



Environmental Studies For Undergraduate Courses

Erach Bharucha

University Grants Commission, New Delhi

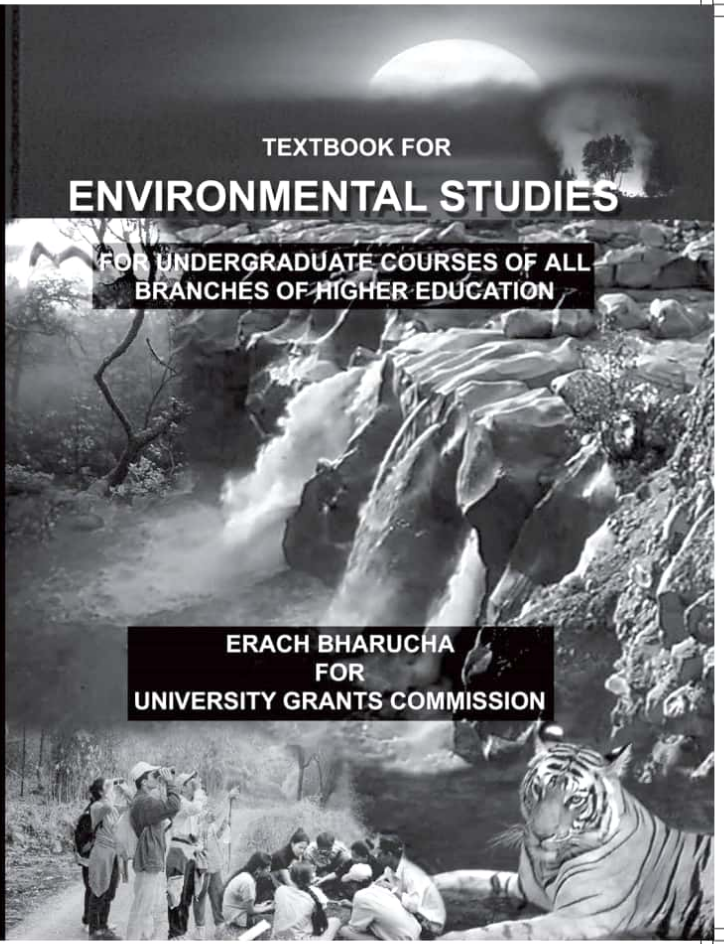
and

Bharati Vidyapeeth Institute of Environment Education and Research, Pune

TEXTBOOK FOR
ENVIRONMENTAL STUDIES

FOR UNDERGRADUATE COURSES OF ALL
BRANCHES OF HIGHER EDUCATION

ERACH BHARUCHA
FOR
UNIVERSITY GRANTS COMMISSION



UNIT 5: Pollution

5.1 DEFINITION	112
5.2 CAUSES, EFFECTS AND CONTROL MEASURES OF:	113
5.2.1 Air Pollution	113
5.2.2 Water Pollution	123
5.2.3 Soil Pollution	131
5.2.4 Marine Pollution	135
5.2.5 Noise Pollution	140
5.2.6 Thermal Pollution	142
5.2.7 Nuclear hazards	143
5.3 SOLID WASTE MANAGEMENT: CAUSES, EFFECTS AND CONTROL MEASURES OF URBAN AND INDUSTRIAL WASTE	145
5.4 ROLE OF INDIVIDUALS IN POLLUTION PREVENTION	150
5.5 POLLUTION CASE STUDIES	153
5.6 DISASTER MANAGEMENT: FLOODS, EARTHQUAKES, CYCLONES, LANDSLIDES	156

<i>Pollution</i>	111
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AIR POLLUTION



WATER POLLUTION



OIL POLLUTION



SOIL POLLUTION



NOISE POLLUTION



LOSS OF RENEWABLE RESOURCES



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

Environmental Studies for Undergraduate Courses

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 19th 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 3rd 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°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 CO₂), 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.

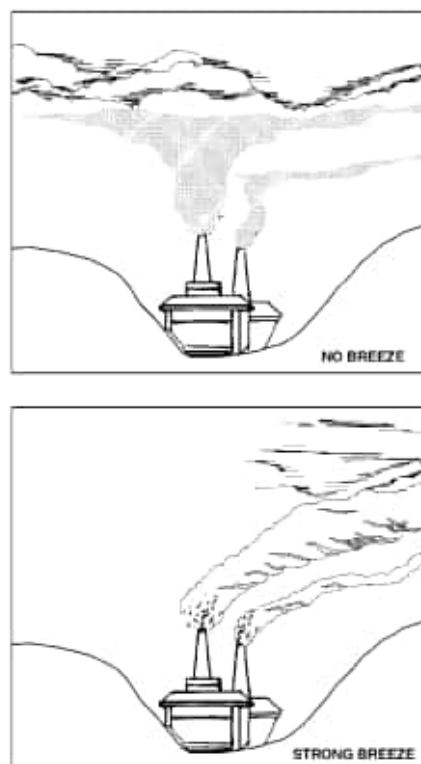
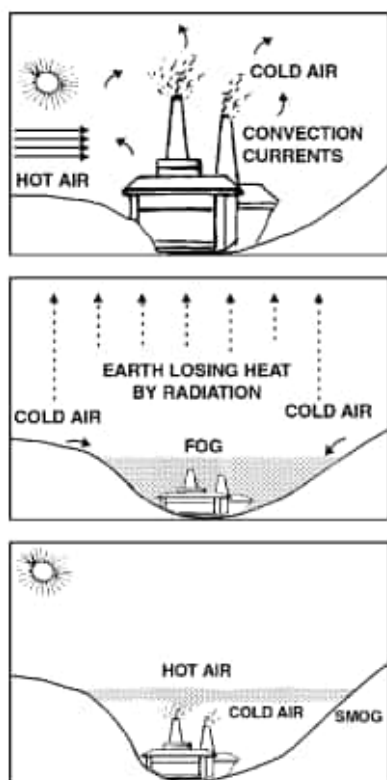
However on a still evening, the process is reversed. An hour or two before sunset after a sunny day, the ground starts to lose heat and the air near the ground begins to cool rapidly. Due to the absence of wind, a static layer of cold air is produced as the ground cools. This in turn induces condensation 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).

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.



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

Pollution

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_2 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 CFC's (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

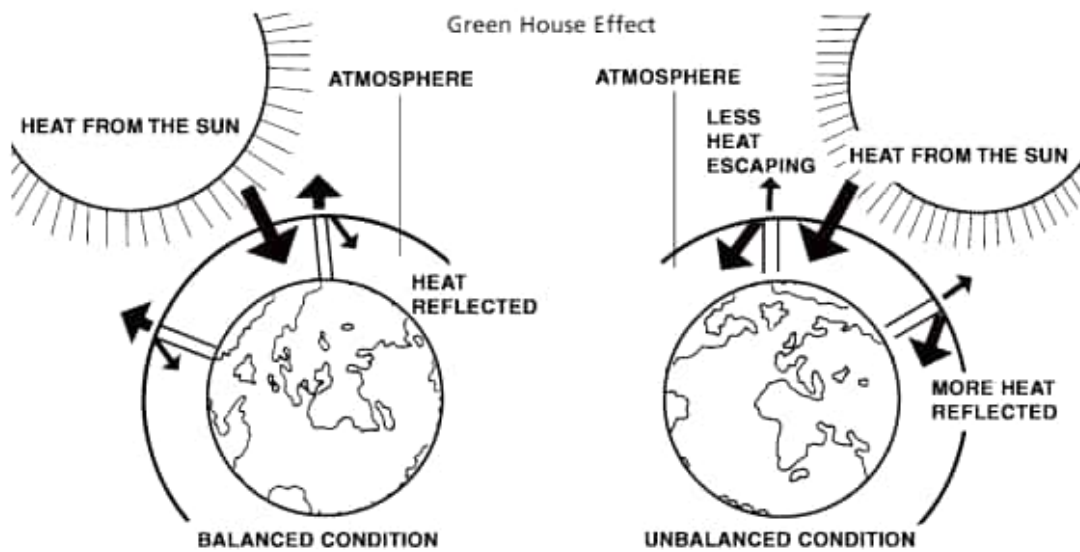
increased ultra-violet radiation. It weakens the immune system by suppressing the resistance of the whole body to certain infections like measles, chicken pox and other viral diseases that elicit rash and parasitic diseases such as malaria introduced through the skin.

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 (PM10) 3-4 times the standard of 60 microgram per cubic meter (mg/m^3). 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 $60 \text{ mg}/\text{m}^3$. 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 $\mu\text{g}/\text{m}^3$	SO ₂ $\mu\text{g}/\text{m}^3$	Co $\mu\text{g}/\text{m}^3$	NO _x $\mu\text{g}/\text{m}^3$
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.

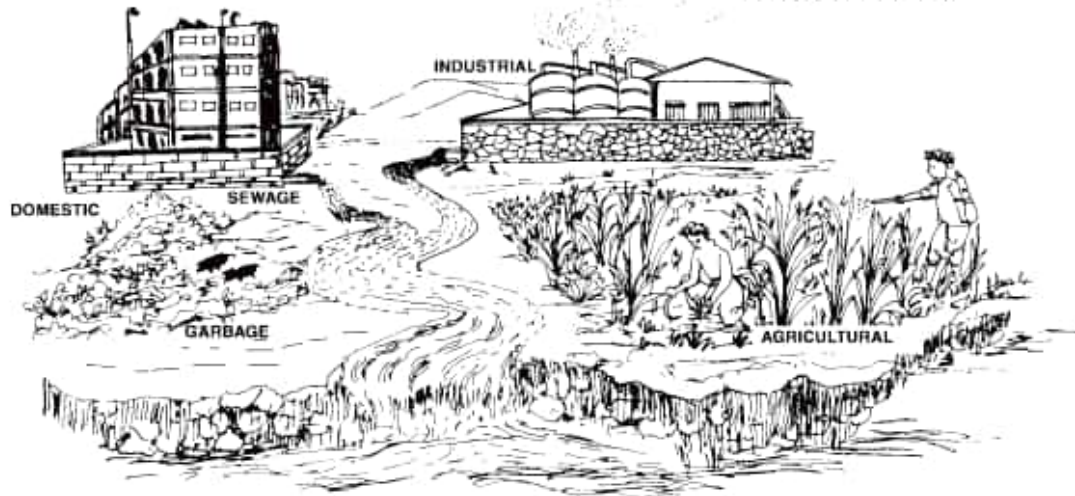
India receives most of her rainfall during the months of June to September due to the seasonal winds and the temperature differences between the land and the sea. These winds blow from the opposite directions in the different seasons. They blow into India from the surrounding oceans during the summer 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

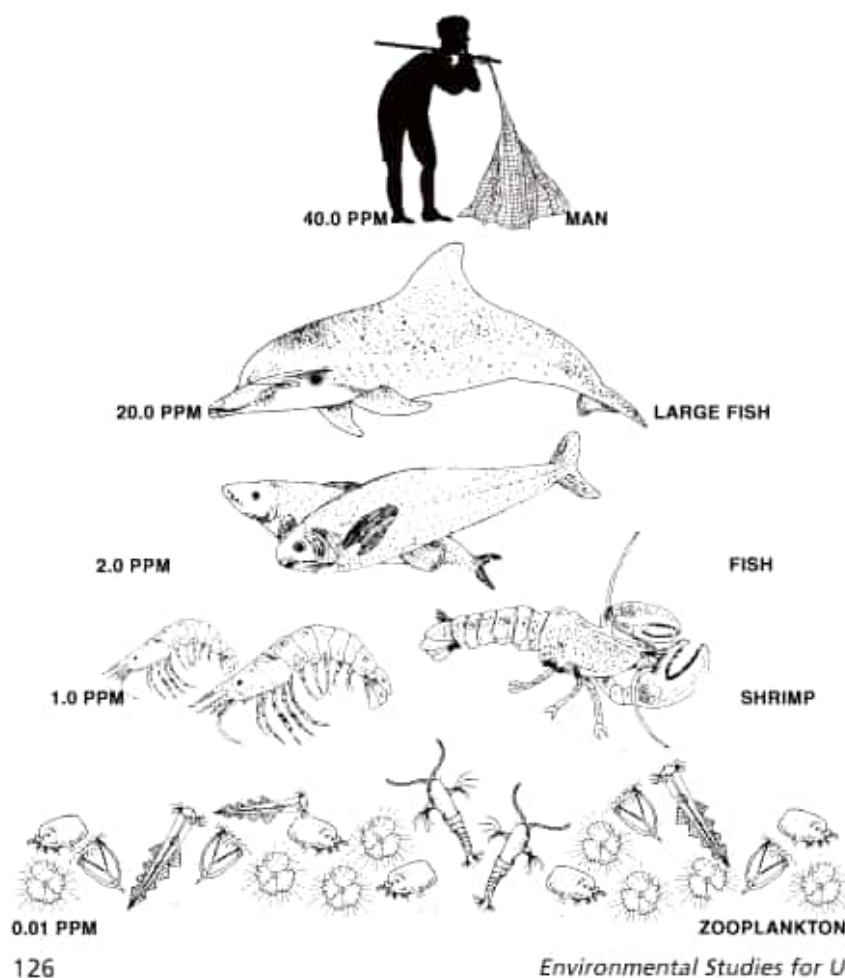
degrade these wastes. In the process this degrades water quality. The amount of oxygen required to break down a certain amount of organic matter is called the biological oxygen demand (BOD). The amount of BOD in the water is an indicator of the level of pollution. If too much organic matter is added 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 15°C 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 24th 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, i.e; 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 runoff 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 these 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 base 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-