewage and industrial effluents. The residual freshwater, is unable to dilute the pol-

lutants and the rivers turn into stinking sewers. In spite of data from scientifically competent studies conducted by the Central Pollution Control Board (CPCB), the Government has not been able to tackle this issue. Sewage and municipal effluents account for 75% of the pollution load in rivers while the remaining 25% is from industrial effluents and non-point pollution sources.

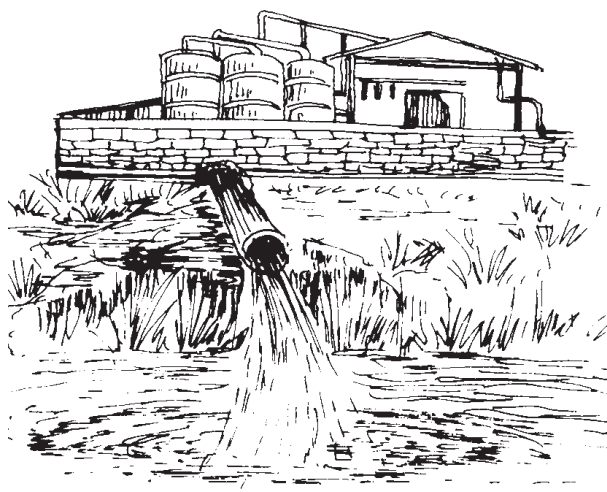
In 1985, India launched the Ganga Action plan (GAP) the largest ever river clean-up operation in the country. The plan has been criticized for, overspending and slow progress. The GAP Phase II in 1991 included cleaning operations for the tributaries of the Ganga, ie; the Yamuna, Gomti and the Damodar. Thus the Yamuna Action Plan (YAP), Gomti Action Plan and the Damodar Action plan were added.

In 1995 the National River Conservation plan was launched. Under this all the rivers in India were taken up for clean-up operations. In most of these plans, attempts have been made to tap drains, divert sewage to sewage treatment plants before letting out the sewage into the rivers. The biggest drawback of these river cleaning programs was that they failed to pin responsibilities as to who would pay for running the treatment facilities in the long run. With the power supply being erratic and these plants being heavily dependent on power, most of these facilities lie underutilized. Moreover the problem of river pollution due to agricultural run-off has not been addressed in these programs. NRCP is scheduled to be completed by March 2005. The approved cost for the plan is Rs. 772.08 crores covering 18 rivers in 10 states including 46 towns. The cost is borne entirely by the Central Government and the Ministry of Environment and Forests is the nodal agency that co-ordinates and monitors the plan. Under this plan the major activities include treating the pollution load from sewer systems of towns and cities, setting up of Sewage treatment plants, electric crematoria, low cost sanitation facilities,

riverfront development, afforestation and solid waste management.

### **Control measures for preventing water pollution**

While the foremost necessity is prevention, setting up effluent treatment plants and treating waste through these can reduce the pollution load in the recipient water. The treated effluent can be reused for either gardening or cooling purposes wherever possible. A few years ago a new technology called the Root Zone Process has been developed by Thermax. This system involves running contaminated water through the root zones of specially designed reed beds. The reeds, which are essentially wetland plants have the capacity to absorb oxygen from the surrounding air through their stomatal openings. The oxygen is pushed through the porous stem of the reeds into the hollow roots where it enters the root zone and creates conditions suitable for the growth of numerous bacteria and fungi. These micro-organisms oxidize impurities in the wastewaters, so that the water which finally comes out is clean.



**Water Pollution**



### 5.2.3 Soil Pollution

**Introduction:** We can no more manufacture a soil with a tank of chemicals than we can invent a rain forest or produce a single bird. We may enhance the soil by helping its processes along, but we can never recreate what we destroy. The soil is a resource for which there is no substitute. (Environmental historian Donald Worster reminds us that fertilizers are not a substitute for fertile soil).

Soil is a thin covering over the land consisting of a mixture of minerals, organic material, living organisms, air and water that together support the growth of plant life. Several factors contribute to the formation of soil from the parent material. This includes mechanical weathering of rocks due to temperature changes and abrasion, wind, moving water, glaciers, chemical weathering activities and lichens. Climate and time are also important in the development of soils. Extremely dry or cold climates develop soils very slowly while humid and warm climates develop them more rapidly. Under ideal climatic conditions soft parent material may develop into a centimeter of soil within 15 years. Under poor climatic conditions a hard parent material may require hundreds of years to develop into soil.

Mature soils are arranged in a series of zones called soil horizons. Each horizon has a distinct texture and composition that varies with different types of soils. A cross sectional view of the horizons in a soil is called a soil profile.

The top layer or the surface litter layer called the O horizon consists mostly of freshly fallen and partially decomposed leaves, twigs, animal waste, fungi and other organic materials. Normally it is brown or black.

The uppermost layer of the soil called the A horizon consists of partially decomposed organic matter (humus) and some inorganic mineral particles. It is usually darker and looser than the

deeper layers. The roots of most plants are found in these two upper layers. As long as these layers are anchored by vegetation soil stores water and releases it in a trickle throughout the year instead of in a force like a flood. These two top layers also contain a large amount of bacteria, fungi, earthworms and other small insects that form complex food webs in the soil that help recycle soil nutrients and contribute to soil fertility.

The B horizon often called the subsoil contains less organic material and fewer organisms than the A horizon. The area below the subsoil is called the C horizon and consists of weathered parent material. This parent material does not contain any organic materials. The chemical composition of the C-horizon helps to determine the pH of the soil and also influences the soil's rate of water absorption and retention.

Soils vary in their content of clay (very fine particles), silt (fine particles), sand (medium size particles) and gravel (coarse to very coarse particles). The relative amounts of the different sizes and types of mineral particles determine soil texture. Soils with approximately equal mixtures of clay, sand, silt and humus are called loams.

### Causes of soil degradation

#### Erosion

Soil erosion can be defined as the movement of surface litter and topsoil from one place to another. While erosion is a natural process often caused by wind and flowing water it is greatly accelerated by human activities such as farming, construction, overgrazing by livestock, burning of grass cover and deforestation.

Loss of the topsoil makes a soil less fertile and reduces its water holding capacity. The topsoil, which is washed away, also contributes to water pollution clogging lakes, increasing turbidity of the water and also leads to loss of aquatic



life. For one inch of topsoil to be formed it normally requires 200-1000 years depending upon the climate and soil type. Thus if the topsoil erodes faster than it is formed the soil becomes a non-renewable resource.

Thus it is essential that proper soil conservation measures are used to minimize the loss of top soil. There are several techniques that can protect soil from erosion. Today both water and soil are conserved through integrated treatment methods. Some of the most commonly employed methods include the two types of treatment that are generally used.

- Area treatment which involves treating the land
- Drainage line treatment which involves treating the natural water courses (nalas)

*Continuous contour trenches* can be used to enhance infiltration of water reduce the run-off and check soil erosion. These are actually shallow trenches dug across the slope of the land and along the contour lines basically for

the purpose of soil and water conservation. They are most effective on gentle slopes and in areas of low to medium rainfall. These bunds are stabilized by fast growing tree species and grasses. In areas of steep slopes where the bunds are not possible, continuous contour benches (CCBs) made of stones are used for the same purpose.

Gradonies can also be used to convert wastelands into agricultural lands. In this narrow trenches with bunds on the downstream side are built along contours in the upper reaches of the catchment to collect run-off and to conserve moisture from the trees or tree crops. The area between the two bunds is use for cultivation of crops after development of fertile soil cover.

Some of the ways in which this can be achieved are:

**Live check dams** which barriers created by planting grass, shrubs and trees across the gullies can be used for this purpose.

A **bund constructed out of stones** across the stream can also be used for conserving soil and water.

Area Treatment

Purpose	Treatment Measure	Effect
Reduces the impact of rain drops on the soil	Develop vegetative cover on the non arable land	Minimum disturbance and displacement of soil particles
Infiltration of water where it falls	Apply water infiltration measures on the area	In situ soil and moisture conservation
Minimum surface run off	Store surplus rain water by constructing bunds, ponds in the area	Increased soil moisture in the area, facilitate ground water recharge
Ridge to valley sequencing	Treat the upper catchment first and then proceed towards the outlet	Economically viable, less risk of damage and longer life of structures of the lower catchments

## Drainage line treatment

Purpose	Treatment measure	Effect
Stop further deepening of gullies and retain sediment run-off	Plug the gullies at formation	Stops erosion, recharges groundwater at the upper level.
Reduce run-off velocity, pass cleaner water to the downstream side	Crate temporary barriers in nalas	Delayed flow and increased groundwater recharge
Minimum sedimentation in the storage basins	Use various methods to treat the catchments	
Low construction cost	Use local material and skills for constructing the structures	Structures are locally maintained

**An Earthen checkbund** is constructed out of local soil across the stream to check soil erosion and flow of water.

A **Gabion structure** is a bund constructed of stone and wrapped in galvanized chainlink.

**A Gabion structure with ferrocement impervious barrier** has a one inch thick impervious wall of ferrocement at the center of the structure which goes below the ground level upto the hard strata. This ferrocement partition supported by the gabion portion is able to retain the water and withstand the force of the runoff water.

**An Underground bandhara** is an underground structure across a nalla bed to function as a barrier to check the ground water movement.

**Excess use of fertilizers:** Approximately 25 percent of the world's crop yield is estimated to be directly attributed to the use of chemical fertilizers. The use of chemical fertilizes has increased significantly over the last few decades

and is expected to rise even higher. Fertilizers are very valuable as they replace the soil nutrients used up by plants. The three primary soil nutrients often in short supply are potassium, phosphorus and nitrogen compounds. These are commonly referred to as macronutrients. Certain other elements like boron, zinc and manganese are necessary in extremely small amounts and are known as micronutrients. When crops are harvested a large amount of macronutrients and a small amount of micronutrients are removed with the crops. If the same crop is grown again depleted levels of thee nutrients can result in decreased yields. These necessary nutrients can be returned to the soil through the application of fertilizers. In addition to fertilizers a large amount of pesticides (chemicals used to kill or control populations of unwanted fungi, animals or plants often called pests) are also used to ensure a good yield. Pesticides can be subdivided into several categories based on the kinds of organisms they are used to control. *Insecticides* are used to control insect populations while *fungicides* are used to control unwanted fungal growth. Mice and rats are killed by *rodenticides* while plant pests are controlled by *herbicides*.

## Problems with pesticide use

Pesticides not only kill the pests but also a large variety of living things including humans. They may be persistent or non-persistent. Persistent pesticides once applied are effective for a long time. However as they do not break down easily they tend to accumulate in the soil and in the bodies of animals in the food chain.

For example, DDT which was one of the first synthetic organic insecticide to be used was thought to be the perfect insecticide. During the first ten years of its use (1942-1952) DDT is estimated to have saved about five million lives primarily because of its use to control disease carrying mosquitoes. However after a period of use many mosquitoes and insects became tolerant of DDT, thus making it lose its effectiveness. DDT in temperate regions of the world has a half life (the amount of time required for half of the chemical to decompose) of 10 to 15 years. This means that if 100 kilograms of DDT were to be sprayed over an area, 50 kilograms would still be present in the area 10 to 15 years later. The half-life of DDT varies according to the soil type, temperature, kind of soil organisms present and other factors. In tropical parts of the world the half life may be as short as six months. The use of DDT has been banned in some countries. India still however permits the use of DDT though for purposes of mosquito control only. Persistent pesticides become attached to small soil particles which are easily moved by wind and water to different parts thus affecting soils elsewhere. Persistent pesticides may also accumulate in the bodies of animals, and over a period of time increase in concentration if the animal is unable to flush them out of its system thus leading to the phenomenon called bioaccumulation. When an affected animal is eaten by another carnivore these pesticides are further concentrated in the body of the carnivore. This phenomenon of acquiring increasing levels of a substance in the bodies of higher trophic level organisms is known as biomagnification. This process especially in the

case of insecticides like DDT have been proved to be disastrous. DDT is a well known case of biomagnification in ecosystems. DDT interferes with the production of normal eggshells in birds making them fragile.

Other problems associated with insecticides is the ability of insect populations to become resistant to them thus rendering them useless in a couple of generations. Most pesticides kill beneficial as well as pest species. They kill the predator as well as the parasitic insects that control the pests. Thus the pest species increase rapidly following the use of a pesticide as there are no natural checks to their population growth. The short term and the long-term health effects to the persons using the pesticide and the public that consumes the food grown by using the pesticides are also major concerns. Exposure to small quantities of pesticides over several years can cause mutations, produce cancers, etc.

Thus the question that comes to mind is that if pesticides have so many drawbacks then why are they used so extensively and what are the substitutes for them? There are three main reasons for the use of pesticides. Firstly the use of pesticides in the short term has increased the amount of food that can be grown in many parts of the world as the damage by pests is decreased. The second reason for its extensive use is based on an economic consideration. The increased yields more than compensates the farmer for cost of pesticides. Thirdly current health problems especially in developing countries due to mosquitoes are impossible to control without insecticides.

However more and more farmers are increasingly opting to replace chemical fertilizers and use different methods of controlling pests without affecting their yield. Thus several different approaches that have slightly varying and overlapping goals have been developed. Alternative agriculture is the broadest term that is used that includes all non-traditional agricultural methods

and encompasses sustainable agriculture, organic agriculture, alternative uses of traditional crops, alternative methods for raising crops, etc.

Sustainable agriculture advocates the use of methods to produce adequate safe food in an economically viable manner while maintaining the state of the ecosystem. Organic agriculture advocates avoiding the use of chemical fertilizers and pesticides. A wide variety of techniques can be used to reduce this negative impact of agriculture. Leaving crop residue on the soil and incorporating it into the soil reduces erosion and increase soil organic matter. Introduction of organic matter into the soil also makes compaction less likely. Crop rotation is an effective way to enhance soil fertility, reduce erosion and control pests. There have been arguments both for and against organic farming. Critics argue that organic farming cannot produce the amount of food required for today's population and it is economically viable only in certain conditions. However supporters for organic farming feel that of the hidden costs of soil erosion and pollution are taken into account it is a viable approach. Besides organic farmers do not have to spend on fertilizers and pesticides and also get a premium price for their products thus making it financially viable for them.

Another way to reduce these impacts is through the use of *integrated pest management*. This is a technique that uses a complete understanding of all ecological aspects of a crop and the particular pests to which it is susceptible to establish pest control strategies that uses no or few pesticides. IPM promotes the use of biopesticides. Biopesticides are derived from three sources: microbial, botanical and biochemical. Microbial pesticides are micro-organisms such as bacteria, fungus, virus or protozoa that fight pests through a variety of ways. They produce toxins specific to the pests and produce diseases in them. Biochemical pesticides contain several chemicals that affect the reproductive and digestive mechanisms of the pests. The most

commonly used biopesticides are *Bacillus thuringiensis* (Bt), neem (*Azadirachta indica*) and trichogramma. Although they are available in the market they are yet to become market favourites.

### **Excess salts and water**

Irrigated lands can produce crop yields much higher than those that only use rainwater. However this has its own set of ill effects. Irrigation water contains dissolved salts and in dry climates much of the water in the saline solution evaporates leaving its salts such as sodium chloride in the topsoil. The accumulation of these salts is called salinization, which can stunt plant growth, lower yields and eventually kill the crop and render the land useless for agriculture. These salts can be flushed out of the soil by using more water. This practice however increases the cost of crop production and also wastes enormous amounts of water. Flushing salts can also make the downstream irrigation water saltier.

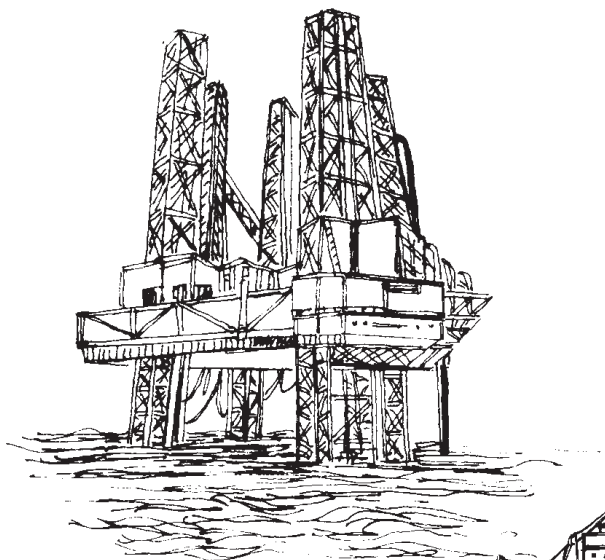
Another problem with irrigation is water logging. This occurs when large amounts of water is used to leach the salts deeper into the soil. However if the drainage is poor this water accumulates underground gradually raising the water table. The roots of the plants then get enveloped in this saline water and eventually die.

Thus in the long run it is better for us to adopt sustainable farming practices so as to prevent the degradation of soil.

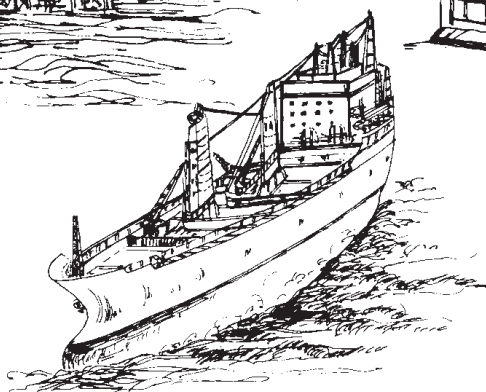
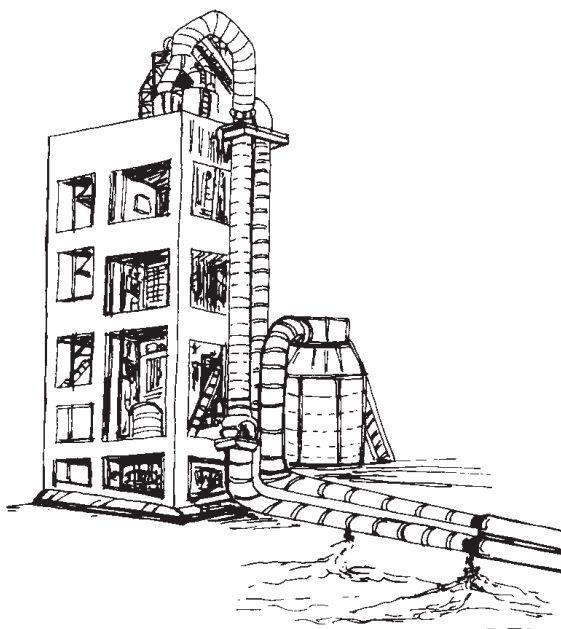
### **5.2.4 Marine Pollution**

Marine pollution can be defined as the introduction of substances to the marine environment directly or indirectly by man resulting in adverse effects such as hazards to human health, obstruction of marine activities and lowering the quality of sea water. While the causes of ma-

### SPILLAGE FROM OIL RIGS



### SPILLAGE FROM OIL PIPELINES



### SPILLAGE FROM TANKERS

rine pollution may be similar to that of general water pollution there are some very specific causes that pollute marine waters.

- The most obvious inputs of waste is through pipes directly discharging wastes into the sea. Very often municipal waste and sewage from residences and hotels in coastal towns are directly discharged into the sea.
- Pesticides and fertilizers from agriculture which are washed off the land by rain, enter water courses and eventually reach the sea.
- Petroleum and oils washed off from the roads normally enter the sewage system but stormwater overflows carry these materials into rivers and eventually into the seas.
- Ships carry many toxic substances such as oil, liquefied natural gas, pesticides, industrial chemicals, etc. in huge quantities sometimes to the capacity of 350,000 tonnes. Ship accidents and accidental spillages at sea therefore can be very damaging to the marine environment. Shipping channels in estuaries and at the entrances to ports often require frequent dredging to keep them open. This dredged material that may contain heavy metals and other contaminants are often dumped out to sea.
- Offshore oil exploration and extraction also pollute the seawater to a large extent.

## Pollution due to organic wastes

The amount of oxygen dissolved in the water is vital for the plants and animals living in it. Wastes, which directly or indirectly affect the oxygen concentration, play an important role in determining the quality of the water. Normally the greatest volume of waste discharged to watercourses, estuaries and the sea is sewage, which is primarily organic in nature and is degraded by bacterial activity. Using the oxygen present in the water these wastes are broken down into stable inorganic compounds. However as a result of this bacterial activity the oxygen concentration in the water is reduced. When the oxygen concentration falls below 1.5 mg/lit, the rate of aerobic oxidation is reduced and their place is taken over by the anaerobic bacteria that can oxidize the organic molecules without the use of oxygen. This results in end products such as hydrogen sulphide, ammonia and methane, which are toxic to many organisms. This process results in the formation of an anoxic zone which is low in its oxygen content from which most life disappears except for anaerobic bacteria, fungi, yeasts and some protozoa. This makes the water foul smelling.

**Control measures:** One way of reducing the pollution load on marine waters is through the introduction of sewage treatment plants. This will reduce the biological oxygen demand (BOD) of the final product before it is discharged to the receiving waters.

Various stages of treatment such as primary, secondary or advanced can be used depending on the quality of the effluent that is required to be treated.

**Primary treatment:** These treatment plants use physical processes such as screening and sedimentation to remove pollutants that will settle, float or, that are too large to pass through simple screening devices. This includes, stones, sticks, rags, and all such material that can clog pipes. A *screen* consists of parallel bars spaced 2 to 7cms apart followed by a wire mesh with smaller

openings. One way of avoiding the problem of disposal of materials collected on the screens is to use a device called a comminuter which grinds the coarse material into small pieces that can then be left in the waste water. After screening the wastewater passes into a *grit chamber*. The detention time is chosen to be long enough to allow lighter, organic material to settle. From the grit chamber the sewage passes into a *primary settling tank* (also called as sedimentation tank) where the flow speed is reduced sufficiently to allow most of the suspended solids to settle out by gravity. If the waste is to undergo only primary treatment it is then chlorinated to destroy bacteria and control odours after which the effluent is released. Primary treatment normally removes about 35 percent of the BOD and 60 percent of the suspended solids.

**Secondary treatment:** The main objective of secondary treatment is to remove most of the BOD. There are three commonly used approaches: trickling filters, activated sludge process and oxidation ponds. Secondary treatment can remove at least 85 percent of the BOD.

A *trickling filter* consists of a rotating distribution arm that sprays liquid wastewater over a circular bed of 'fist size' rocks or other coarse materials. The spaces between the rocks allow air to circulate easily so that aerobic conditions can be maintained. The individual rocks in the bed are covered with a layer of slime, which consists of bacteria, fungi, algae, etc. which degrade the waste trickling through the bed. This slime periodically slides off individual rocks and is collected at the bottom of the filter along with the treated wastewater and is then passed on to the secondary settling tank where it is removed.

In the *activated sludge process* the sewage is pumped into a large tank and mixed for several hours with bacteria rich sludge and air bubbles to facilitate degradation by micro-organisms. The water then goes into a sedimentation tank



where most of the microorganisms settle out as sludge. This sludge is then broken down in an anaerobic digester where methane-forming bacteria slowly convert the organic matter into carbon dioxide, methane and other stable end products. The gas produced in the digester is 60 percent methane, which is a valuable fuel and can be put to many uses within the treatment plant itself. The digested sludge, which is still liquid, is normally pumped out onto sludge drying beds where evaporation and seepage remove the water. This dried sludge is potentially a good source of manure. Activated sludge tanks use less land area than trickling filters with equivalent performance. They are also less expensive to construct than trickling filters and have fewer problems with flies and odour and can also achieve higher rates of BOD removal. Thus although the operating costs are a little higher due to the expenses incurred on energy for running pumps and blowers they are preferred over trickling filters.

*Oxidation ponds* are large shallow ponds approximately 1 to 2 metres deep where raw or partially treated sewage is decomposed by microorganisms. They are easy to build and manage and accommodate large fluctuations in flow and can provide treatment at a much lower cost. They however require a large amount of land and hence can be used where land is not a limitation.

**Advanced sewage treatment:** This involves a series of chemical and physical process that removes specific pollutants left in the water after primary and secondary treatment. Sewage treatment plant effluents contain nitrates and phosphates in large amounts. These contribute to eutrophication. Thus advanced treatment plants are designed to specifically remove these contaminants. Advanced treatment plants are very expensive to build and operate and hence are rarely used.

**Pollution due to oil:** Oil pollution of the sea normally attracts the greatest attention because of its visibility. There are several sources though which the oil can reach the sea.

#### *Tanker operations*

Half the world production of crude oil which is close to three billion tones a year is transported by sea. After a tanker has unloaded its cargo of oil it has to take on seawater as ballast for the return journey. This ballast water is stored in the cargo compartments that previously contained the oil. During the unloading of the cargo a certain amount of oil remains clinging to the walls of the container and this may amount to 800 tonnes in a 200,000 tonne tanker. The ballast water thus becomes contaminated with this oil. When a fresh cargo of oil is to be loaded, these compartments are cleaned with water, which discharges the dirty ballast along with the oil into the sea. Two techniques have substantially reduced this oil pollution. In the *load-on-top* system, the compartments are cleaned by high pressure jets of water. The oily water is retained in the compartment until the oil floats to the top. The water underneath that contains only a little oil is then discharged into the sea and the oil is transferred to a slop tank. At the loading terminal, fresh oil is loaded on top of the oil in the tank and hence the name of the technique. In the second method called '*crude oil washing*', the clingage is removed by jets of crude oil while the cargo is being unloaded. Some modern tankers have *segregated ballast* where the ballast water does not come in contact with the oil. Thus with the introduction of these new methods of deballasting, the amount of oil entering the sea has been considerably reduced.

#### *Dry docking*

All ships need periodic dry docking for servicing, repairs, cleaning the hull, etc. During this period when the cargo compartments are to

completely emptied, residual oil finds its way into the sea.

#### *Bilge and fuel oils*

As ballast tanks take up valuable space, additional ballast is sometimes carried in empty fuel tanks. While being pumped overboard it carries oil into the sea. Individually the quantity of oil released may be small but it becomes a considerable amount when all the shipping operations are taken into consideration.

#### *Tanker accidents*

A large number of oil tanker accidents happen every year. Sometimes this can result in major disasters such as that of the Exxon Valdez described in the section on water pollution.

#### *Offshore oil production*

Oil that is extracted from the seabed contains some water. Even after it is passed through oil separators the water that is discharged contains some oil, which adds to marine pollution. Drilling muds which are pumped down oil wells when it is being drilled normally contain 70 to 80 percent of oil. They are dumped on the seabed beneath the platform thus heavily contaminating the water. Uncontrolled release of oil from the wells can be catastrophic events resulting in oil pollution.

**Control measures for oil pollution:** Cleaning oil from surface waters and contaminated beaches is a time consuming labour intensive process. The natural process of emulsification of oil in the water can be accelerated through the use of *chemical dispersants* which can be sprayed on the oil. A variety of *slick-lickers* in which a continuous belt of absorbent material dips through the oil slick and is passed through rollers to extract the oil have been designed. Rocks, harbour walls can be cleaned with high-

pressure steam or dispersants after which the surface must be hosed down.

**Effects of marine pollution:** Apart from causing eutrophication a large amount of organic wastes can also result in the development of red tides. These are phytoplankton blooms of such intensity that the area is discolored. Many important commercially important marine species are also killed due to clogging of gills or other structures.

When liquid oil is spilled on the sea it spreads over the surface of the water to form a thin film called an *oil slick*. The rate of spreading and the thickness of the film depends on the sea temperature and the nature of the oil.

Oil slicks damage marine life to a large extent. Salt marshes, mangrove swamps are likely to trap oil and the plants, which form the basis for these ecosystems thus suffer. For salt marsh plants, oil slicks can affect the flowering, fruiting and germination.

If liquid oil contaminates a bird's plumage its water repellent properties are lost. Water thus penetrates the plumage and displaces the air trapped between the feathers and the skin. This air layer is necessary as it provides buoyancy and thermal insulation. With this loss the plumage becomes water logged and the birds may sink and drown. Even if this does not happen loss of thermal insulation results in exhaustion of food reserves in an attempt to maintain body temperature often followed by death. Birds often clean their plumage by preening and in the process consume oil which depending on its toxicity can lead to intestinal, renal or liver failure.

Drill cuttings dumped on the seabed create anoxic conditions and result in the production of toxic sulphides in the bottom sediment thus eliminating the benthic fauna.

Fish and shellfish production facilities can also be affected by oil slicks. The most important commercial damage can however also come from tainting which imparts an unpleasant flavour to fish and seafood and is detectable at extremely low levels of contamination. This reduces the market value of seafood.

5.2.5 Noise Pollution

Noise may not seem as harmful as the contamination of air or water but it is a pollution problem that affects human health and can contribute to a general deterioration of environmental quality.

Noise is undesirable and unwanted sound. Not all sound is noise. What may be considered as music to one person may be noise to another. It is not a substance that can accumulate in the environment like most other pollutants. Sound is measured in a unit called the ‘Decibel’.

Decibel levels of common sounds

dB	Environmental Condition
0	Threshold of hearing
10	Rustle of leaves
20	Broadcasting studio
30	Bedroom at night
40	Library
50	Quiet office
60	Conversational speech (at 1m)
70	Average radio
74	Light traffic noise
90	Subway train
100	Symphony orchestra
110	Rock band
120	Aircraft takeoff
146	Threshold of pain

There are several sources of noise pollution that contribute to both indoor and outdoor noise pollution. Noise emanating from factories, vehicles, playing of loudspeakers during various festivals can contribute to outdoor noise pollution while loudly played radio or music systems, and other electronic gadgets can contribute to indoor noise pollution. A study conducted by researchers from the New Delhi based National Physical Laboratory show that noise generated by firecrackers (presently available in the market) is much higher than the prescribed levels. The permitted noise level is 125 decibels, as per the Environment (Protection) (second amendment) Rules, 1999.

The differences between sound and noise is often subjective and a matter of personal opinion. There are however some very harmful effects caused by exposure to high sound levels. These effects can range in severity from being extremely annoying to being extremely painful and hazardous.

Effects of noise pollution on physical health

The most direct harmful effect of excessive noise is physical damage to the ear and the temporary or permanent hearing loss often called a temporary threshold shift (TTS). People suffering from this condition are unable to detect weak sounds. However hearing ability is usually recovered within a month of exposure. In Maharashtra people living in close vicinity of Ganesh mandals that play blaring music for ten days of the Ganesh festival are usually known to suffer from this phenomenon. Permanent loss, usually called noise induced permanent threshold shift (NIPTS) represents a loss of hearing ability from which there is no recovery.

Below a sound level of 80 dBA hearing loss does not occur at all. However temporary effects are noticed at sound levels between 80 and 130 dBA. About 50 percent of the people exposed

to 95 dBA sound levels at work will develop NIPTS and most people exposed to more than 105 dBA will experience permanent hearing loss to some degree. A sound level of 150 dBA or more can physically rupture the human eardrum.

The degree of hearing loss depends on the duration as well as the intensity of the noise. For example, 1hour of exposure to a 100 dBA sound level can produce a TTS that may last for about one day. However in factories with noisy machinery workers are subjected to high sound levels for several hours a day. Exposure to 95 dBA for 8 hours everyday for over a period of 10 years may cause about 15 dBA of NIPTS. In addition to hearing losses excessive sound levels can cause harmful effects on the circulatory system by raising blood pressure and altering pulse rates.

**Effects of noise pollution on mental health:**

Noise can also cause emotional or psychological effects such as irritability, anxiety and stress. Lack of concentration and mental fatigue are significant health effects of noise. It has been observed that the performance of school children is poor in comprehension tasks when schools are situated in busy areas of a city and suffer from noise pollution.

As noise interferes with normal auditory communication, it may mask auditory warning signals and hence increases the rate of accidents especially in industries. It can also lead to lowered worker efficiency and productivity and higher accident rates on the job.

Thus noise is just more than a mere nuisance or annoyance. It definitely affects the quality of life. It is thus important to ensure mitigation or control of noise pollution.

**Permitted noise levels**

**Ambient Noise Levels dB**

<i>Zone</i>	<i>Day-time</i>	<i>Night-time</i>
Silent Zone	50	40
Residential Zone	55	45
Commercial Zone	65	55
Industrial Zone	70	70

A standard safe time limit has been set for exposure to various noise levels. Beyond this ‘safe’ time continuing exposure over a period of a year will lead to hearing loss.

<b>Duration</b>	<b>dBA</b>
8 hours	90
4 hours	93
2 hours	96
1 hour	99
30 minutes	102
15 minutes	105
7 minutes	108
4 minutes	111
2 minutes	114
1 minute	117
30 seconds	120
Instantaneous rupture of membrane	150

**Noise Control techniques**

There are four fundamental ways in which noise can be controlled: Reduce noise at the source, block the path of noise, increase the path length and protect the recipient. In general, the best control method is to reduce noise levels at the source.

Source reduction can be done by effectively muffling vehicles and machinery to reduce the noise. In industries noise reduction can be done by using rigid sealed enclosures around machinery lined with acoustic absorbing material. Isolating machines and their enclosures from the floor using special spring mounts or absorbent mounts and pads and using flexible couplings for interior pipelines also contribute to reducing noise pollution at the source.

However one of the best methods of noise source reduction is regular and thorough maintenance of operating machinery. Noise levels at construction sites can be controlled using proper construction planning and scheduling techniques. Locating noisy air compressors and other equipment away from the site boundary along with creation of temporary barriers to physically block the noise can help contribute to reducing noise pollution. Most of the vehicular noise comes from movement of the vehicle tires on the pavement and wind resistance. However poorly maintained vehicles can add to the noise levels. Traffic volume and speed also have significant effects on the overall sound. For example doubling the speed increases the sound levels by about 9 dBA and doubling the traffic volume (number of vehicles per hour) increases sound levels by about 3 dBA. A smooth flow of traffic also causes less noise than does a stop-and-go traffic pattern. Proper highway planning and design are essential for controlling traffic noise. Establishing lower speed limits for highways that pass through residential areas, limiting traffic volume and providing alternative routes for truck traffic are effective noise control measures. The path of traffic noise can also be blocked by construction of vertical barriers alongside the highway. Planting of trees around houses can also act as effective noise barriers. In industries different types of absorptive material can be used to control interior noise. Highly absorptive interior finish material for walls, ceilings and floors can decrease indoor noise levels significantly. Sound levels drop significantly with increasing

distance from the noise source. Increasing the path length between the source and the recipient offers a passive means of control. Municipal land-use ordinances pertaining to the location of airports make use of the attenuating effect of distance on sound levels. Use of earplugs and earmuffs can protect individuals effectively from excessive noise levels. Specially designed earmuffs can reduce the sound level reaching the eardrum by as much as 40 dBA. However very often workers tend not to wear them on a regular basis despite company requirements for their use.

### 5.2.6 Thermal Pollution

**Sources:** The discharge of warm water into a river is usually called a **thermal pollution**. It occurs when an industry removes water from a source, uses the water for cooling purposes and then returns the heated water to its source. Power plants heat water to convert it into steam, to drive the turbines that generate electricity. For efficient functioning of the steam turbines, the steam is condensed into water after it leaves the turbines. This condensation is done by taking water from a water body to absorb the heat. This heated water, which is at least 15°C higher than the normal is discharged back into the water body.

**Effects:** The warmer temperature decreases the solubility of oxygen and increases the metabolism of fish. This changes the ecological balance of the river. Within certain limits thermal additions can promote the growth of certain fish and the fish catch may be high in the vicinity of a power plant. However sudden changes in temperature caused by periodic plant shutdowns both planned and unintentional can change result in death of these fish that are acclimatized to living in warmer waters.

Tropical marine animals are generally unable to withstand a temperature increase of 2 to 3°C

and most sponges, mollusks and crustaceans are eliminated at temperatures above 37°C. This results in a change in the diversity of fauna as only those species that can live in warmer water survive.

**Control measures:** Thermal pollution can be controlled by passing the heated water through a cooling pond or a cooling tower after it leaves the condenser. The heat is dissipated into the air and the water can then be discharged into the river or pumped back to the plant for reuse as cooling water. There are several ways in which thermal pollution can be reduced. One method is to construct a large shallow pond. Hot water is pumped into one end of the pond and cooler water is removed from the other end. The heat gets dissipated from the pond into the atmosphere. A second method is to use a cooling tower. These structures take up less land area than the ponds. Here most of the heat transfer occurs through evaporation. Here warm waters coming from the condenser is sprayed downward over vertical sheets or baffles where the water flows in thin films. Cool air enters the tower through the water inlet that encircles the base of the tower and rises upwards causing evaporative cooling. A natural draft is maintained because of the density difference between the cool air outside and the warmer air inside the tower. The waste heat is dissipated into the atmosphere about 100 m above the base of the tower. The cooled water is collected at the floor of the tower and recycled back to the power plant condensers. The disadvantage in both these methods is however that large amounts of water are lost by evaporation.

### 5.2.7 Nuclear Hazards

Nuclear energy can be both beneficial and harmful depending on the way in which it is used. We routinely use X-rays to examine bones for fractures, treat cancer with radiation and diagnose diseases with the help of radioactive iso-

topes. Approximately 17 % of the electrical energy generated in the world comes from nuclear power plants. However on the other hand it is impossible to forget the destruction that nuclear bombs caused the cities of Hiroshima and Nagasaki. The radioactive wastes from nuclear energy have caused serious environmental damage.

Nuclear fission is the splitting of the nucleus of the atom. The resulting energy can be used for a variety of purposes. The first controlled fission of an atom was carried out in Germany in 1938. However the United States was the first country to develop an atomic bomb which was subsequently dropped on the Japanese cities of Hiroshima and Nagasaki. The world's first electricity generating reactor was constructed in the United States in 1951 and the Soviet Union built its first reactor in 1954. In December 1953, President Dwight D. Eisenhower in his 'Atoms for Peace' speech made the following prediction: *'Nuclear reactors will produce electricity so cheaply that it will not be necessary to meter it. The users will pay a fee and use as much electricity as they want. Atoms will provide a safe, clean and dependable source of electricity.'*

Today however though nuclear power is being used as a reliable source of electricity the above statement sounds highly optimistic. Several serious accidents have caused worldwide concern about safety and disposal of radioactive wastes.

In order to appreciate the consequences of using nuclear fuels to generate energy it is important to understand how the fuel is processed. Low-grade uranium ore, which contains 0.2 percent uranium by weight, is obtained by surface or underground mining. After it is mined the ore goes through a milling process where it is crushed and treated with a solvent to concentrate the uranium and produces yellow cake a material containing 70 to 90 percent uranium oxide. Naturally occurring uranium contains only 0.7 percent of fissionable U-235, which is not



high enough for most types of reactors. Hence it is necessary to increase the amount of U-235 by enrichment though it is a difficult and expensive process. The enrichment process increases the U-235 content from 0.7 to 3 percent. Fuel fabrication then converts the enriched material into a powder, which is then compacted into pellets. These pellets are sealed in metal fuel rods about 4 meters in length which is then loaded into the reactor. As fission occurs the concentration of U-235 atoms decreases. After about three years, a fuel rod does not have enough radioactive material to sustain a chain reaction and hence the spent fuel rods must be replaced by new ones. The spent rods are however still very radioactive containing about one percent U-235 and one percent plutonium. These rods are a major source of radioactive waste material produced by a nuclear reactor.

Initially it was thought that spent fuel rods could be reprocessed to not only provide new fuel but also to reduce the amount of nuclear waste. However the cost of producing fuel rods by reprocessing was found to be greater than the cost of producing fuel rods from ore. Presently India does operate reprocessing plants to reprocess spent fuel as an alternative to storing them as nuclear waste. At each step in the cycle there is a danger of exposure and poses several health and environmental concerns.

Although nuclear power has significant benefits an incident which changed people's attitudes towards nuclear power plants was the Chernobyl disaster that occurred in 1986. Chernobyl is a small city in Ukraine near the border with Belarus north of Kiev. At 1.00 am April 25, 1986 a test to measure the amount of electricity that the still spinning turbine would produce if steam were shut off was being conducted at the Chernobyl Nuclear Power Station-4. This was important information since the emergency core cooling system required energy for its operation and the coasting turbine could provide some of that energy until another source

became available. The amount of steam being produced was reduced by lowering the control rods into the reactor. But the test was delayed because of a demand for electricity and a new shift of workers came on duty. The operators failed to program the computer to maintain power at 700 megawatts and the output dropped to 30 megawatts. This presented an immediate need to rapidly increase the power and many of the control rods were withdrawn. Meanwhile an inert gas (xenon) had accumulated on the fuel rods. The gas absorbed the neutrons and slowed the rate of power increase. In an attempt to obtain more power the operators withdrew all the control rods. This was a second serious safety violation.

At 1.00am, the operators shut off most of the emergency warning signals and turned on all the eight pumps to provide adequate cooling for the reactor following the completion of the test. Just as the final stages for the test were beginning a signal indicated excessive reaction in the reactor. In spite of the warning the operators blocked the automatic reactor shutdown and began the test. As the test continued the power output of the reactor rose beyond its normal level and continued to rise. The operators activated the emergency system designed to put the control rods back into the reactor and stop the fission. But it was already too late. The core had already been deformed and the rods would not fit properly thus the reaction could not be stopped. In 4.5 seconds the energy level of the reactor increased two thousand times. The fuel rods ruptured the cooling water turned into steam and a steam explosion occurred. The lack of cooling water allowed the reactor to explode. The explosion blew the 1000 metric ton concrete roof from the reactor and the reactor caught fire. This resulted in the world's worst nuclear accident and it took ten days to bring the runaway reaction under control.

There were of course immediate fatalities, but the long-term consequences were devastating. 116,000 people were evacuated of which 24,000 had received high doses of radiation. Even today many people suffer from illnesses they feel are related to their exposure to the fallout from Chernobyl. In 1996 ten years after the accident it was clear that one of the long-term effects was the increased frequency of thyroid cancer in children.

The degree and the kind of damage from nuclear accidents vary with the kind of radiation, the amount of radiation, the duration of exposure and the types of cells irradiated. Radiation can also cause mutations which are changes in the genetic makeup of the cells. Mutations can occur in the ovaries or the testes leading to the formation of mutated eggs or sperms which in turn can lead to abnormal offspring. Mutations can also occur in the tissues of the body and may manifest themselves as abnormal tissue growths known as cancer. Two common cancers that are linked to increased radiation exposure are leukemia and breast cancer.

### **5.3 SOLID WASTE MANAGEMENT: CAUSES, EFFECTS AND CONTROL MEASURES OF URBAN AND INDUSTRIAL WASTE**

In ancient cities, food scraps and other wastes were simply thrown into the unpaved streets where they accumulated. Around 320 B.C. in Athens, the first known law forbidding this practice was established and a system of waste removal began to evolve in several eastern Mediterranean cities. Disposal methods were very crude and often were just open pits outside the city walls. As populations increased, efforts were made to transport the wastes out further thus creating city dumps. Until recently the disposal of municipal solid waste did not attract much public attention. The favoured

means of disposal was to dump solid wastes outside the city or village limits.

Around most towns and cities in India the approach roads are littered with multi-coloured plastic bags and other garbage. Waste is also burnt to reduce its volume. Modern methods of disposal such as incineration and the development of sanitary landfills, etc. are now attempting to solve these problems. Lack of space for dumping solid waste has become a serious problem in several cities and towns all over the world. Dumping and burning wastes is not an acceptable practice today from either an environmental or a health perspective. Today disposal of solid waste should be part of an integrated waste management plan. The method of collection, processing, resource recovery and the final disposal should mesh with one another to achieve a common objective.

### **Characteristics of municipal solid waste**

Solid wastes are grouped or classified in several different ways. These different classifications are necessary to address the complex challenges of solid waste management in an effective manner. The term municipal solid waste (MSW) is generally used to describe most of the non-hazardous solid waste from a city, town or village that requires routine collection and transport to a processing or disposal site. Sources of MSW include private homes, commercial establishments and institutions as well as industrial facilities. However MSW does not include wastes from industrial processes, construction and demolition debris, sewage sludge, mining wastes or agricultural wastes.

Municipal solid waste contains a wide variety of materials. It can contain food waste such as vegetable and meat material, left over food, egg shells, etc which is classified as wet garbage as well as paper, plastic, tetrapacks, plastic cans, newspaper, glass bottles, cardboard boxes, alu-

minum foil, metal items, wood pieces, etc. which is classified as dry garbage.

### **Control measures of urban and industrial wastes:**

An integrated waste management strategy includes three main components:

1. Source reduction
2. Recycling
3. Disposal

**Source reduction** is one of the fundamental ways to reduce waste. This can be done by using less material when making a product, reuse of products on site, designing products or packaging to reduce their quantity. On an individual level we can reduce the use of unnecessary items while shopping, buy items with minimal packaging, avoid buying disposable items and also avoid asking for plastic carry bags.

**Recycling** is reusing some components of the waste that may have some economic value. Recycling has readily visible benefits such as conservation of resources reduction in energy used during manufacture and reducing pollution levels. Some materials such as aluminum and steel can be recycled many times. Metal, paper, glass and plastics are recyclable. Mining of new aluminum is expensive and hence recycled aluminum has a strong market and plays a significant role in the aluminum industry. Paper recycling can also help preserve forests as it takes about 17 trees to make one ton of paper. Crushed glass (cullet) reduces the energy required to manufacture new glass by 50 percent. Cullet lowers the temperature requirement of the glassmaking process thus conserving energy and reducing air pollution. However even if recycling is a viable alternative, it presents several problems.

The problems associated with recycling are either technical or economical. Plastics are difficult to recycle because of the different types of polymer resins used in their production. Since each type has its own chemical makeup differ-

ent plastics cannot be recycled together. Thus separation of different plastics before recycling is necessary. Similarly in recycled paper the fibers are weakened and it is difficult to control the colour of the recycled product. Recycled paper is banned for use in food containers to prevent the possibility of contamination. It very often costs less to transport raw paper pulp than scrap paper. Collection, sorting and transport account for about 90 percent of the cost of paper recycling. The processes of pulping, deinking and screening wastepaper are generally more expensive than making paper from virgin wood or cellulose fibers. Very often thus recycled paper is more expensive than virgin paper. However as technology improves the cost will come down.

**Disposal** of solid waste is done most commonly through a sanitary landfill or through incineration. A modern sanitary landfill is a depression in an impermeable soil layer that is lined with an impermeable membrane. The three key characteristics of a municipal sanitary landfill that distinguish it from an open dump are:

- Solid waste is placed in a suitably selected and prepared landfill site in a carefully prescribed manner.
- The waste material is spread out and compacted with appropriate heavy machinery.
- The waste is covered each day with a layer of compacted soil.

The problem with older landfills are associated with groundwater pollution. Pollutants seeping out from the bottom of a sanitary landfill (leachates) very often percolate down to the groundwater aquifer no matter how thick the underlying soil layer. Today it is essential to have suitable bottom liners and leachate collection systems along with the installation of monitoring systems to detect groundwater pollution. The organic material in the buried solid waste

will decompose due to the action of microorganisms. At first the waste decomposes aerobically until the oxygen that was present in the freshly placed fill is used up by the aerobic microorganisms. The anerobes take over producing methane which is poisonous and highly explosive when mixed with air in concentrations between 5 and 15 percent. The movement of gas can be controlled by providing impermeable barriers in the landfill. A venting system to collect the blocked gas and vent it to the surface where it can be safely diluted and dispersed into the atmosphere is thus a necessary component of the design of sanitary landfills.

Even though landfilling is an economic alternative for solid waste disposal, it has become increasingly difficult to find suitable landfilling sites that are within economic hauling distance and very often citizens do not want landfills in their vicinity. Another reason is that no matter how well engineered the design and operation may be, there is always the danger of some environmental damage in the form of leakage of leachates.

**Incineration** is the process of burning municipal solid waste in a properly designed furnace under suitable temperature and operating conditions. Incineration is a chemical process in which the combustible portion of the waste is combined with oxygen forming carbon dioxide and water, which are released into the atmosphere. This chemical reaction called oxidation results in the release of heat. For complete oxidation the waste must be mixed with appropriate volumes of air at a temperature of about 815o C for about one hour. Incineration can reduce the municipal solid waste by about 90 percent in volume and 75 percent in weight. The risks of incineration however involve air-quality problems and toxicity and disposal of the fly and bottom ash produced during the incineration process. Fly ash consists of finely divided particulate matter, including cinders, mineral dust and soot. Most of the incinerator ash is

bottom ash while the remainder is fly ash. The possible presence of heavy metals in incinerator ash can be harmful. Thus toxic products and materials containing heavy metals (for example batteries and plastics) should be segregated. Thus extensive air pollution control equipment and high-level technical supervision and skilled employees for proper operation and maintenance is required.

Thus while sanitary landfills and incinerators have their own advantages and disadvantages, the most effective method of solid waste management is source reduction and recycling.

### **Vermi – Composting**

Nature has perfect solutions for managing the waste it creates, if left undisturbed. The biogeochemical cycles are designed to clear the waste material produced by animals and plants. We can mimic the same methods that are present in nature. All dead and dry leaves and twigs decompose and are broken down by organisms such as worms and insects, and is finally broken down by bacteria and fungi, to form a dark rich soil-like material called compost.

These organisms in the soil use the organic material as food, which provides them with nutrients for their growth and activities. These nutrients are returned to the soil to be used again by trees and other plants. This process recycles nutrients in nature.

This soil can be used as a manure for farms and gardens.

### *Steps for Vermi-Compost*

- Dig a pit about half a meter square, one meter deep.
- Line it with straw or dried leaves and grass.
- Organize the disposal of organic waste into the pit as and when generated.
- Introduce a culture of worms that is now produced commercially.
- Ensure that the contents are covered with a sprinkling of dried leaves and soil everyday.
- Water the pit once or twice a week to keep it moist.
- Turn over the contents of the pit ever 15 days.
- In about 45 days the waste will be decomposed by the action of the microorganisms.
- The soil derived is fertile and rich in nutrients.

## **Hazardous wastes**

Modern society produces large quantities of hazardous waste which are generated by chemical manufacturing companies, petroleum refineries, paper mills, smelters and other industries. Hazardous wastes are those that can cause harm to humans or the environment. Wastes are normally classified as hazardous waste when they cause or significantly contribute to an increase in mortality or an increase in serious irreversible or incapacitating reversible illness or pose a sub-

stantial present or potential hazard to human health or the environment when improperly treated, stored, transported or disposed of.

## **Characteristics of hazardous wastes**

A waste is classified as a hazardous waste if it exhibits any of the four primary characteristics based on the physical or chemical properties of toxicity, reactivity, ignitability and corrosivity. In addition to this waste products that are either infectious or radioactive are also classified as hazardous

*Toxic wastes* are those substances that are poisonous even in very small or trace amounts. Some may have an acute or immediate effect on humans or animals causing death or violent illness. Others may have a chronic or long term effect slowly causing irreparable harm to exposed persons. Acute toxicity is readily apparent because organisms respond to the toxin shortly after being exposed. Chronic toxicity is much more difficult to determine because the effects may not be seen for years. Certain toxic wastes are known to be carcinogenic, causing cancer and others may be mutagenic causing biological changes in the children of exposed people and animals.

*Reactive wastes* are those that have a tendency to react vigorously with air or water, are unstable to shock or heat, generate toxic gases or explode during routine management. For example, gunpowder, nitroglycerine, etc.

*Ignitable wastes* are those that burn at relatively low temperatures (less than 60 C) and are capable of spontaneous combustion during storage, transport or disposal. For example, gasoline, paint thinners, and alcohol.

*Corrosive wastes* are those that destroy materials and living tissue by chemical reaction. For example, acids and bases.



*Infectious wastes* include human tissue from surgery, used bandages and hypodermic needles, microbiological materials, etc.

*Radioactive waste* is basically an output from the nuclear power plants and can persist in the environment for thousands of years before it decays appreciably.

### **Environmental problems and health risks caused by hazardous wastes.**

As most of the hazardous wastes are disposed of on or in land the most serious environmental effect is contaminated groundwater. Once groundwater is polluted with hazardous wastes it is very often not possible to reverse the damage.

Pesticides are used increasingly to protect and increase food production. They form residues in the soil which are washed into streams which then carry them forwards. The residues may persist in the soil or in the bottom of lakes and rivers. Exposure can occur through ingestion, inhalation and skin contact resulting in acute or chronic poisoning. Today we have an alternative to the excess use of pesticides through the use of Integrated Pest Management (IPM). The IPM system uses a wide variety of plants and insects to create a more natural process. The natural balance between climate, soil and insect populations can help to prevent an insect from overpopulating an area and destroying a particular crop.

Lead, mercury and arsenic are hazardous substances which are often referred to as heavy metals. Lead is an abundant heavy metal and is relatively easy to obtain. It is used in batteries, fuel, pesticides, paints, pipes and other places where resistance to corrosion is required. Most of the lead taken up by people and wildlife is stored in bones. Lead can affect red blood cells by reducing their ability to carry oxygen and

shortening their life span. Lead may also damage nerve tissue which can result in brain disease.

Mercury occurs in several different forms. Mercury is used in the production of chlorine. It is also used as a catalyst in the production of some plastics. Industrial processes such as the production of chlorine and plastics are responsible for most of the environmental damage resulting from mercury. Our body has a limited ability to eliminate mercury. In the food web mercury becomes more concentrated as it is taken up by various organisms. In an aquatic environment, mercury can be absorbed by the plankton which are then consumed by fish. In addition, fish take up mercury through their gills and by eating

#### **Minamata-An important lesson about mercury**

A case of human mercury poisoning which occurred about forty years ago in the Minamata bay in Japan taught the world an important lesson about the dangers of mercury poisoning. A large plastics plant located near the Minamata bay used a mercury containing compound in a reaction to produce vinyl chloride a common plastic material. The left over mercury was dumped into the Bay along with other wastes from the plant. Though the mercury was in its less toxic inorganic state when dumped microorganisms at the bottom of the bay converted the mercury into its organic form. This organic mercury then entered into the tissues of fish which were in turn consumed by the people living in the area. The contaminated fish thus caused an outbreak of poisoning killing and affecting several people. Mothers who had eaten the contaminated fish gave birth to infants who showed signs of mercury poisoning. Mercury poisoning is thus called Minamata Disease.



other fish contaminated with mercury. Generally older the fish greater is the mercury concentration in its body. Birds that eat the fish concentrate even more mercury in their bodies. It is a cumulative poison ( it builds up in the body over long periods of time) and is known to cause brain damage.

Thousands of chemicals are used in industry everyday. When used incorrectly or inappropriately they can become health hazards. PCBs (Polychlorinated biphenyls) are resistant to fire and do not conduct electricity very well which makes them excellent materials for several industrial purposes. Rainwater can wash PCBs out of disposal areas in dumps and landfills thus contaminating water. PCBs do not break down very rapidly in the environment and thus retain their toxic characteristics. They cause long term exposure problems to both humans and wildlife. PCBs are concentrated in the kidneys and liver and thus cause damage. They cause reproductive failure in birds and mammals.

Vinyl chloride is a chemical that is widely used in the manufacture of plastic. Usually people are only exposed to high levels of vinyl chloride if they work with it or near it but exposure can also occur from vinyl chloride gas leaks. After a long continuous exposure (one to three years) in humans, vinyl chloride can cause deafness, vision problems, circulation disorders and bone deformities. Vinyl chloride can also cause birth defects.

It is essential to substitute the use of PCBs and vinyl chloride with chemicals that are less toxic. Polyvinyl chloride use can be lowered by reducing our use of plastics. Thus by reducing waste, encouraging recycling and using products that are well made and durable we can greatly reduce our consumption of these chemicals thus curtailing our exposure to these substances.

We may not realize it but many household chemicals can be quite toxic to humans as well

as wildlife. Most of the dangerous substances in our homes are found in various kinds of cleaners, solvents and products used in automotive care. When these products are used incorrectly they have the potential to be harmful.

Today the most common methods for disposing off hazardous wastes are land disposal and incineration. In countries where there is abundant land available for disposal for example, North America land disposal is the most widely used method. In countries like Europe and Japan where land is not readily available and is expensive, incineration is the preferred method for disposal. In spite of strong laws however illegal dumping of these wastes continues. Hazardous waste management must move beyond burying and burning. Industries need to be encouraged to generate less hazardous waste in their manufacturing processes. Although toxic wastes cannot be entirely eliminated, technologies are available for minimizing, recycling and treating wastes. An informed public can also contribute in a big way towards this end. It is essential for us to understand the ill effects of chemical substances so that we can make informed decisions about its use. We might decide that the benefits of the use of a toxic substance do not outweigh the risks and choose not to use it at all or we may decide that it is acceptable to use a substance under certain specific circumstances where it is adequately controlled and exposure to toxic levels is prevented.

## **5.4 ROLE OF AN INDIVIDUAL IN PREVENTION OF POLLUTION**

There are a host of environmental problems caused by human actions on the environment. If we are to respond to these problems we have to recognize that each of us is individually responsible for the quality of the environment we live in. Our personal actions can either worsen or improve our environmental quality. Several

people may feel that environmental problems can be solved with quick technological fixes. While a majority of individuals would want a cleaner environment, not many of them want to make major changes in their lifestyle that could contribute to a cleaner environment. Decisions and actions taken by individuals to a very large extent determine the quality of life for everyone. This necessitates that individuals should not only be aware of various environmental issues and the consequences of their actions on the environment but should also make a firm resolve to develop environmentally ethical lifestyles.

With the help of solar energy, natural processes developed over billions of years can indefinitely renew the topsoil, water, air, forests, grasslands and wildlife on which all forms of life depend, but only as long as we do not use these potentially renewable resources faster than they are replenished. Some of our wastes can be diluted, decomposed and recycled by natural processes indefinitely as long as these processes are not overloaded. Natural processes also provide services of flood prevention, erosion control at no costs at all. We must therefore learn to value these resources and use them sustainably.

Concepts that help individuals contribute towards a better quality of our environment and human life.

- Develop respect or reverence for all forms of life.
- Each individual must try to answer four basic questions:  
     Where do the things that I consume come from?  
     What do I know about the place where I live?  
     How am I connected to the earth and other living things?  
     What is my purpose and responsibility as a human being?

- Try to plant trees wherever you can and more importantly take care of them. They reduce air pollution.
- Reduce the use of wood and paper products wherever possible. Manufacturing paper leads to pollution and loss of forests which releases oxygen and takes up carbon dioxide. Try to recycle paper products and use recycled paper wherever possible.
- From the mail you receive reuse as many envelopes that you can.
- Do not buy furniture, doors, window frames made from tropical hardwoods such as teak and mahogany. These are forest based.
- Help in restoring a degraded area near your home or join in an afforestation program.
- Use pesticides in your home only when absolutely necessary and use them in as small amounts as necessary. Some insect species help to keep a check on the populations of pest species.
- Advocate organic farming by asking your grocery store to stock vegetables and fruits grown by an organic method. This will automatically help to reduce the use of pesticides.
- Reduce the use of fossil fuels by either walking up a short distance using a car pool, sharing a bike or using public transport. This reduces air pollution.
- Shut off the lights and fans when not needed.
- Don't use aerosol spray products and commercial room air fresheners. They damage the ozone layer.

- Do not pour pesticides, paints, solvents, oil or other products containing harmful chemicals down the drain or on the ground.
- Buy consumer goods that last, keep them as long as possible and have them repaired as far as possible instead of disposing them off. Such products end up in landfills that could pollute ground water.
- Buy consumer goods in refillable glass containers instead of cans or throwaway bottles.
- Use rechargeable batteries.
- Try to avoid asking for plastic carry bags when you buy groceries or vegetables or any other items. Use your own cloth bag instead.
- Use sponges and washable cloth napkins, dish towels and handkerchiefs instead of paper ones.
- Don't use throwaway paper and plastic plates and cups when reusable versions are available.
- Recycle all newspaper, glass, aluminum and other items accepted for recycling in your area. You might have to take a little trouble to locate such dealers.
- Set up a compost bin in your garden or terrace and use it to produce manure for your plants to reduce use of fertilizers.
- Try to lobby and push for setting up garbage separation and recycling programs in your localities.
- Choose items that have the least packaging or no packaging.
- Start individual or community composting or vermicomposting plants in your neighborhood and motivate people to join in.
- Do not litter the roads and surroundings just because the sweeper from the Municipal Corporation will clean it up. Take care to put trash into dustbins or bring it back home with you where it can be appropriately disposed.
- You must realize that you cannot do everything and have solutions for every problem in the world. You can however concentrate on issues that you feel strongly about and can do something about. Focusing your energy on a particular issue will help you get better results.
- You could join any of the several NGOs that exist in our country or become volunteers. Organize small local community meetings to discuss positive approaches of pollution prevention.
- Learn about the biodiversity of your own area. Understand the natural and cultural assets. This would help you to develop a sense of pride in your city/town/village and will also help you understand the problems facing their survival.
- You cannot improve your world by not voting. You have the option to make a choice rather than complain later on.
- It is important that you do not get discouraged at the first sign of trouble. Do not dwell on the negative aspects. But take positive actions wherever you can to make the world a better place to live in.
- When talking to elected officials always be courteous and reasonable. You may disagree with a particular position but be re-

spectful in doing so as you will gain little by being hostile and brash.

- Take care to put into practice what you preach. Remember environment protection begins with YOU.

## 5.5 POLLUTION CASE STUDIES

### A case study of groundwater pollution in India

An example of groundwater pollution caused by excessive extraction is that fluoride contamination. Fluorosis is not a localized problem. It has spread across 19 states and across a variety of ecological regions ranging from the Thar desert, the Gangetic plains and the Deccan plateau. Each of these regions are distinct in terms of rainfall, soil type, groundwater recharge regime, climatic conditions and hydrology. High fluoride concentration in groundwater is a natural phenomenon in several countries such as China, Sri Lanka, West Indies, Spain, Holland, Italy and Mexico. Experts claim that a fluoride belt stretches across the Middle East across Pakistan and India and then into Southeast Asia and the South of China. According to a report of the Rajiv Gandhi National Drinking Water mission, the bedrock of the Indian peninsula consists of a number of fluoride bearing minerals. When the bedrock weathers the fluoride leaches into water and the soil. Although the Indian peninsular bedrock has always been the same, this problem has only surfaced during the last three decades. This is related to the over extraction of groundwater which has resulted in the tapping of aquifers with high fluoride concentrations.

The beginnings of this phenomenon can be traced back to the 1970s and the 1980s when there was massive state investment in rural water development for irrigation as well as for drinking. Encouraged by state subsidies on diesel and electricity, people invested in diesel and

submersible pumps in a bid to extract groundwater through borewells. This policy aggravated the fluoride problem.

Fluoride mainly enters the human body through drinking water where 96 to 99 percent of it combines with the bones as it has an affinity for calcium phosphate in the bones. Excess intake of fluoride can lead to dental fluorosis, skeletal fluorosis or non-skeletal fluorosis. Dental fluorosis is characterized by discoloured, blackened, mottled or chalky white teeth. Skeletal fluorosis leads to severe and permanent bone and joint deformities. Non-skeletal fluorosis leads to gastro-intestinal problems and neurological disorders. Fluoride can damage the foetus and adversely affect the IQ of children.

Once fluoride is detected in water, the only solution is to defluoridate it. Various technologies are available for this process. However the type of technology to be selected depends upon the fluoride levels in the water and the volume of water to be defluoridated. None of the Indian technologies are however fool-proof. Defluoridation plants and household water treatment kits are stop-gap solutions.

### A case study of pesticide pollution in India

One of the most terrifying effects of pesticide contamination of ground water came to light when pesticide residues were found in bottled water. Between July and December 2002, the Pollution Monitoring Laboratory of the New Delhi based Center for Science and Environment (CSE) analysed 17 brands of bottled water both packaged drinking water and packaged natural mineral water commonly sold in areas that fall within the national capital region of Delhi. Pesticide residues of organochlorine and organophosphorus pesticides which are most commonly used in India were found in all the samples. Among organochlorines, gamma-hexachlorocyclohexane (lindane) and DDT were

prevalent while among organophosphorus pesticides, Malathion and Chlorpyrifos were most common. All these were present above permissible limits specified by the European Economic Community, which is the norm, used all over Europe.

One may wonder as to how these pesticide residues get into bottled water that is manufactured by several big companies. This can be traced to several facts. There is no regulation that the bottled water industry must be located in 'clean' zones. Currently the manufacturing plants of most brands are situated in the dirtiest industrial estates or in the midst of agricultural fields. Most companies use bore wells to pump out water from the ground from depths varying from 24m to even 152 m below the ground. The raw water samples collected from the plants also revealed the presence of pesticide residues. This clearly indicated that the source of pesticide residues in the polluted groundwater are used to manufacture the bottled water. This is despite the fact that all bottled water plants use a range of purification methods. Thus obviously the fault lies in the treatment methods used.

These plants use the membrane technology where the water is filtered using membranes with ultra-small pores to remove fine suspended solids and all bacteria and protozoa and even viruses. While nanofiltration can remove insecticides and herbicides it is expensive and thus rarely used. Most industries also use an activated charcoal adsorption process, which is effective in removing organic pesticides but not heavy metals. To remove pesticides the plants use reverse osmosis and granular activated charcoal methods. Thus even though manufacturers claim to use these process the presence of pesticide residues points to the fact that either manufacturers do not use the treatment process effectively or only treat a part of the raw water.

The low concentration of pesticide residues in bottled water do not cause acute or immediate effect. However repeated exposure even to extremely miniscule amounts can result in chronic effects like cancer, liver and kidney damage, disorders of the nervous system, damage to the immune system and birth defects.

Similarly six months after CSE reported pesticide residues in bottled water it also found these pesticides in popular cold drink brands sold across the country. This is because the main ingredient in a cold drink or a carbonated non-alcoholic beverage is water and there are no standards specified for water to be used in these beverages in India.

There were no standards for bottled water in India till on September 29, 2000 the Union Ministry of Health and Family Welfare issued a notification (no759(E)) amending the Prevention of Food Adulteration Rules, 1954. The BIS (Bureau of Indian Standards) certification mark became mandatory for bottled water from March 29, 2001. However the parameters for pesticide residues remained ambiguous. Following the report published by CSE in *Down to Earth*, Vol 11, no. 18, a series of Committees were established and eventually on 18<sup>th</sup> July 2003 amendments were made in the Prevention of Food Adulteration Rules stating that pesticide residues considered individually should not exceed 0.0001mg.lit and the total pesticide residues will not be more than 0.0005 mg/lit that the analysis shall be conducted by using internationally established test methods meeting the residue limits specified herein. This notification came into force from January 1, 2004.

### **A case study of river pollution in India**

Almost all the rivers in India are polluted. The causes of pollution may also be more or less similar. This is a case study of the river Damodar as reported in *Down to Earth*. The 563 km long

Damodar river originates near Chandwa village in the Chhotanagpur hills in Bihar's Palamau district. It flows through one of the richest mineral belts in the world before draining into the Hooghly, about 50 km south of Calcutta. Indian industry depends heavily on this region as 60 percent of the coal consumed in our country comes from the Chhotanagpur belt. Coal based industries of all types dot the area because of locational advantages and the easy availability of water and power. In addition various industries such as the steel, cement, fertilizer and explosive plants are also located here. The river Damodar is polluted with minerals, mine rejects and toxic effluents. Both its water and its sand are infested by coal dust and waste from these industries. There are seven thermal power plants in the Damodar valley. The states of Bihar and West Bengal depend almost entirely on this area for their power requirements. These power plants not only consume a lot of water but also dump ash in the valley.

### *Mining*

As underground mines cannot keep pace with the rising demand, 60 percent of the coal extracted from the area comes from open cast mines which are responsible for serious land degradation. The disposal of rock and soil extracted along with the coal only adds to the problem.

### *Industries*

The industries in the area do not have proper effluent treatment plants. Among the big coal based industries the washeries account for the bulk of the pollution in terms of the total suspended solids (TSS), oil and grease. About 20 percent of the coal handled goes out in the form of slurry which is deposited in the ponds outside. After the slurry settles, coalfine (the sediment) is collected manually. Due to inadequate retrieval methods very often the water discharges into the river from the pond carries high

amounts of fine coal particles and oil thus polluting the river. The other major coal based polluters are the coke oven plants that heat coal to temperatures as high as 1100°C in the absence of oxygen to prepare it for use in blast furnaces and foundries. The volatile components in the coal are removed, leaving hot, non-volatile coke in the oven which is washed with huge quantities of water. This water that contains oil and suspended particles is then discharged into the river.

### *Flyash from the thermal power plants*

Only one of the thermal power plants has an electrostatic precipitator to collect the fly ash while the other just make do with mechanical dust collectors. As most of these plants are located on the banks of the river the fly ash eventually finds its way into the river. The bottom ash from the boilers is mixed with water to form a slurry which is then drained into ash ponds. Most of the ponds are full and in several cases the drainage pipes are choked. The slurry is therefore directly discharged into the river.

### *Effects*

The river and its tributaries are the largest source of drinking water for the huge population that lives in the valley. On April 2, 1990 about 200,000 litres of furnace oil spilled into the river from the Bokaro Steel Plant. This oil traveled 150 km downstream to Durgapur. For a week after the incident five million people drank contaminated water in which the oil levels were 40 to 80 times higher than the permissible value of 0.03 mg/l.

The Damodar Action Plan an end-of-the pipe pollution treatment scheme seeks to tackle effluents. One viable option could be to switch to less polluting industries and cleaner technology. This would need strong Government initiative and also a mass movement by people.

### *Pollution*



## 5.6 DISASTER MANAGEMENT: FLOODS, EARTHQUAKES, CYCLONES, LANDSLIDES

The Indian subcontinent is very vulnerable to droughts, floods, cyclones, earthquakes, landslides, avalanches and forest fires. Among the 36 states and Union territories in the country, 22 are prone to disasters.

Among all the disasters that occur in the country, floods are the most frequently occurring natural disasters, due to the irregularities of the Indian monsoon. About 75 percent of the annual rainfall in India is concentrated in three to four months of the monsoon season. As a result there is a very heavy discharge from the rivers during this period causing widespread floods. Approximately 40 million hectares of land in the country has been identified as being prone to floods. Major floods are mainly caused in the Ganga-Brahmaputra-Meghna basin which carries 60 percent of the total river flow of our country.

India has a long coastline of 5700 kms, which is exposed to tropical cyclones arising in the Bay of Bengal and the Arabian sea. The Indian Ocean is one of the six major cyclone prone regions of the world. In India, cyclones occur usually between April and May and also between October and December. The eastern coastline is more prone to cyclones as it is hit by about 80 percent of the total cyclones generated in the region.

Droughts are a perennial feature in some states of India. Sixteen percent of the country's total area is drought prone. Drought is a significant environmental problem as it is caused by a lower than average rainfall over a long period of time. Most of the drought prone areas identified by the Government lie in the arid and semi-arid areas of the country.

Earthquakes are considered to be one of the most destructive natural hazards. The impact of

this phenomenon occurs with so little warning that it is almost impossible to make preparations against damages and collapse of buildings. About 50 to 60 percent of India is vulnerable to seismic activity of varying intensities. Most of the vulnerable areas are located in the Himalayan and sub-Himalayan regions.

### From management to mitigation of disasters

Till very recently the approach towards dealing with natural disasters has been post disaster management involving problems such as evacuation, warnings, communications, search and rescue, fire-fighting, medical and psychiatric assistance, provision of relief, shelter, etc. After the initial trauma and the occurrence of the natural disaster is over and reconstruction and rehabilitation is done by people, NGOs and the Government, its memories are relegated to history.

It is evident today that human activities are responsible for accelerating the frequency and severity of natural disasters. Natural occurrences such as floods, earthquakes, cyclones, etc. will always occur. They are a part of the environment that we live in. However destruction from natural hazards can be minimized by the presence of a well functioning warning system combined with preparedness on part of the community that will be affected. Thus though traditionally disaster management consisted primarily of reactive mechanisms, the past few years have witnessed a gradual shift towards a more proactive, mitigation based approach.

Disaster management is a multidisciplinary area in which a wide range of issues that range from forecasting, warning, evacuation, search and rescue, relief, reconstruction and rehabilitation are included. It is also multi-sectoral as it involves administrators, scientists, planners, volunteers and communities. These roles and activities span

the pre-disaster, during disaster and post disaster plans. Since their activities are complementary as well as supplementary to each other there is a critical need for coordinating these activities.

In order to transfer the benefits of scientific research and development to the communities links must be developed between scientific communities and field agencies. Coordination between Government agencies and NGOs needs to be built up so that overlap of activities may be avoided and linkages between the Government and communities are established.

Today we have a range of early warning systems for a range of natural hazards. Although they are more accurate than before and can help in prediction it is not enough to ensure communities are safe from disasters. This is where disaster mitigation can play an important role. Mitigation means lessening the negative impact of the natural hazards. It is defined as sustained action taken to reduce long term vulnerability of human life and property to natural hazards. While the preparatory, response and the recovery phases of emergency management relate to specific events, mitigation activities have the potential to produce repetitive benefits over time.

Certain guidelines if followed can result in an effective mitigation program.

- Pre-disaster mitigation can help in ensuring faster recovery from the impacts of disasters.
- Mitigation measures must ensure protection of the natural and cultural assets of the community.
- Hazard reduction methods must take into account the various hazards faced by the affected community and their desires and priorities.

- Any mitigation program must also ensure effective partnership between Government, scientific, private sector, NGOs and the community.

The main elements of a mitigation strategy are as follows:

#### *Risk assessment and Vulnerability analysis*

This involves identification of hot spot areas of prime concern, collection of information on past natural hazards, information of the natural ecosystems and information on the population and infrastructure. Once this information is collected a risk assessment should be done to determine the frequency, intensity, impact and the time taken to return to normalcy after the disaster. The assessment of risk and vulnerabilities will need to be revised periodically. A regular mechanism will therefore have to be established for this. The use of Geographical Information Systems (GIS) a computer program can be a valuable tool in this process as the primary data can be easily updated and the corresponding assessments can be made.

#### *Applied research and technology transfer*

There is a need to establish or upgrade observation equipment and networks, monitor the hazards properly, improve the quality of forecasting and warning, disseminate information quickly through the warning systems and undertake disaster simulation exercises.

Thus space technologies such as remote sensing, satellite communications and Global Positioning Systems have a very important role to play. Government organizations like ISRO (Indian Space Research Organization) can play a vital role. Similarly Government organizations the National Building Research Organization, the Meteorological Department, Irrigation Department, etc. can undertake applied research for devising locale specific mitigation strategies in

collaboration with educational institutions or Universities.

Such steps could lead to the formulation of locale specific mitigation measures. A combination of scientific knowledge and expertise with the community based mitigation measures would not only enhance the database but would also form the basis of a successful mitigation strategy.

#### *Public awareness and training*

One of the most critical components of a mitigation strategy is the training to be imparted to the officials and staff of the various departments involved at the state and the district level. This enables sharing of information and methodology. The success of a mitigation strategy will depend to a large extent on the inter-sectional, inter-departmental coordination and efficient teamwork. Thus a training program that is designed after assessment of gaps in knowledge, skills and attitude with respect to the various tasks that need to be undertaken is a vital component.

#### *Institutional mechanisms*

The most important need at the National level is to strengthen or develop the capacity to undertake disaster mitigation strategies. There is a need to emphasize on proactive and pre-disaster measures rather than post disaster response. It is thus essential to have a permanent administrative structure which can monitor the developmental activities across departments and provides suggestions for necessary mitigation measures. The National Disaster Management Center (NDMC) can perform such a task. Professionals like architects, structural engineers, doctors, chemical engineers who are involved with management of hazardous chemicals can be asked to form groups that can design specific mitigation measures.

#### *Incentives and resources for mitigation*

To a very large extent the success of mitigation programs will depend upon the availability of continued funding. There is thus a need to develop mechanisms to provide stable sources of funding for all mitigation programs. This will include incentives for relocation of commercial and residential activities outside the disaster prone areas. Housing finance companies should make it mandatory for structures in such hazard prone areas to follow special building specifications. The introduction of disaster linked insurance should be explored and should cover not only life but also household goods, cattle, structures and crops.

#### *Landuse planning and regulations*

Long term disaster reduction efforts should aim at promoting appropriate land-use in the disaster prone areas. Separation of industrial areas from residential areas, maintaining wetlands as buffer zones for floods, creation of public awareness of proper land practices and formation of land-use policies for long term sustainable development is imperative.

#### *Hazard resistant design and construction*

In areas that are prone to disasters protection can be enhanced by careful selection of sites and the way the buildings are built. Thus it is essential to promote the knowledge of disaster resistant construction techniques and practices among engineers, architects and technical personnel.

#### *Structural and Constructional reinforcement of existing buildings*

It is also possible to reduce the vulnerability of existing buildings through minor adaptations or alterations thereby ensuring their safety. This can be done by insertion of walls on the outside of the building, buttresses, walls in the interior of the building, portico fill-in-walls, specially an-

chored frames, covering of columns and beams, construction of new frame system, placing residential electrical equipment above flood level, designing water storage tanks to be able to withstand cyclonic winds, earthquakes and floods, etc.

## **Floods and mitigation measures**

The lower plain regions of India in particular Bihar, Uttar Pradesh and West Bengal in respect of the Ganga and Assam in respect of the Brahmaputra suffer from the adverse effects of floods every year. The Ganga Brahmaputra basin receives maximum run off within the three monsoon months. Based on hydrological studies carried out, it is estimated that only 18 percent of the rainwater can be stored in dams, reservoirs, etc. while 82 percent of the rainwater flows through rivers ultimately into the sea. Floods are therefore a recurring phenomenon in our country.

Floods can be caused by natural, ecological or anthropogenic factors either individually or as a combined result. Anthropogenic activities such as deforestation and shifting cultivation can also contribute to floods. Forests on the hill slopes normally exert a sponge effect soaking up the abundant rainfall and storing it before releasing it in small amounts over a period of time. However when the forests are cleared the rivers turn muddy and swollen during the wet monsoon season and run dry later on in the year during the drier periods. An increasing proportion of the rainfall is therefore released shortly after precipitation in the form of floods.

The mitigation measures for floods include both structural and non-structural measures. The structural measures include:

- Reservoirs for impounding monsoon flows to be released in a regulated manner after the peak flood flow passes.

- Prevention of over-bank spilling by the construction of embankments and floodwalls.
- Improvement of flow conditions in the channel and anti-erosion measures.
- Improved drainage.

The non-structural measures include:

- Flood plain management such as Flood Plain Zoning and Flood Proofing including Disaster Preparedness
- Maintaining wetlands
- Flood forecasting and warning services
- Disaster relief, flood fighting and public health measures
- Flood insurance

## **Earthquakes and mitigation measures**

It has been several years since the earthquake struck Gujarat on January 26, 2001. In these years rehabilitation has been done on a massive scale. Gujarat's experience has taught that building shelters with less vulnerability to earthquakes should also take into consideration the specific needs of the victims instead of being a top down approach. The role of NGOs in this is very important. Their strength lies in their manpower, informality in operations and valuable human resources. Their ability to reach out to the community and sensitivity to local traditions is an asset in such situations. A report on the various initiatives in Gujarat reported in Down to Earth (Vol 12, No. 2) by Mihir Bhatt throws light on the various developments that have taken place after the earthquake. According to the report the initiatives of the International Fund for

Agriculture Development in supporting the Self Employed Women's Association and the Government's initiative in community based livelihood security for earthquakes and drought victims have the potential to shape future disaster response and development projects in Gujarat. Similarly the Gujarat Woman's Economic Development Corporation initiative in reviving women's businesses after the calamity also provides many practical lessons in regenerating local economies and artisan markets. This project supported by the Asian Development Bank, puts premium on investments in income generation and asset building after a natural disaster. The farming kits provided to affected farmers by Gujarat's agriculture ministry is also showing promising results after two seasons. The author however states that coordination between Government, local NGOs and local community initiatives both for rescue as well as rehabilitation needs to be strengthened as this can cause delays, overlaps and waste of relief material and efforts.

## **Cyclones and mitigation measures**

Tropical cyclones are the worst natural hazards in the tropics. They are large revolving vortices in the atmosphere extending horizontally from 150 to 1000 km and vertically from the surface to 12 to 14 km. These are intense low-pressure areas. Strong winds spiraling anti clockwise in the Northern Hemisphere blow around the cyclone center at the lower level. At the higher levels the sense of rotation is just opposite to that at the lower level. They generally move 300 to 5000 km per day over the ocean. While moving over the ocean they pick up energy from the warm water of the ocean and some of them grow into a devastating intensity. On an average about 5 to 6 tropical cyclones form in the Bay of Bengal and the Arabian Sea every year out of which 2 to 3 may be severe. More cyclones form in the Bay of Bengal than in the Arabian Sea. The main dangers from cyclones

are very strong winds, torrential rains and high storm tides. Most of the casualties are caused by coastal inundation by storm tides. This is often followed by heavy rainfall and floods. Storm surges cause the greatest destruction.

Although one cannot control cyclones, the effects of cyclones can be mitigated through effective and efficient mitigation policies and strategies. A brief description of the same is given below.

*Installation of early warning systems:* Such systems fitted along the coastlines can greatly assist forecasting techniques thus helping in early evacuation of people in the storm surge areas.

*Developing communication infrastructure:* Communication plays a vital role in cyclone disaster mitigation and yet this is one of the first services that gets disrupted during cyclones. Amateur Radio has today emerged as a second line unconventional communications systems and is an important tool for disaster mitigation.

*Developing shelter belts:* Shelter belts with plantations of trees can act as effective wind and tide breakers. Apart from acting as effective windbreakers and protecting soil crops from being damaged they prevent soil erosion.

*Developing community cyclone shelters:* Cyclone shelters at strategic locations can help minimizing the loss of human life. In the normal course these shelters can be used as public utility buildings.

*Construction of permanent houses:* There is a need to build appropriately designed concrete houses that can withstand high winds and tidal waves.

*Training and education:* Public awareness programs that inform the population about their response to cyclone warnings and preparedness can go a long way in reducing casualties.

*Landuse control and settlement planning:* No residential and industrial units should be ideally permitted in the coastal belt of 5 km from the sea as it is the most vulnerable belt. No further growth of settlements in this region should allowed. Major settlements and other important establishments should be located beyond 10 km from the sea.

## **Landslides and mitigation measures**

Landslides are recurring phenomena in the Himalayan region. In the recent years however intensive construction activity and the destabilizing forces of nature have aggravated the problem. Landslides occur as a result of changes on a slope, sudden or gradual, either in its composition, structure, hydrology or vegetation. The changes can be due to geology, climate, weathering, land-use and earthquakes.

A significant reduction in the hazards caused by landslides can be achieved by preventing the exposure of population and facilities to landslides and by physically controlling the landslides. Developmental programs that involve modification of the topography, exploitation of natural resources and change in the balance load on the ground should not be permitted. Some critical measures that could be undertaken to prevent further landslides are drainage measures, erosion control measures such a bamboo check dams, terracing, jute and coir netting and rock-fall control measures such as grass plantation, vegetated dry masonry wall, retaining wall and most importantly preventing deforestation and improving afforestation.

Disasters cannot be totally prevented. However early warning systems, careful planning and preparedness on part of the vulnerable community would help in minimizing the loss of life and property due to these disasters.