# Understanding Environment

Editors

Kiran B. Chhokar • Mamata Pandya • Meena Raghunathan

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**CEE**
Centre for Environment Education



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# Contents


List of Tables 7
List of Illustrations 8
Preface 11

1. Understanding Environment 13
   Kartikeya V. Sarabhai

2. Ecology 18
   Shivani Jain

3. Biodiversity 47
   Seema Bhatt

4. Water 73
   Avanish Kumar and Sarita Thakore

5. Energy 104
   Kiran B. Chhokar

6. Pollution 136
   Hema Jagadeesan

7. Agriculture 153
   Kalyani Kandula

8. The Urban Environment 175
   Vivek S. Khadpekar and Sunil Jacob

9. Industry 202
   Meena Raghunathan

10. Climate Change and Ozone Depletion 215
Kiran B. Chhokar, Mamata Pandya and Meena Raghunathan

11. Population, Consumption and Environment 238
Kalyani Kandula

12. Environment and Development: The Links 263
Kalyani Kandula

13. Citizen Action 279
Kiran B. Chhokar, Mamata Pandya and Avanish Kumar

Appendices
1. Environmental Laws in India 298
2. International Environmental Agreements 304

Glossary 310

About the Editors and Contributors 321

Index 325

# List of Tables


| | | |
|---|---|---|
| 2.1 | Major types of ecosystems in the world | 23 |
| 2.2 | India's biodiversity | 27 |
| 4.1 | Sectorwise present and future water requirements: 1990–2050 | 78 |
| 4.2 | Specifications for drinking water quality | 92 |
| 6.1 | Decibel levels of common sounds and effects of prolonged exposure | 145 |
| 7.1 | Diversity of agricultural crops in India | 165 |
| 7.2 | Diversity of domestic livestock breeds in India | 166 |
| 7.3 | Paddy output from a half-acre plot | 171 |
| 8.1 | Slum population of selected million plus cities, 1991 and 2001 | 181 |
| 8.2 | Level of air pollution in selected cities | 185 |
| 8.3 | Physical characteristics of municipal solid wastes in Indian cities | 188 |
| 8.4 | Indian cities: Waste generation per capita | 188 |
| 9.1 | Industrial contribution of pollution by subsector in India | 204 |
| 10.1 | Carbon emissions per year from burning fossil fuels | 226 |
| 11.1 | India's population | 243 |
| 11.2 | Ecological footprints | 255 |
| 11.3 | Population share of Indian states/union territories, 2001 | 260 |
| 12.1 | Per capita GDP of selected countries (2001) | 264 |

# List of Illustrations

## Illustrations


2.1 Ecology at various levels 19
2.2 The ecosystem as a dynamic network of interactions between living and non-living components 22
2.3 India: Biogeographic zones 25
2.4 Energy flow 33
2.5 Food chains 35
2.6 Organisms at various trophic levels 36

3.1 Genetic diversity gives rise to several varieties of wheat 48
3.2 There are no cheetahs left in the wild in India today 54
3.3 Project Tiger has helped not only to protect the tiger, but numerous other wild inhabitants of India's tiger sanctuaries as well 63

4.1 Water cycle 74

5.1 Consumption of energy in development of human society 105
5.2 Energy ladder 109
5.3 Solar panel 123

6.1 Industrial effluents 142
6.2 Biohazard symbol 144

8.1 Thermal inversion 186

9.1 India's ecomark 211

10.1 The greenhouse effect 217
10.2 How ozone is destroyed 232

## Figures

3.1 Causes and mechanics of the loss of biodiversity 55

4.1 Sector-wise utilization of total water resource in India (1997) 79
4.2 Increase in annual groundwater demand (cubic kilometres) 80
4.3 Rapid drop in groundwater in Ahmedabad between 1960 and 1995 81
4.4 Drinking water availability in rural areas 83
4.5 Drinking water availability in urban areas 83

5.1 India: Sources of commercial energy (1997–98) 111
5.2 India: Sectoral consumption of commercial energy (1999–2000) 125

8.1 India: Population distribution in rural areas, urban areas, 1951–2001 179
8.2 Total number of motor vehicles in India (1951–2001) 190

# PREFACE

The Supreme Court of India has ruled that a course on Environment be made compulsory at the undergraduate level. Some universities have already initiated such a course; many others introduced it in the academic year beginning 2004, and still others will follow soon after. The basic purpose of the course is to create environmentally and socially aware and responsible citizens.

The United Nations has declared the decade beginning 2005 as the Decade for Education for Sustainable Development (ESD). ESD is seen as a process that develops vision, builds capacity, and empowers people to make changes within their societies. The goal is to create citizens who can actively participate in creating a sustainable world for themselves and for future generations.

This book tries to address both these situations.

To live sustainably, people need to:

*Understand* how the Earth's natural systems work.
Access *information* about the state of the planet.
*Aquire tools and skills* for wise, efficient and productive environmental management.
Be *committed* to use the Earth's resources sensitively and share its bounty equitably.

The different components of the book address these needs. The book introduces readers to some of the key scientific concepts and issues related to environment. It also sensitizes them to environmental issues and concerns. Environmental issues make better sense when one can understand them in the context of one's own cognitive sphere. The chapters in this book provide several examples and a fair amount of data. We hope this will help contextualize the information. We hope readers will also try to think about, or make an effort to find out about, similar or related examples from their own region, state, district or neighbourhood to better understand the issues.

The book contains several 'boxes' of information. The boxed items in the text have been introduced to serve two functions—to expand on ideas mentioned in the text and to present related examples. They are also intended to provide a stimulus to readers to explore on their own and find out more about the topic. The book also contains several

case studies. These highlight examples of individual and collective actions by citizens that have 'made a difference'.

At the end of each chapter are three sections for self-learning and evaluation: Questions, Exercises, and Discuss. The first section includes a list of questions, some of which are intended to get readers to review the key ideas introduced in the chapter and to test comprehension. Others are more open-ended and have been framed to encourage analytical and critical thinking. The exercises require reading and analysis of information, or gathering information through library research, field visits, surveys or interviews. The section Discuss requires students to reflect on statements and think critically; in some cases to think about the pros and cons of an issue and take a position. We hope that readers will enjoy the exercises and find the questions challenging but not daunting!

We also hope that the book generates enough interest in the readers so that they follow environmental debates in the media, and that it creates enough concern so that they question their own behaviour from time to time, out of a concern for the environment.

Our attempt has been to provide current data and information. But the rapidity of economic, political, social, and technological change and the constant flow of new research findings make the goal of providing up-to-date information elusive. We are aware that by the time the book is printed, some of the information will have changed. By the time the book reaches the readers, some more information and analysis might no longer be current. We are confident, however, that the 'information age' readers will seek out and keep abreast with the latest information and interpretation.

All the chapters were reviewed by subject experts to ensure accuracy of information and quality. However, some errors might still remain for which the editors take full responsibility. We hope that our readers will bring these to our attention so that we can correct them in future editions.

## A Last Word

The test of how relevant or useful this book is lies in using it. We look forward to suggestions from readers, what they think about this book, and what additional information and features they would like to see in this book in the future. Please send us this information at highereducation@ceeindia.org or write to us at Higher Education Programme, Centre for Environment Education, Thaltej Tekra, Ahmedabad 380 054.

Teachers' guide

To help teachers use this textbook more effectively, notes, suggestions and support material, including teachers' guides for some of the chapters, are available from the Higher Education Programme, Centre for Environment Education, Thaltej Tekra, Ahmedabad 380 054.

# Chapter 1

# Understanding Environment

Kartikeya V. Sarabhai

Academic disciplines are created to help us understand the universe better. While nature can be understood using the disciplines, it is not 'divided' into disciplines. For instance, a certain phenomenon may be referred to as a chemical change while another as a physical one. But these categories are only perceptions.

'Environmental Studies' is about the environment. Not the environment from the point of view of any one particular discipline, but a study and understanding of the interlinkages—the complex ways in which one phenomenon, one action, is connected to another; how the same thing can be understood from different perspectives, perspectives often rooted in different disciplines.

## Kaleidoscope in Real Life

Vavania is a village near Kachchh that was severely affected by an earthquake in 2001. The Centre for Environment Education got involved in the rehabilitation activities in this village. The first task was to rebuild the houses, the school and the health centre. The next task was that of providing the village with a water system. It was here that we realized the multidisciplinary nature of the problem at hand.

To study water in the village, we had to first understand the pattern of rainfall and total water availability. This required knowledge of meteorology. Indeed, to understand the phenomenon of rain itself one needs some grounding in Physics. Then, to understand groundwater one needs to study hydrology. To understand soil types and the permeability of water, we need geology. The quality of water requires an understanding of chemistry. To study lakes, life forms in them and their impact on the water and its quality requires one to garner knowledge of biology and ecology. Water and its use are integral to society

and cultures for which one must have at least background knowledge of cultural anthropology, sociology and political science. Finally, to evaluate various alternatives for a new infrastructure, an understanding of economics is essential.

## A SENSE OF PLACE

I first used the word 'environment' in the urban context. The organization had been studying the responses of people living in the old walled city of Ahmedabad and comparing them with the responses of people who had moved to the newer housing societies which were coming up in the western part of the city. While the new houses and the amenities they provided were much better in terms of infrastructure, the people felt that something was missing, but it was difficult to articulate what that something was. The old *Pols*, as the narrow streets in the old city are called, had a friendliness, a feeling of community, a sense of neighbourhood that seemed to have disappeared in the new residential areas. We realized that the built environment had changed the social one, but it was difficult to understand all the dynamics of this relationship.

Our survey led us to an even more challenging task. We had asked the people in the mid-1970s what they would like to see in their city in the year 2000, at the time a far-off date. One answer which was repeated many times was that it was possible for a woman to travel alone late at night in the city, and that this security should be maintained in the city of the future. We had before us the plans for the city. The plans of the Urban Development Authority spoke of infrastructure, building bye-laws and zoning of urban use, but nowhere did it make a link to human or societal security. And yet we realized that these were interconnected. The fact that so many metropolitan areas were de-humanized had a lot to do with the environment they had created. These issues required skill and understanding from a variety of disciplines to even start appreciating the linkages and defining the problem.

## TOWARDS UNDERSTANDING THE ENVIRONMENT

The term 'Environment Studies' takes on an even deeper meaning in the Indian context. Concern for the environment was put on the world political map largely as a result of the UN Conference on the Human Environment, held in Stockholm in 1972. The only Head of Government, besides the host country, to attend the conference was Indira Gandhi, the then Prime Minister of India. And it was here that she made the statement

that one could not think of the environment without also looking at issues of poverty; that environmental issues and developmental ones were two sides of the same coin. It was indeed human 'developmental' activity that had had a very substantial impact on the natural environment. And in turn, the rapid decline in the natural resource base was affecting the quality of human life in several parts of the globe, especially the lives of the poor and the marginalized.

It took two decades for the world to recognize this relationship. This came in the form of the UN Conference on Environment and Development (UNCED) held in Rio de Janeiro, Brazil, in 1992. The conference was one of the largest gatherings ever of Heads of State and Government, a far cry from Stockholm 20 years before. The study of the environment now required an understanding of development issues, further expanding the interdisciplinary nature of the subject. But most importantly, Rio drew attention to two major and global crises. One was the realization that human activity was leading to the rapid extinction of species. The other was that industrial activity was directly responsible for global warming and the thinning of the ozone layer that provided a shield from ultraviolet radiation.

The complex link between human activities and the loss of biodiversity was rapidly coming to light. Loss of habitats and poaching of wildlife were the more obvious reasons. But more complex and unsuspected links are being thrown up as scientists go deeper into the subject. The recent rapid decline of species of vultures in South Asia could be the result of the impact of a veterinary drug given to cattle which is eventually passed on to vultures when they feed on the carcasses of these animals. The study required a number of disciplines to establish this relationship.

Similarly, while atmospheric science and chemistry may seem distantly related subjects, it was the study of CFCs and their impact on ozone that finally led to an understanding of the ozone 'hole', and the Montreal Protocol (a commitment by governments to phase out the use of CFCs), which has been one of the success stories of a global response to a global problem. The more complex issues relating to climate change are still to achieve such success.

## Environment and Development

But moving from a sectoral approach to one which is interdisciplinary is not easy. Governments and the division of work within them and the ways in which ministries are formed and work divided, essentially reflect the thinking of the period before environmental understanding had reached current levels. So one may find an ironical situation wherein the Ministry of Power subsidizes electricity, making it cheaper to withdraw groundwater. The water then seems to be plentiful and cheap, leading to the plantation of more water

consumptive commercial crops. Very soon groundwater levels fall so low that even with cheap electricity this type of agriculture cannot be sustained. Usually there is not enough water left even to go back to growing traditional crops.

There are numerous examples of how the policies of different departments of the government led to contradictory or counter productive results (unintended or unanticipated) in the real environment. For instance, an initiative to plant a tree called *Prosopis juliflora* on the border of the Rann of Kachchh to prevent the spread of the desert proved counter productive as the tree spread so rapidly that it wiped out the native species of grass on which the livestock economy of the region depended.

As we recognize the relationship between environment and development, we realize that the path we are following is neither desirable nor sustainable. We need to move towards what is being called 'sustainable development'; development that leads to a better life for *all*, now and in the future. For that to happen, much more public awareness and, in particular, awareness among decision-makers, is required. Environmental studies forms the backbone of this understanding. It is the younger generation, which is on the threshold of assuming critical roles and responsibilities, to whom we can look at to spread this understanding to a wider audience and apply it in all spheres of life.

## I QUESTIONS

1. List all the subjects that you are studying. How is each of these connected with the environment? Is there any subject which is *not* in any way connected with the environment?
2. One of the development goals of the Government of India is education for all, especially education for women. Many suggest that women's education depends on several factors such as the status of women in society; poverty; availability of water, firewood and fodder; and toilets for girl students in schools. Do you agree? If so, what are the links? Describe each relationship in about a paragraph.
3. Given below is a partial list of India's national development goals. Which do you think should be the main ministry of the Government of India responsible for each? Which two other ministries should be involved?

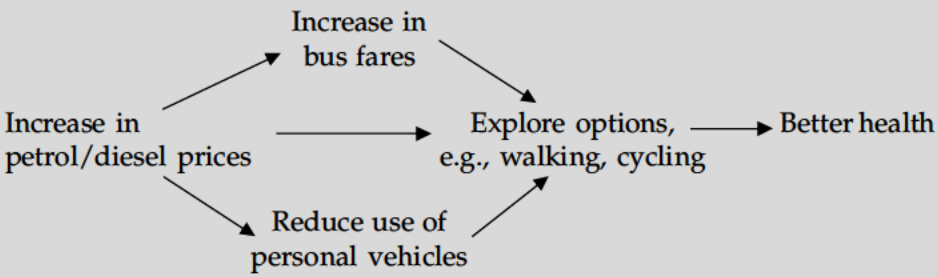
| Development goals | Lead ministry | Other ministries (any two) |
|---|---|---|
| Poverty removal | | |
| Food sufficiency | | |
| Drinking water | | |
| Sanitation | | |

| Development goals | Lead ministry | Other ministries (any two) |
|---|---|---|
| Education for all | | |
| Primary health care for all | | |
| Containing population growth | | |
| Public transport | | |

Now do a search in the library or on the Internet to find out which ministries are actually involved.

## II EXERCISES

1. You may have come across a few unfamiliar terms in this chapter. List them. These terms are used and explained in different parts of this book. Find these terms and what they mean.
2. 'Increase in fuel prices leads to better health.' The diagram below explains how.




Read the statements given below and draw diagrams to illustrate the connections. There should be at least two links between the two ends.

1. Move to a 'modern' residential complex leads to unhappy family elders.
2. Road building leads to spread of malaria.
3. Large-scale afforestation (planting of trees) leads to a decrease in the number of children who drop out of school.
4. Rainwater harvesting leads to an improvement in the health of women.

# Chapter 2

# Ecology

Shivani Jain

The word **'ecology'** is derived from the Greek words *oikos*, meaning household, and *logos*, meaning study. Literally, then, ecology is the study of 'life at home'. In other words, ecology is the study of the interconnections and interdependence of plants, animals and their environment. The essence of ecology lies in the study of the togetherness of everything—plants, animals, micro-organisms and their environment—because, in nature, everything is connected.

There are intricate connections between the various components of nature. For instance, green plants take nutrients and water from the soil. Their leaves, fruits and other parts may then be eaten by a bird or a deer. When these die, a part of their dead remains are eaten up by bacteria, fungi, etc., while the remainder is broken down into smaller molecules like nitrogen, carbon, sulphur, etc. (decomposition), and goes back to the soil, thus connecting them all.

A large number of such connections exist in nature, and hence the essence of ecology lies in a holistic approach to the subject. However, in order to understand the 'whole' and all the connections, let us try to understand the 'parts' or the components.

## Levels of Organization in Nature

Perhaps the best way to understand ecology is to look at it from the point of view of the **levels (hierarchy) of organization** that ecology focuses on. These levels are: organisms (individuals), species, populations, communities and ecosystems. Interaction with the physical environment (energy and matter) at each level produces characteristic functional systems. This **hierarchical theory** of levels of organization provides a convenient framework for dealing with complex situations, because each of these levels has some special features, and hence the study of ecology in parts, at these levels, becomes easier. Let us understand these levels one by one.

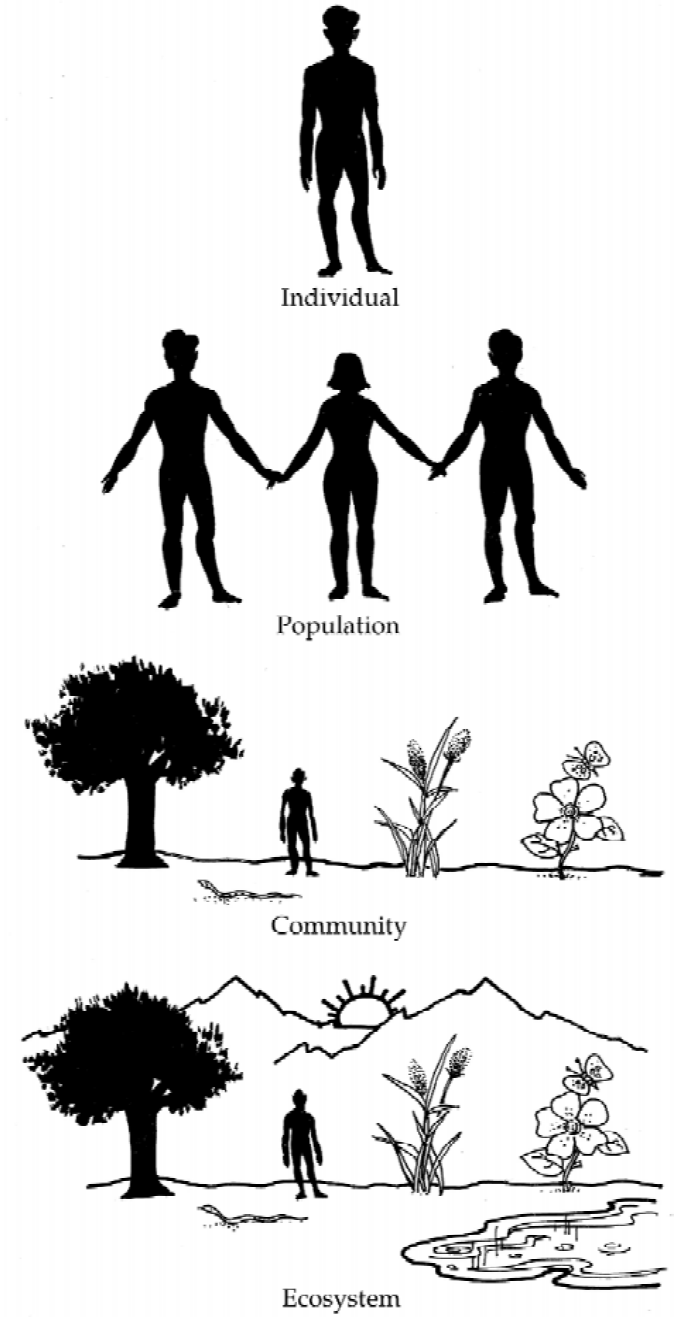



Illustration 2.1 Ecology can be studied at various levels

## Organisms

An organism is any form of life. A wide range and variety of organisms is present on the earth—from the single-celled amoeba to huge sharks, from microscopic blue-green algae to massive banyan trees.

## Species

Groups of organisms that resemble one another in appearance, behaviour, chemistry and genetic structure form a species. Organisms of the same species can breed with one another and produce fertile offspring under natural conditions. For instance, all human beings (*Homo sapiens*) resemble one another in their body structure, body systems, and they all have similar genetic structure. They are thus grouped together under the species *sapiens*.

## Population

A population is a group of individuals of the same species occupying a given area at a given time. For example, the Asiatic lions in the Gir National Park, Gujarat, make a population.

## Communities

Populations of various species occupying a particular area and interacting with each other make up a community. For instance, when we say 'the community of the Gir National Park', we refer to the lion population, the deer population, the cattle population, the grass population and populations of all kinds of life forms present there. Thus, a community comprises several species interacting with each other.

## Ecosystems

An ecosystem is a community of organisms involved in a dynamic network of biological, chemical and physical interactions between themselves and with the non-living components. Such interactions sustain the system and allow it to respond to changing conditions. Thus, an ecosystem includes the community, the non-living components and their interactions. The Gir ecosystem will thus include the various life forms found in the park (the community) and also the non-living components of the park, like the soil, rocks, water, etc., and even the solar energy that is captured by the plants.

The sum total of all the ecosystems on planet Earth is called the **biosphere**, which includes all the earth's living organisms interacting with the physical environment as a whole to maintain a steady-state ecosystem.

It is clear from the foregoing description that an organism forms the basic level for studying ecology. The study of ecology at the organism level is called **autecology**. When studied at a system level (ecosystem, community, etc.), it is called **synecology**. While autecology allows detailed study of an individual organism, its behaviour, ecology, etc., synecology becomes significant for finding solutions to the environmental problems emerging today. It allows us to study the system in its totality and hence understand the interconnections.

There are several examples where efforts to improve environmental quality have failed because the problem has not been approached in a holistic manner. To understand these complexities, it is necessary to understand what makes an ecosystem and how the different components are interconnected.

## Components of an Ecosystem

There are two 'parts' to every ecosystem: the living (**biotic**) components like plants and animals; and the non-living (**abiotic**) components like water, air, nutrients and solar energy. Let us analyse them one by one.

### Living Components

Living organisms (biotic components) in an ecosystem can be classified as either producers or consumers, depending on how they get their food.

Producers **(autotrophs,** i.e. self-feeders) can make the organic nutrients they need, using simple inorganic compounds in their environment. For instance, the green plants on land and the small algae in aquatic ecosystems produce their food by the process of photosynthesis.

Consumers **(heterotrophs,** i.e. other-feeders) are those organisms that directly or indirectly depend on food provided by producers. Consumers, depending on their food habits, can be further classified into four types.

- **Herbivores**, like deer, rabbits, cattle, etc., are plant eaters and they feed directly on producers. They are also referred to as the primary consumers.
- **Carnivores** are meat eaters and they feed on herbivores (primary consumers). They are thus known as secondary consumers. Examples include lions, tigers, wolves, etc.
- **Omnivores** eat both plants and animals. Examples of omnivores are pigs, rats, cockroaches and humans.

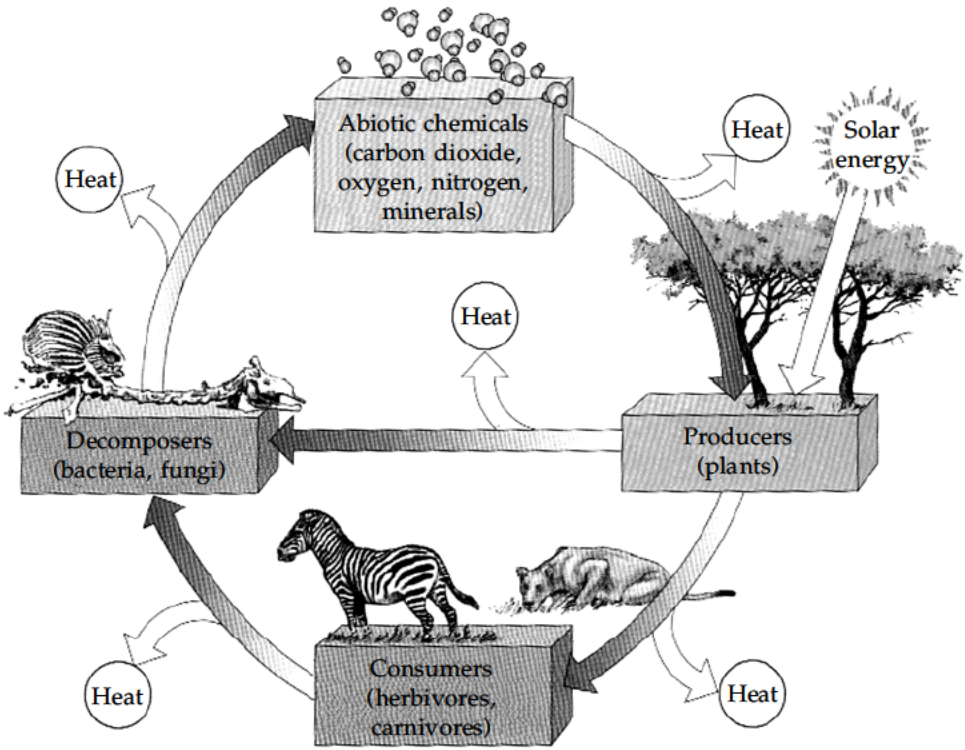



Illustration 2.2 Ecosystem is a dynamic network of interactions between the living and the non-living components

- **Decomposers** digest and convert the complex organic molecules in dead organic matter into simpler inorganic compounds. They absorb the soluble nutrients as their food. Some examples are bacteria, fungi and mites.

### Our planet without decomposers

Decomposers (primarily bacteria, fungi, nematodes like tapeworms, mites and certain insects) are organisms that feed by degrading organic matter. Decomposers break down organic waste and recycle the nutrients present in it. Decomposers use dead organisms as a source of energy and nutrition. As they consume material for their own use, they return nutrients to the environment in forms that can be used again by producers. Decomposers are nature's recyclers. If decomposers are removed from the biosphere, the earth will become a vast dump of dead organisms. Life will probably stop as the nutrients for life would be tied up in the dead organisms.

## Non-living Components

Non-living (or abiotic) components of an ecosystem include all the physical and chemical factors that influence living organisms, like air, water, soil, rocks, etc. Non-living components are essential for the living world. With no sunlight, water, air and minerals, life cannot exist.

Abiotic components

Non-living components include all the physical and chemical factors of an ecosystem that affect the living organisms. Some examples are:

| **Physical factors** | **Chemical factors** |
|---|---|
| Sunlight | Percentage of water and air in soil |
| Temperature | Salinity of water |
| Precipitation | Oxygen dissolved in water |
| Nature of soil | Nutrients present in soil |
| Fire | |
| Water currents | |

# Classification of Ecosystems

As a result of the influence abiotic factors exert on organisms, different ecosystems develop differently. The major factors that determine the growth and type of ecosystem include temperature, rainfall, soil type and location (the latitude and altitude). These factors, their interactions with each other and with the local biotic community, have resulted in a variety of ecosystems.

Table 2.1
Major types of ecosystems in the world

| *Ecosystem type* | *Area (millions sq km)* |
|---|---|
| **Terrestrial ecosystems** | |
| Tropical rainforest | 17.0 |
| Tropical seasonal forest | 7.5 |
| Temperate evergreen forest (taiga) | 5.0 |

*(continued)*

*(continued)*

| *Ecosystem type* | *Area (millions sq km)* |
|---|---|
| Temperate deciduous forest | 7.0 |
| Boreal forest | 12.0 |
| Woodland and shrubland | 8.5 |
| Savannah | 15.0 |
| Temperate grassland | 9.0 |
| Tundra | 8.0 |
| Desert/semi-desert shrub | 18.0 |
| Extreme desert, rock, sand and ice | 24.0 |
| Cultivated land | 14.0 |
| **Total terrestrial** | **145.0** |
| **Aquatic ecosystems** | |
| Swamp and marsh | 2.0 |
| Lake and stream | 2.0 |
| Open ocean | 332.0 |
| Upwelling zones | 0.4 |
| Continental shelf | 26.6 |
| Algal beds and reefs | 0.6 |
| Estuaries and brackish waters | 1.4 |
| **Total aquatic** | **365.0** |
| **Total biosphere** | **510.0** |

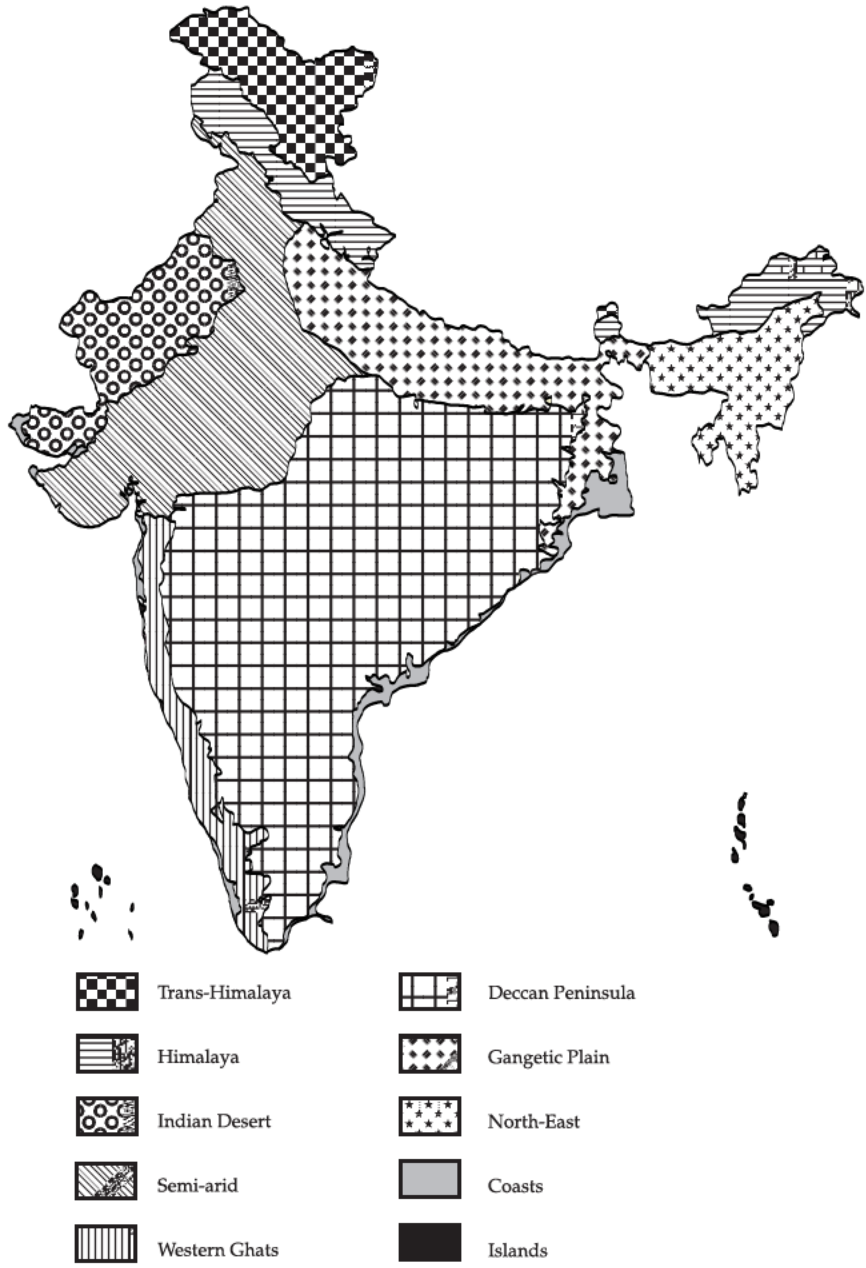
**Source:** Tyler G. Miller, Jr. 1994. *Living in the Environment: Principles, Connections and Solutions*, 8th ed. Belmont: Wadsworth Publishing Company.

## AN ECOLOGICAL PROFILE OF INDIA

India, the seventh largest country in the world, possesses a variety of ecosystems. These include mountains, plateaus, rivers, wetlands, lakes, mangroves, forests and coastal ecosystems. This section looks at the ecological profile of India.

### THE TRANS-HIMALAYAN REGION

'Trans' means the other side of, or beyond. Trans-Himalaya means beyond the Himalayas. Outside the Indian region, Trans-Himalaya is very extensive, covering a total of nearly 2.6 million sq km comprising the Tibetan plateau. Within India, in Ladakh (Jammu & Kashmir), and in Lahaul–Spiti (Himachal Pradesh), the Trans-Himalaya covers an estimated area of 186,200 sq km. The entire zone is a high-altitude cold desert, with altitudes




Ref: Wildlife Protected Area Network in India: A Review, Executive Summary, Wildlife Institute of India, 2000.

Illustration 2.3 India: Biogeographic zones

varying between 4,500 m and above 6,600 m above mean sea level (msl). It is a sparsely populated region, the population in the Indian part being approximately 250,000.

Though the area accounts for just over 5 per cent of the country's total land area, its value is tremendous as a drainage and feeder region for some of the greatest Indian river systems such as the Indus, Brahmaputra and Sutlej. Three mountain ranges, the Zanskar, Ladakh and the Karakoram, dominate the Trans-Himalaya.

The Trans-Himalaya cold desert is characterized by a distinct lack of natural forests, the vegetation being primarily sparse alpine type. Though the environment here appears harsh and inhospitable, a wealth of animal life exists. The largest number of wild sheep and goats in the world are, for instance, found here. They include the *nayan* or great Tibetan sheep, the *urial* or *shapu*, the *bharal* or blue sheep and the ibex. Other wildlife includes the Tibetan antelope, known locally as the *chiru*, and the Tibetan gazelle. Smaller animals of the region include pikas, marmots and Tibetan hares. The habitat is also shared by predators like the snow leopard, the Pallas cat, the Indian wolf and the lynx.

## The Himalayas

The Himalayas account for nearly 7 per cent of the country's total surface area. The mountains extends more than 2,000 km across the states of Jammu & Kashmir, Himachal Pradesh, Uttar Pradesh, Sikkim and Arunachal Pradesh in India. Outside India, they extend into Pakistan, Nepal and Bhutan.

Mountains are very fragile ecosystems, and the Himalayas are perhaps the youngest mountain chain in the world. Intense rainfall, steep slopes and infirm soils, all due either to young age or to geological location, make the Himalayan mountains extremely vulnerable.

The Himalayas have extreme habitat types, ranging from arid Mediterranean and temperate in the western parts, to warm, moist, evergreen jungles in the east. Altitudinally and longitudinally, the Himalayas can be grouped into three distinct habitat types:

1. The low altitude foothills region is the most highly populated portion of the Himalayas.
2. The temperate region above the foothills, roughly between 1,500 and 3,500 m, is covered by a complex mix of broadleaved and coniferous vegetation. The faunal community includes musk deer, sloth bears, several birds, especially of the pheasant family, mountain sheep and goats. The western part of the Himalayas has a rich herbivore structure as in the ibex and the *markhor*. In the more luxuriant eastern parts where the treeline is higher, animals like the red panda, binturong and several lesser cats are found.
3. The subalpine habitat type (higher than 3,500 m) consists of birch, rhododendrons, junipers, dwarf bamboo and a mixture of open meadows and scrub-dotted grasslands. The western part is very dry, but in the moist east the treeline

is higher. Above 5,000 m, rock and snow dominate the landscape and mark the ultimate limit of vegetation. As habitat types change, a noticeable transformation takes place in the faunal community as well. The higher reaches house several threatened species such as the ibex, *shapu*, wolf and snow leopard.

Table 2.2
India's biodiversity

| *Group* | *Number of species in India (SI)* | *Number of species in the world (SW)* | *SI/SW (%)* |
|---|---|---|---|
| Mammals | 350 | 4,629 | 7.6 |
| Birds | 1,228 | 9,702 | 12.6 |
| Reptiles | 428 | 6,550 | 6.2 |
| Amphibians | 197 | 4,522 | 4.4 |
| Fishes | 2,546 | 21,730 | 11.7 |
| Flowering plants | 15,000 | 250,000 | 6.0 |

**Source:** http://www.teriin.org/biodiv/status.htm

## The Desert

The desert region of the north-west has large expanses of grasslands in patches. For kilometres together, we may not find any signs of vegetation in the desert. Water, or the lack of it, is the single most significant feature in the desert. In this region, both plants and animals face the problem of maintaining the water balance of their bodies under extreme diurnal (daily) temperature variation. They adapt to cope with this in different ways. For instance, to reduce water loss, desert trees are mostly thorny with highly reduced leaf surfaces, and their roots go deep in search of water. A large number of desert mammals live in burrows to cope with extreme temperature variations. Similarly, desert vertebrates like the camel have efficient kidneys which secrete concentrated urine, thereby reducing water loss. The Asiatic wild ass, found in the salt flats of the Little Rann of Kachchh, has great tolerance to dehydration.

Rodents probably represent the largest group in desert fauna. A common example is the desert gerbil. Other commonly found desert animals include blackbuck, desert cat, desert lizard, snakes and the Great Indian Bustard.

## The Semi-arid Zone

The semi-arid zone is a transition from true desert to semi-desert. Here scrub and stunted forests spread over low mountain ranges. Lying to the east of the Indian desert and west of the Gangetic Plain, the semi-arid zone encompasses a total area of 508,000 sq km.

Covering nearly 15 per cent of India's area, this is a rich agricultural belt (especially in the states of Punjab and Haryana) and has thus far been considered the granary of India. Poor land management and short-term planning have, however, adversely affected the ecology of the region already. Additionally, a sizeable chunk of India's 400-million-strong livestock is to be found here, a factor leading to the demise of vast grasslands due to overgrazing.

The northern part of this zone comprises the flat, alluvial deposits of the Indus river drainage system. Intensely irrigated and cultivated, this northern stretch, known as the Punjab Plains, includes Haryana and Punjab, the southern margins of Jammu & Kashmir and Himachal Pradesh. The outskirts of Delhi as also the western end of Uttar Pradesh and a part of the Bharatpur district in Rajasthan, fall within the Punjab Plains belt. The region comprises predominantly cultivated flatlands, interspersed with a network of wetlands—marshes and rivers.

In marked contrast to the northern parts of the semi-arid zone, the southern expanse (including Rajasthan, Gujarat and the north-western part of Madhya Pradesh) is much drier and less cultivated. The Aravalis and the Vindhyan mountain ranges dominate the central portion of this zone, while the Kathiawar peninsula of Gujarat, with its black cotton soil, characterizes the southern sprawl. The herbivores in this area include *nilgai*, blackbuck, *chowsingha* or four-horned antelope, *chinkara* or Indian gazelle, *sambar* and spotted deer. With such a rich and healthy population of herbivores, it is hardly surprising that the semi-arid zone boasts of a good population and a variety of predators. In fact, it is the only zone which harbours the three large cats of India—the tiger, the leopard and the Asiatic lion. Other predators include the wolf, the caracal and the jackal.

## The Gangetic Plain

The Gangetic Plain extends along the foothills of the Himalayas, from Uttar Pradesh eastwards through Nepal, Bihar, West Bengal and parts of coastal Orissa. The entire area is a vast, flat alluvial expanse, both to the north and to the south of the river Ganga and its many tributaries. The Plains are characterized by fertile soils, moderate climate and abundant water.

Known to be one of the world's most fertile regions, the Gangetic Plain is densely populated. Elephants, rhinoceros, swamp deer, wild buffaloes and tigers are found in the region. By far the finest feature of this zone is its wetland habitats, a well-formed and distributed network of lakes, marshes and rivers. Harbouring over 20 species of turtles, as also animals like the non-gregarious Gangetic dolphin, the mugger and *gharial*, this vital wetlands' network is one of the subcontinent's wintering strongholds for migratory waterfowl.

## The Western Ghats

Along the west coast of India—from the Dangs at the western extremity of the Satpuras in south Gujarat, for over 1,500 km, to the southern tip of India in Kerala—stretch the Western Ghats. The Ghats form the catchment area for the complex river system of peninsular India that drains almost 40 per cent of the country. This zone also contains the second largest tropical evergreen and semi-evergreen forest belt of the subcontinent. The Western Ghats are characterized by a series of forest gaps which are actually valleys that break the continuity of the mountain ranges and thus of the biological components as well. These series of gaps have prevented the spread of certain species, and have thus facilitated local speciation and endemism.

A wide climatic (rainfall and temperature) and spatial (altitudinal and latitudinal) gradient has resulted in major habitat variations in this zone. The animal species found here include the tiger, elephant, *gaur*, dhole, sloth bear, panther and several species of deer.

The Nilgiris, an offshoot of the Western Ghats, are characterized by extensive grassy areas interspersed with densely forested evergreen vegetation, together known as the *sholas*. They provide shelter to elephants, *gaur* and other large animals. Many of the trees and also some of the animals found in these high *sholas* are also found in the high-altitude forests of the north-eastern region of India.

### Hotspots of biodiversity

Hotspots are areas that are extremely rich in endemic species (a species that is native to a particular region and found only in that region), and have been significantly impacted and altered by human activities.

Plant diversity is the biological basis for hotspot designation—to qualify as a hotspot, a region must support at least 1,500 endemic plant species, i.e. 0.5 per cent of the global total. Existing primary vegetation is the basis for assessing human impact in a region—to qualify as a hotspot, a region should have lost more than 70 per cent of its original habitat. Thus, the hotspot concept targets regions where the threat is greatest to the greatest number of species and allows conservationists to focus cost-effective efforts there.

The 25 biodiversity hotspots identified in the world contain 44 per cent of all plant species and 35 per cent of all terrestrial vertebrate species in only 1.4 per cent of the planet's land area. Of these 25 hotspots, two are in India, extending into neighbouring countries—the Western Ghats/Sri Lanka and the Indo–Burma region (covering the eastern Himalayas). These areas are particularly rich in floral wealth. Endemism here is prevalent not only in flowering plants but also in reptiles, amphibians, swallowtail butterflies, and some mammals.

**Source:** http://www.biodiversityhotspots.org/xp/Hotspots/hotspotsScience/

## THE DECCAN PENINSULA

With an area of 1,421,000 sq km, the Deccan Peninsula extends over 43 per cent of India's land mass, spreading over eight states. Though the massive zone is more or less homogeneous, at least three principal habitat types are easily recognized. These are deciduous forests, thorn forests and scrublands. Additionally, there are pockets of semi-evergreen and evergreen forests, mainly in the mountain range known as the Eastern Ghats. Ancient forests, older than the Himalayan forests, characterize this most diverse zone. Elephants, tigers, *gaur*, buffaloes and birds of all descriptions are to be found here.

## ISLANDS AND WETLANDS

India also has two major groups of islands—the Lakshadweep Islands in the Arabian Sea, and the Andaman–Nicobar Islands in the Bay of Bengal. These islands receive both the south-west and the north-east monsoons. These islands are home to tropical rainforests. The Andaman and Nicobar group is a largely north–south running archipelago with 348 islands stretching over a length of nearly 600 km. The total land area of these islands is 8,327 sq km. The Lakshadweep group consists of 25 islands in three clusters, with a total land area of a mere 109 sq km.

India with its varied terrain and climate, supports a rich diversity of inland and coastal wetlands. Twenty-one of these wetlands have been declared National Wetlands. An important wetland is the Keoladeo National Park in Bharatpur, Rajasthan, which is a man-made wetland. Among the various migratory species of birds that visit this park almost every winter is the endangered Siberian crane (*Grus leucogeranus*). Another important wetland is Chilika (1,100 sq km), the largest brackish water lake in India, situated in the Puri and Ganjam districts of Orissa.

Did you know?

Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life. They occur where the water table is at or near the surface of the land or where the land is covered by shallow water.

Wetlands are among the world's most highly productive environments. They are cradles of biological diversity. Wetlands are also important storehouses of plant genetic material. Wetlands perform a number of ecological functions—water storage, flood mitigation, shoreline stabilization, groundwater recharge and discharge, water purification and the stabilization of local climatic conditions, particularly rainfall and temperature.

Besides their ecological value, wetlands are also economically valuable as they support a number of economic activities such as fisheries, agriculture, transport, wildlife resources, recreation and tourism opportunities.

(*The SASEANEE Circular*; 6[2], December 1998.)

## The Coast and the Sea

Among the countries of the world, India has the seventh longest coastline measuring over 7,500 km. Starting at the Pakistan border, the Indian shoreline extends from Gujarat in the west, down along the Konkan and Malabar coasts, around Kanyakumari, and then up along the Coromandel coast to Bengal's Sundarbans, and continues into Bangladesh. The western coast borders the Arabian Sea and the eastern coast lies along the Bay of Bengal. The western coast is divided into three parts: the Saurashtra coast along the northern part; the Konkan coast in the middle; and the southern part known as the Malabar Coast. The eastern coast extends from Kanyakumari to the delta of the Ganga in the Bay of Bengal. The southern half of the coast is called the Coromandel coast.

Oceans have great diversity of life forms as they provide a gradient of habitats in terms of varied light and pressure zones. Dugongs, marine turtles, estuarine crocodiles and a myriad waders constitute the most obvious 'wildlife' of the shore and nearshore habitat. Crabs, lobsters, oysters, jellyfish, puffer fish, octopus and sea slugs can be easily observed by those venturing into the coral belts. With their rich cache of fish, minerals and potential energy, marine ecosystems make an invaluable resource in the form of food reservoirs and the resource base for aquacultural practices.

All ecosystems are linked. While it is convenient to divide the living world into different ecosystems for purposes of study, in nature there are seldom distinct boundaries between them. They are never totally isolated from one another. Any disturbance or change in any one of these, sooner or later, influences the other.

## Ecotones: The Transitional Zones

A transitional region between ecosystems is known as an ecotone; for example, the region between a forest and grassland. This region shares many of the species and characteristics of the adjacent ecosystems, and also has species unique to it. The ecotone region provides conditions of both types of neighbouring ecosystems and thus supports a greater variety of life forms. It also has species living exclusively in the ecotone region. An ecotone is thus a biologically rich area with very high species diversity. In some cases, the number of species and the population density of some of the species is greater in the ecotone than in the adjacent ecosystems. This tendency for an increased diversity and density is called the 'edge effect'.

A common example of ecotones is an estuary—the transitional area between a river and the ocean. The variety of species found in an estuary is much higher than in the river or in the shallow sea water. But high levels of pollution in river water as well as in marine systems are destroying these unique habitats. Today, these unique micro-environments are being threatened by human activities.

Disturbances in estuaries

Some fish species not only migrate between the water of the various oceans and seas, but also between fresh waters and marine waters. Such fishes, which spend part of their life cycle in saltwater and part in fresh water, are called diadromous fishes, e.g. the eel, the salmon, and the trout. These include the anadromous species, which migrate from the sea to fresh water for spawning (process of laying eggs), and the catadromous species, which spawn in the ocean or at sea and migrate towards fresh water as juveniles. Thus, for such migratory species to complete their life cycles the ecotone areas of estuaries are critical.

Today ecotone regions in many coastal areas are immensely disturbed due to constant disturbance from the mainland from pollution in the fresh waters—pesticidal pollution, discharge of effluents, silt, etc. Pollution in the estuarine and coastal areas makes the migration of diadromous fishes to their spawning areas difficult and adversely affects their populations. Such disturbances act as major bottlenecks in the life cycle of these species.

## MAJOR BIOCHEMICAL PROCESSES IN ECOSYSTEMS

We have looked at some basic ecological concepts. We know that the 'organism' provides the basis for the study of ecology, eventually leading to understanding the highest level, the ecosystem. Let us now try to understand the functioning of ecosystems. How does an ecosystem function? What gives an ecosystem its balance? These are some of the questions that come to mind when we think of a forest, desert or pond ecosystem. To gain some clarity on these, we need to understand how ecosystems work.

In an ecosystem, several kinds of biochemical processes take place. The two major processes that form the basis of ecosystem functioning are energy flow and nutrient cycling.

1. Energy flow is the flow of energy from the sun through the materials and living things (as food) on the earth, then into the environment (as heat), and eventually into space as infrared radiations.
2. Nutrient cycling is the cycling of nutrients required by living organisms through different parts of the biosphere.

### UNDERSTANDING ENERGY FLOW

Any kind of 'work process' either requires energy or releases it. Thus, if we want to study the functioning or the working of an ecosystem, we must understand the basic principles and laws of thermodynamics in an ecological context.

1. The first law of thermodynamics states that energy may be transformed from one type into another but is neither created nor destroyed.
2. The second law states that no energy transformations are 100 per cent efficient, i.e. energy is always being transformed from a more useful to a less useful form.
3. Under natural conditions, energy tends to flow from a higher level to the lower one. This is a derivation from the second law of thermodynamics.

The ecological implication of these laws is that energy cannot be produced in ecosystems from nowhere. Thus, when we say 'productivity of ecosystems', we are referring to the transformation of one form of energy (say, solar) into another (say, organic form in plant bodies). Secondly, the process of transformation of energy from one form into another, or even the transfer of energy from one organism to another, is never a 100 per cent efficient; all energy transformations always involve energy loss in the form of heat energy which is not available to the organism. The amount of the loss may vary from one transformation process to the other, but it invariably occurs. In the light of these two laws of thermodynamics, let us try to analyse the energy flow in an ecosystem.

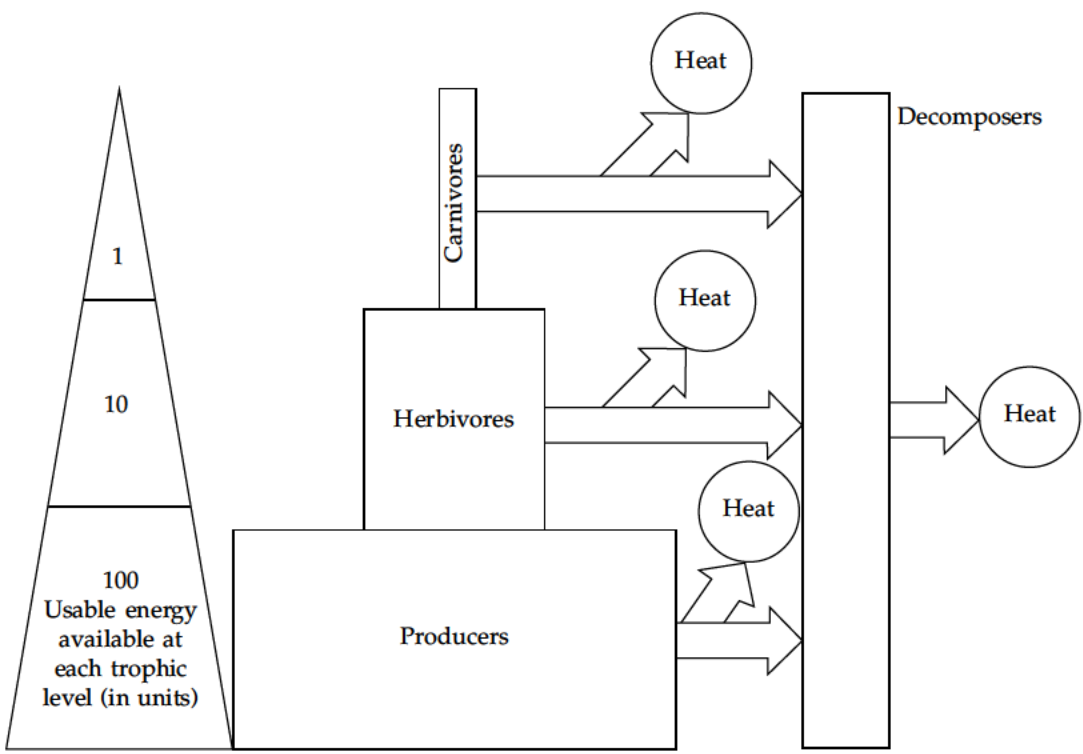



Illustration 2.4 Flow of energy in ecosystems

Energy Flows in Ecological Systems: The ultimate source of energy for all ecological systems is the sun. The energy that enters the earth's atmosphere as heat and light is balanced by the energy that is absorbed by the biosphere, plus the amount that leaves the earth's surface as invisible heat radiation (first law of thermodynamics). When solar energy strikes the earth, it tends to be degraded into heat energy. Only a very small part (about 10 per cent) of this energy gets absorbed by the green plants, and is subsequently transformed into food energy. The food energy then flows through a series of organisms in ecosystems. All organisms, dead or alive, are potential sources of food for other organisms. A grasshopper eats the grass, a frog eats the grasshopper, a snake eats the frog and is in turn eaten by a peacock. When these creatures die, they are all consumed by decomposers (bacteria, fungi, etc.).

Food Chains: In an ecosystem, the sequential chain of eating and being eaten is called a food chain. It is this process which determines how energy moves from one organism to another within the system. In a food chain, energy (organic form) is transferred from one organism to another. Ideally, this transfer or flow of energy from the sun to green plants to herbivores to carnivores should be 100 per cent efficient. But in reality this does not happen, because at each link in a food chain, 80 to 90 per cent of the energy transferred is lost as heat (second law of thermodynamics). It is because of this loss that fewer individuals are found at each successive level of the food chain (e.g. fewer carnivores than herbivores). This also limits the number of levels in a food chain. All organisms are part of a food chain, and may be part of more than one. Food chains usually consist of producers, primary consumers, secondary consumers, tertiary consumers and decomposers.

Every organism in an ecosystem can be assigned a feeding level, referred to as the **trophic level**. A trophic level consists of those organisms in food chains that are the same number of steps away from the original source of energy. Green plants would be grouped in the first trophic level (producers), herbivores in the second trophic level (primary consumers), carnivores in the third (secondary consumers), and so on.

*Types of food chains:* Though all food chains comprise a series of living organisms which are interdependent on each other for food and hence energy, they may not always be similar. In nature there are two major types of food chains: the first—called the grazing food chain—starts from a base of green plants and goes on to herbivores and finally to carnivores; the second starts from a base of dead organic matter, and proceeds to a variety of other organisms, including scavengers, insects and micro-organisms—called the detritus food chain—and helps the dead organic matter flow back into the food chains. Grazing food chains and detritus food chains are linked, as dead organisms from the grazing food chain form the base for the detritus food chain. This in turn provides nutrients vital to green plants. One cannot exist without the other.

A number of food chains interwoven with one another give rise to a structure similar to the web of a spider. These interlocking patterns formed by several food chains that are linked together are called food webs. Exploring connections between various components of an ecosystem can be an exciting activity.

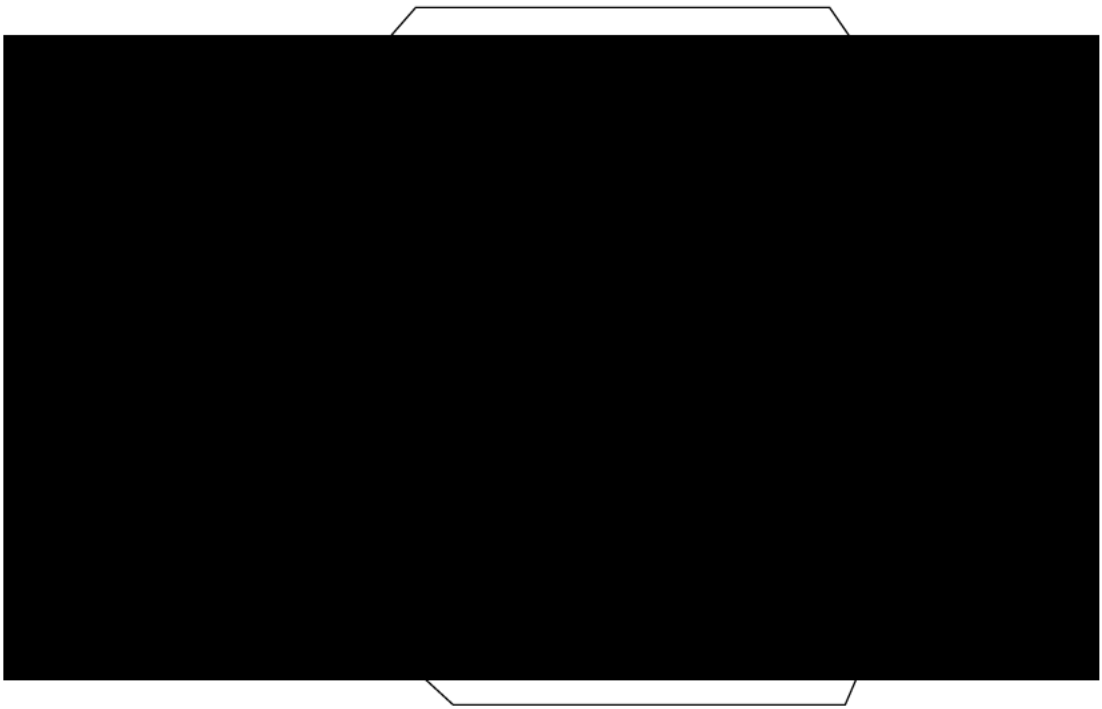


Illustration 2.5 Food chains in nature do not operate in isolation but are linked to each other forming food webs

*Understanding food chains:* Trophic levels in a food chain can be shown graphically through ecological pyramids, with producers at the base and successive levels of consumers forming the higher layers. Ecological pyramids are of three basic types: the pyramid of numbers, in which the numbers of individual organisms are depicted; the pyramid of biomass, based on the total dry weight or other measures of the total amount of living matter; and the pyramid of energy, in which the energy assimilated and/or productivity at successive trophic levels is shown. Ecological pyramids are used for comparing biomass and energy flow between trophic levels. Such comparisons can be used for identifying/comparing which ecosystems and communities are more efficient in terms of energy transfer.

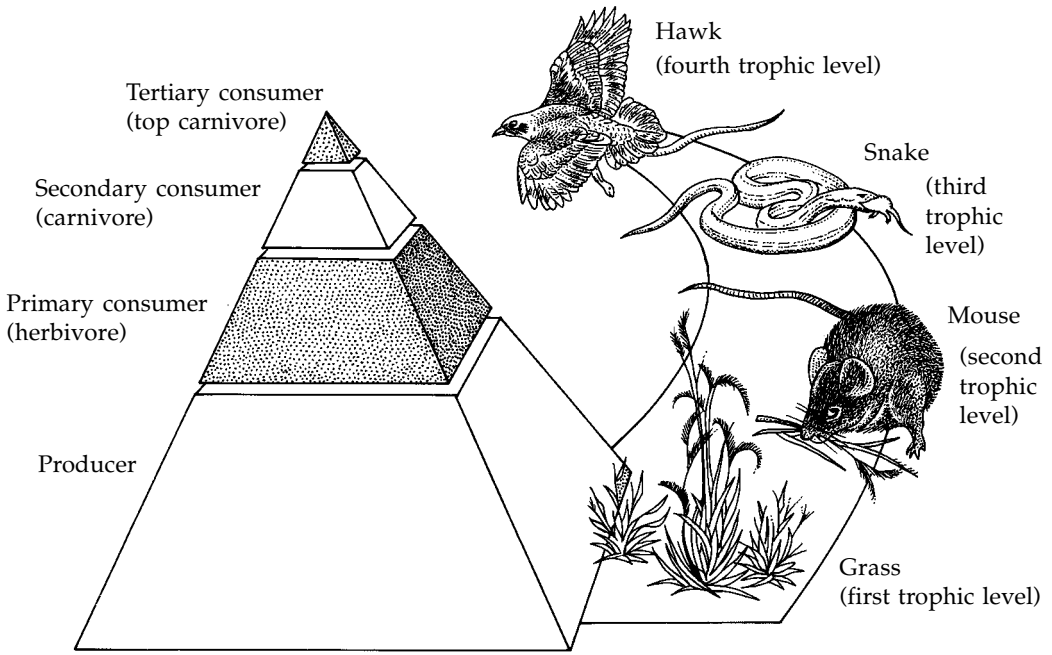



Illustration 2.6 Organisms at various trophic levels

## NUTRIENT CYCLING: LINKING BIOTIC AND ABIOTIC COMPONENTS

Living organisms need food to grow and to reproduce. Any food or element required by an organism to live, grow or reproduce is called a nutrient. Depending on the amount in which it is needed, a nutrient can be classified as a macronutrient (needed in large quantities, e.g. carbon, oxygen, hydrogen, nitrogen, phosphorous, etc.), or a micronutrient (needed in small quantities, e.g. iron, zinc, copper, iodine, etc.).

In nature, these nutrient elements and their compounds move continuously from the non-living environment to the living organisms, and back to the non-living environment. This cyclic movement of minerals from their reservoirs (air, water and soil) to the living components, and back to the reservoirs is called nutrient cycling or **biogeochemical** cycles. These nutrient cycles, driven directly or indirectly by incoming solar energy and gravity, include the carbon, oxygen, nitrogen, phosphorous, sulphur and hydrological (water) cycles. Since the amount of the various nutrients present on our planet is constant and the nutrients have been cycling through the biotic and abiotic components of the biosphere for millions of years, the biogeochemical cycles connect past, present and future forms of life. Thus, some of the carbon atoms in the skin of your nose may once have been a part of a petal, a dinosaur's skin, or even a diamond!

### Biological magnification

In food chains, it is not only nutrients that get transferred. Toxic substances too may be transferred from one trophic level to another. In such cases, the concentration of the toxic substance increases with every increase in the trophic level. This increase in concentration with every link in the food chain is called biological magnification or biomagnification. In food chains, larger organisms at higher trophic levels accumulate more because they ingest numerous smaller organisms, each of which contains a small amount of the toxic chemical. It is important to understand that not all chemicals present at the beginning of the food chain get magnified. Some get washed off/diluted. But certain chemicals, which by their nature are persistent, get absorbed and accumulated in the tissues of living organisms. Such pollutants and toxic substances like mercury and lead, usually released in the environment in low concentrations and thus thought to be harmless, over a period of time, tend to build up to critical toxic or lethal levels in the body of living organisms through the process of biomagnification.

The oft-quoted example of biomagnification is the build-up of DDT across various trophic levels in a food chain. To control mosquitoes, DDT was sprayed in Long Island, USA. The DDT levels used were carefully regulated so that they were not directly lethal to fish and other wildlife, but only to the mosquitoes. Though the mosquitoes were destroyed, the DDT did not get washed out to sea as was predicted. Rather, the poisonous residues were absorbed by detritus and eventually became concentrated in the tissues of detritus feeders and small fishes, and, step by step, got concentrated in the top predators such as fish-eating birds. As a result, the shells of eggs laid by these birds were not fully formed and hence could not give protection to the embryo. Thus no chicks hatched. This ultimately wiped out whole populations of the predatory birds.

## Ecosystems: Some Concerns

If ecosystems are self-maintaining, then why not throw all waste into nature and let nature take care of it? But it has been realized and experienced that whether it is an ecosystem, a community, or even an organism, every system has its tolerance limits. We have seen the various ill effects of creating drastic disturbances in natural systems. Stresses beyond the tolerance limits of these systems can be fatal for the biosphere and hence for us. For example, Srinagar's Dal Lake, one of India's most well-known lakes, is rapidly deteriorating. The lake attracts thousands of visitors every year, who stay in houseboats on the lake and in hotels around it. This pressure from the tourism industry adds nutrient-rich sewage to the lake which has resulted in eutrophication, whereby the lake is being rapidly colonized by a fern called *Salvinia natans* and by algae. The lake is getting choked

and will die if corrective measures are not taken. Here, it is important to mention that wetlands also play a key role in groundwater recharge, therefore, destroying a wetland can affect the groundwater status of that region.

### Eutrophication

Eutrophication is a natural process by which waterbodies gradually become more productive. Three main stages explain the process of eutrophication. These are **oligotrophy, mesotrophy** and **eutrophy**. Stagnant waterbodies go through these stages as part of their life cycle. In nature, eutrophication is a slow process and may take thousands of years to progress.

When one or more of these stages is speeded up or even skipped completely, the natural balance is disrupted and may destroy the ecosystem. Human activities have accelerated this process tremendously. Nitrates and phosphates from synthetic detergents, domestic sewage, agricultural run-off and some industrial wastes give unnatural nourishment to algae (microscopic plants), causing them to flourish in huge amounts on waterbodies. As the algal growth explodes, it forms a cover on the water surface. This could starve the submerged life in the waterbody of oxygen and sunlight, which are vital for life and photosynthetic activity. If uncontrolled, they choke the oxygen supply normally shared with other organisms like fish, etc., living in the water.

When these algae die, they decompose. The decomposition uses up even more oxygen. As a result, the water becomes deficient in oxygen. This condition encourages organisms that can survive in the absence of oxygen (anaerobic organisms) to increase in number and attack the organic wastes. When anaerobic organisms break down organic substances, they release foul-smelling gases such as methane and hydrogen sulphide, which are harmful to the oxygen-requiring (aerobic) forms of life. Such disturbances slowly lead to the death of all forms of life in the waterbodies.

The other concern is that in the process of modifying ecosystems to suit our demands, we unknowingly simplify them. For instance, on the one hand we clear dense forests containing thousands of interrelated plant and animal species for a variety of 'development' requirements, and on the other hand, we try to balance it by afforestation programmes which create plantations of single or fewer species and not forests that are made up of numerous species in close interaction. Comparatively, such simplified systems are much more vulnerable to any disturbance—natural or caused by humans. With the growing human population, too many of the world's complex mature ecosystems have been made young and simple. Such alarming trends, if not attended to in time, can jeopardize the biosphere.

# From Ecosystems Back to Organisms, Species ...

We have just looked at some of the unique features of ecosystems. Let us now identify some of those characteristics of organisms, species, populations and communities that make them unique and distinct from one another.

## Some Features of Organisms

A unique feature of all organisms is their ability to adapt to the surrounding environment. **Adaptation** is any alteration in the structure or function of an organism or any of its parts, which results from natural selection and by which the organism becomes better fitted to survive and multiply in its environment. Adaptations can be classified into three basic types: *physiological, behavioural*, and *structural.*

Physiological adaptations are adaptations in the processes carried out in the body of the organism. For example, camels produce concentrated urine for water conservation.

Behavioural adaptations are adaptations with regard to behaviour, i.e. what an organism does. Examples include migration and other diurnal/nocturnal activities. During winters the Siberian cranes migrate from Siberia to escape the harsh winter weather conditions to places with relatively mild weather. In hot deserts, to avoid the harshness of extreme high daytime temperatures, many desert species hide away in humid and cool places during the harsh day hours, thereby avoiding the heat, and become active during the night hours. Such nocturnal behaviour helps desert animals survive in the heat. Structural adaptations are changes in the anatomy or body structure of an organism, for example, the webbed feet of the duck for swimming and cactus leaves modified into thorns to cope with desert conditions.

## Some Characteristics of Species

Like organisms, species also have certain characteristics that help us to differentiate them from populations and communities. Two of these are:

1. **Ecological niche:** The physical space occupied by a species, along with its functional role in the community and its position in the environmental gradients of temperature, moisture, pH, soil and other conditions of existence, is its ecological niche. The ecological niche of a species is a way of life that is unique to that species. Niche and habitat are not the same thing. The ecological niche includes both the physical habitat of the species as well as how it has adapted to life in that habitat.

An ecological niche is a very complex description of the way in which a species lives in its world and habitat. A full description of even the simplest niche is probably too complex to completely understand, but certain parameters or boundaries of a niche can be measured, studied and reported. For example, a bare-skinned human will freeze to death at temperatures approaching 0°C, and die of heatstroke above about 60°C. The range of permissible temperatures for bare-skinned humans is therefore quite narrow. Polar bears, on the other hand, can live at temperatures much below freezing, and still live quite well at 37°C. So their range of permissible temperatures is different from ours. With respect to this one parameter, the polar bear 'niche' is different from ours.

Any two variables, such as temperature and pH, which can be measured and a range established, will define a 'space' (or set of values) within which a species can be found; i.e. its ecological niche. Move outside this 'space' and you will no longer find that species. You may find another species, but its niche will be different. The more variables one is able to measure (e.g. pH range, temperature range, salinity range, etc.), the more multidimensional the 'space' or niche becomes. This multidimensional space is sometimes called the fundamental niche of the species.

While many species may share a habitat, this is not true of a niche. Each plant and animal species is a member of a community. The niche describes the species' role or function within this community. The ecological niche describes all the physical, chemical and biological factors in an ecosystem that a species needs to survive and reproduce. It also defines the role of the species in the ecosystem. Each species has a defined and unique role in the ecosystem and hence no two species in the same general territory can occupy the identically same ecological niche for long.

Each species has a particular habitat and niche resulting from its interaction with its environment. Understanding habitat and niche requirements is significant for species management.

2. **Species evolution and species extinction:** Extinction of existing species and evolution of new ones is a natural phenomenon. New species arise from pre-existing ones through the process of evolution. The processes of evolution and extinction are very slow and take place over long periods of time. Under natural conditions, these two processes keep pace with the changes in the abiotic environment. However, in recent times, due to human interference, the rate at which species are becoming extinct has outpaced the rate at which new species are evolving. This loss of species is today a global concern, and that is why phrases like 'species at risk' or 'the lost world' often make the headlines of newspapers, magazines and journals. For example, the pink-headed duck became extinct in India due to indiscriminate hunting for its flesh and for its ornamental value.

## Some Characteristics of Populations

The following features characterize a population:

1. **Population size:** The size of a population is the number of individuals making up a population. For example, the human population of India is comprised of over 1 billion individuals.
2. **Population growth:** This refers to the increase in the number of individuals in a population. The factors that affect growth in a population are birth, immigration, death and emigration.
3. **Population density:** This is the number of individuals of a population per unit area at a given time. Thus, to calculate the population density of India for the year 1997, divide 1 billion or 1,000,000,000 (population size) by 3,287,263 sq km (total land area of India).
4. **Population dispersion or distribution:** This refers to the general pattern in which the members of a population exist in their habitat. Population distribution may be random, clumped, regular, or may show a gradient. For example, in a cropland, the crop population is usually distributed in a regular pattern with similar distance between two plants, whereas in a natural forest, the same plant may be dispersed in clumps in those areas where there is no tree shade and where sufficient sunlight is available for their growth. Thus, population dispersion depends on various factors like availability of food, shelter or protection.
5. **Age structure:** The proportion of individuals in each age group in a population is its age structure. Common age categories are pre-reproductive, reproductive and post-reproductive. A larger percentage of individuals in the pre-reproductive and reproductive categories means greater population growth. Understanding the age structure of human populations is important for framing development policies and plans. The age structure helps to make future projections of the nation's population growth. Natural populations maintain a balanced age structure because, in nature, there is always the survival of the fittest. However, human actions may drastically change such balances.

## Some Characteristics of Communities

When individuals of several species come together and interact with each other, they give rise to communities. The following are some of the features that characterize communities:

1. **Species diversity:** This refers to the variety of species present in a community. Each community has a unique set of species. For instance, the types of species

found in a grassland community will be different from those found in a desert or in an estuarine community.

2. **Ecological succession:** In most communities, the variety of species in a given area changes slowly over a period of time. This gradual process of change in the composition and function of communities is called ecological succession. Ecological succession is a way in which communities respond to changes in their environment. Succession is a normal process and is driven by various kinds of interactions between the different species of a community and the environment. Natural, uninterrupted ecological succession leads to the development of young, fragile communities into more mature, developed and sustainable ones.

   Succession may be **primary** or **secondary**. Primary succession is the process of initial establishment of a community in an area where no life forms existed before; e.g., ferns colonizing a barren rock. Secondary succession follows the destruction of all or a part of an earlier community; e.g., grass seeds germinating after a forest fire.

3. **Living interactions:** Different species in a community do not live in isolation from each other. When any two organisms have some activities or requirements in common, they interact with each other. These interactions may occur between individuals of the same species (intraspecific) or between individuals of different species (interspecific).

   There are three major types of interactions—predation, competition and symbiosis.

   **Predation:** The consumption of one individual (prey) by another (predator) is predation. For instance, a lion preys on deer, or a kingfisher feeds on fish in a pond.

   **Competition:** In most communities, each species faces competition from one or more species for common limited resources. Competition can again be of two types: **interference** and **exploitation**.

   Interference is where one species hinders another species' access to some resource, say food, water, shelter, etc., irrespective of whether the resource is abundant or scarce. For instance, some coral animals kill other nearby corals by poisoning them.

   In exploitation, two competing species have equal access to a particular resource, but differ in how quickly or efficiently they exploit it. In this way one species gets more of the resource, thereby hampering the growth, reproduction and survival of the other species. This kind of competition is usually exhibited only when a resource is scarce. For instance, grasses thrive better in deserts than other plants because their root systems are more efficient in absorbing more water in a short time than those of other plant species.

   **Symbiosis:** This includes mutualism, commensalism, and parasitism.

**Mutualism:** Interaction where both the interacting species are mutually benefited is mutualism. A common example is the interaction between flowers and insects, where the flower is benefited by being pollinated and the insect gets the nectar. In some cases, the mutual relationship has become so close that the species involved cannot survive without each other. For example, certain species of fungi and algae live in close association as lichens. The fungus gets its food from the algae. The algae in turn gets protection through certain chemicals secreted by the fungus. If separated, neither can survive.

**Commensalism:** A cooperative relationship where one partner gains from the arrangement while the other is neither helped nor harmed is called commensalism. For example, in dense forests where sunlight does not reach the ground in sufficient quantity, orchids grow on other tree species. The orchid is benefited by getting sufficient light, but the tree is neither benefited nor harmed.

**Parasitism:** This is a one-way relationship where the parasite gains and the host is adversely affected. Parasites are usually smaller than their hosts. They do not kill or consume the hosts but only derive their nutrition from them. For example, ticks attach themselves to dogs and suck the blood. Similarly, tapeworms are found in the human intestine.

Did you know?

*Symbiosis* refers to the phenomenon of 'living together' in close union. Symbiosis is sometimes interpreted to be a beneficial relationship—where the organisms involved always benefit by living together. However, ecologically, any interaction where two or more organisms live in close association is referred to as a symbiotic relationship, irrespective of whether the two are benefited or harmed, or remain unaffected. Thus, symbiosis includes parasitic, commensalistic as well as mutualistic relationships.

## Before We Conclude...

We began this chapter on the basics of ecology by stating that 'in nature everything is connected.' In the later sections, we consciously classified and categorized the natural system into smaller hierarchical units for the convenience of our study about their ecological features and associated processes. Before closing this dialogue, it is desirable to emphasize again that the essential features of the living and non-living parts of ecosystems are interdependence and connectedness. This fact holds the key to understanding various ecological concepts and phenomena.

## BOUNCING OFF THE RESILIENCE

As mentioned in this chapter, human beings are knowingly or unknowingly inflicting a number of damages on many natural ecosystems, several of which are now beyond repair. Drastic disturbances or shocks affect the resilience or the ability of a living system to return to its normal state after an outside disturbance. The repercussions of this, sooner or later, will definitely be felt by the human species because, in nature, we do not stand isolated. Rather, we are a part of the web of life.

### I QUESTIONS

1. What are the various components of ecosystems? What role do they play in ecosystem processes?
2. Are food chains in nature never-ending? Why? Justify your answer.
3. What do you understand by 'nutrient cycling'? What is the significance of decomposers in nature?
4. Define any two types of interactions that take place in the living world. Also mention the significance of those interactions.
5. Define Ecology. How can understanding ecology help strengthen conservation efforts?

### II EXERCISE

Listed below are several events. Read them and arrange the events in chronological order so as to make a sequence that you think is logical and correct.

a. Rats increased
b. Lizards slowed down
c. Caterpillar numbers went up
d. ABC Health Services sent DDT to Gyanpur
e. Mosquitoes were wiped out
f. Caterpillars ate grass roofs
g. Cats were parachuted in
h. Cats died
i. Cats caught lizards
j. Rats spread the plague

k. Lizards disappeared
l. Lizards ate mosquitoes and stored DDT

Now read the actual story below, which is based on a real-life case. After reading the story, answer the questions that follow.

**The Real Story: The Day the Cats were Parachuted In**
Some years ago, the ABC Health Services sent supplies of DDT to Gyanpur to control the mosquitoes that were spreading malaria among the people. As the DDT was sprayed, the mosquitoes were quickly wiped out. But there were thousands of lizards in the village that ate these mosquitoes (which had absorbed the sprayed DDT) and they, in turn, kept accumulating the DDT in their bodies. When these lizards ate mosquitoes, they also absorbed a lot of the DDT. Due to the accumulation of so much DDT in their bodies, the lizards became very inactive and slow. This made it easier for cats to catch the lizards, one of their favourite foods. At about the same time, people also found that hordes of caterpillars had moved in to feed on the roofing materials of their homes. They realized that the lizards, which had previously kept the caterpillar population under control, were now being eaten by the cats. And now, all over Gyanpur, the cats that ate the lizards died from DDT poisoning. Then rats moved in because there were no cats to control their population. With the rats came a new danger: plague. Officials sent out emergency calls for cats, which were sent in by airplane and dropped by parachute.

1. How did one small act of humans (spraying of DDT) disturb the balance of the ecosystem?
2. How did the disappearance of one link in the food chain affect the remaining parts of it?

## III Discuss

Read the following quote and comment on it.

*Life support functions are carried out continuously by self-sustaining, living communities. Natural ecosystems are actively engaged in maintaining the planet's habitability. To the degree that we exterminate the organisms forming our ecosystems, we imperil Earth's capacity to support us. To the extent we preserve our life support systems, we increase our individual and collective chances of survival.*

**Paul Ehrlich**

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# Chapter 3

# Biodiversity

Seema Bhatt

Visitors at the various zoos, wildlife sanctuaries and national parks in India stare in fascination at the magnificent tiger. It is easy to become emotionally involved at the thought of this beautiful species becoming extinct. While tigers have many advocates throughout the world, few people are aware of the enormous variety of other life forms that exist on earth. For example, we do not know exactly how many kinds of insects exist in various parts of the world, what roles they play, and how many of them are disappearing.

Every day, around the globe, species are being lost; others are being pushed towards extinction. Biological diversity, or biodiversity, is more threatened today than at any other time in the past. During the last 200 million years, 100 to 1,000 species became extinct in each century. But evolution also brought forth new life forms, replacing species that were lost. Today we are losing about 1,500 species every two months! This threatened biodiversity needs to be conserved.

## What is Biodiversity?

Biodiversity is a combination of two words 'biological' and 'diversity'. Taken literally, biodiversity refers to the number, variety and variability of all life forms on earth. These include millions of plants, animals and micro-organisms, the genes they contain, and the intricate ecosystems of which they are a part.

Biodiversity is usually described at three levels: genetic, species and ecosystem diversity.

### Genetic Biodiversity

The diversity of genes within a species, passed down the generations is known as genetic biodiversity. It is this type of diversity that gives rise to the different varieties of rice, mangoes, etc. For example, the Alphonso mango is different from the *langda* variety,

which again is different from the Banganapalli. Some variations are easy to see, such as size or colour; some, different, such as taste or flavour, can be perceived by other senses; and some others, such as susceptibility to disease, are not obvious to the senses.



Illustration 3.1 Genetic diversity gives rise to several varieties of wheat

## SPECIES BIODIVERSITY

Species is the unit used to classify the millions of life forms on earth. Each species is distinct from every other species. Horses and donkeys are distinct species, as are lions and tigers. What unites members of a species is the fact that they are genetically so similar that they can produce fertile offspring. Species diversity is usually measured in terms of the total number of species within a defined area.

## ECOSYSTEM BIODIVERSITY

An ecosystem is a set of life forms (plants, animals, micro-organisms) interacting with one another and with non-living elements (soil, air, water, minerals, etc.). Ecosystem

diversity is, therefore, the diversity of habitats which include the different life forms within. The term also refers to the variety of ecosystems found within a biogeographical or political boundary (see Chapter 2, titled Ecology).

## Domesticated Biodiversity

When we think of biodiversity, we tend to think only of wild plants and animals. But there is also considerable diversity among domesticated plants and animals. Domesticated biodiversity may be the result of manipulation by humans, or of natural adaptations to different conditions over a period of time.

Since the dawn of agriculture, people in different parts of the world have developed different plant and animal varieties to meet certain needs and conditions. These include higher productivity, better taste, resistance to pests or disease, and the ability to withstand adverse conditions like floods, drought or frost. When humans first started cultivating cereals, they must have chosen those with characteristics that were suitable for easier cultivation and harvesting; for example, varieties of grains that had larger kernels, more rows of kernels on each stalk, or those whose seeds did not disperse as soon as they were ripe. This selection was done by storing and sowing seeds of a few plants with the desired characteristics. Over a period of time, these developed into the ancestors of the cereal crops we know today.

Different crop varieties and livestock breeds also adapt themselves to different environmental conditions. The Kankrej cow, for example, is adapted to survive in semi-arid conditions. Similarly, a species of rice grown in the hills could develop characteristics to suit that region, such as the ability to tolerate the cooler temperatures of these areas. The same species grown in the plains would evolve characteristics such as stalks which are more resistant to the stronger winds that blow across the plains, or roots and leaves adapted to more or less rainfall and sunlight. Thus, two varieties of rice would evolve.

Over time, this kind of adaptation to natural conditions or to human manipulation has led to large variety in the species of domesticated plants. The number of varieties of rice grown in India is estimated to have been between 50,000 and 60,000. Other crops with high diversity include mango, 1,000 varieties; sorghum, 5,000 varieties and pepper, 500 varieties.

## Micro-organism Diversity

When we think of biodiversity, we rarely think of the most abundant organisms on earth—micro-organisms or microbes. Microbes include bacteria, viruses, protozoa, yeast, fungus, etc., and form a vital part of life on earth. Bacteria are the oldest life forms on earth. Microbes play an important role in various biogeochemical cycles. They live in the digestive tracts of most animals (including humans and insects), where they break down the

food and facilitate digestion. Microbes that live in the roots of leguminous plants transform atmospheric nitrogen and make it available to the plants (nitrogen fixation). The soil contains thousands of species of microbes which decompose dead organic matter and help maintain soil structure. Just a teaspoonful of soil contains billions of these microscopic living organisms!

The number of microbial cells on earth is estimated to be about 4 to $6\times10^{30}$, containing nearly half of the total carbon and 90 per cent of the nitrogen and phosphate on this planet. Micro-organisms are the only living forms which are present in the most extreme environments, such as salt pans, deep down inside rocks and even in extremely cold places.

## Importance of Biodiversity

Biodiversity may sound like an abstract concept, but in reality it touches almost every aspect of our life. The earth has an enormous variety of plants and animals, both domesticated and wild, as also a wide array of habitats and ecosystems. This diversity meets the food, medicinal, clothing, shelter, spiritual as well as the recreational needs of millions of people around the world. It also ensures that ecological functions such as the supply of clean water, nutrient cycling and soil protection are maintained.

In fact, biodiversity loss would mean a threat to the survival of the human race. Here are some reasons why each one of us should be concerned about biodiversity and its loss.

### Survival

Quite simply, without biological diversity we would perish. The global collection of genes, species, habitats and ecosystems is our real wealth, far more important than money. Perhaps the most important value of biodiversity, particularly in a country like India, is that it meets the basic survival needs of a vast number of people. Even today a large number of traditional communities depend, wholly or partially, on the surrounding natural resources for their daily needs of food, shelter, clothing, household goods, medicines, fertilizers, entertainment, etc.

### Health and Healing

Up to 80 per cent of the people in developing countries depend for primary health care on traditional medicine, most of which is derived from plants, and some from animal and mineral sources.

Indigenous systems of medicine

Traditional medicine in India has relied heavily on the rich biodiversity of the region. Three traditional systems of medicine are widely prevalent in the country—Ayurveda, Siddha and Unani.

The Ayurvedic system subscribes to the view that there is no plant on the earth which is not a medicine. The story goes that Brahma ordered the sage Jivaka to find a tree or a herb which had no medicinal property. Jivaka wandered for 11 long years in search of such a plant but could not find one. When he returned and informed Brahma of his failure, much to his surprise, Brahma recognized him as a great physician!

It is not just traditional medicines that are derived from biotic resources. Nearly one-fourth of all prescription drugs used in the developed world are based on plants. These include 21 drugs which are today almost indispensable—whether it is aspirin from the plant *Filipendula ulmaria*, or quinine from the bark of several species of the cinchona tree.

## Food Security

Biodiversity is critical for agriculture. About 90 per cent of the world's food comes from 20 plant species. Genetic diversity is important in breeding crops and livestock. Crop breeders need a diversity of crop varieties in order to breed new varieties that resist evolving pests and diseases. Modern agricultural practices have replaced genetic diversity in crops and livestock with uniformity, and this could have dangerous consequences. The loss of diversity in crop species has severe implications for global food security. A single pest invasion or disease could wipe out all standing crop or a particular livestock.

Many crops have been 'rescued' with genetic material from wild relatives or traditional varieties. In the early 1970s, genes from a wild rice variety from India helped to save rice crops from total destruction by the widespread grassy stunt virus in many parts of Asia. Scientists at the International Rice Research Institute in the Philippines searched 6,723 samples for a gene resistant to the virus. They found it in only one single sample of *Oryza nivara*, collected from eastern UP in 1963. The strain of rice evolved by using that sample is now widely grown all over South and South-east Asia.

## Aesthetic Pleasure

Each species and ecosystem adds to the richness and beauty of life on earth. Perhaps no artificial medium can match the sheer joy of watching a sunset over an ocean, the sight of a leaping deer, the sound of a singing bird, or the smell of wet earth after the first rains. A natural ecosystem, once destroyed, is impossible to recreate. The number of

people who visit a natural site is an indication of its aesthetic value. For example, every year more than 1,500,000 people visit the Sanjay Gandhi National Park on the outskirts of Mumbai.

## Ethical Reasons

Each species is unique and has a right to exist. Humans do not have the right to eliminate any species. Ethics provide the basis for deciding what is good or bad, right or wrong. The World Charter for Nature, adopted by the United Nations in 1982, states that 'Every form of life is unique warranting respect regardless of its worth to man, and to accord other organisms such recognition, man must be guided by a moral code of action.'

## Ecological Services

Species evolve to fill particular niches (roles) in an ecosystem or habitat. Many species also depend on each other in intricate ways for survival. Destroying one species can lead to further extinctions or changes. Specific life forms present in a particular habitat help to create conditions for other life forms to live in that environment. For example, a single tree provides not only its products, which may have economic value, but it is also a habitat for innumerable living things. In addition, it also plays a vital role in conserving soil and water and helping to keep the air clean. Mangroves and coral reefs, apart from their normal ecosystem service role in preventing erosion, play a critical role in protecting offshore life during hurricanes and storms. These are services for which it is very difficult to put a precise monetary value. Sometimes it is even difficult to know what services a species provides. Most often the price for ecological services thus remains unpaid.

Take the case of Mumbai. A substantial part of Mumbai city's drinking water comes from the Tansa and Borivili reservoirs. These reservoirs are in turn protected by the surrounding forests which are under the Wildlife (Protection) Act of 1972. Yet Mumbai's citizens do not pay for the upkeep of these forests and reservoirs.

## Religious and Cultural Purposes

In India, many plants and animals have ritual significance and are associated with religious, spiritual and other cultural uses. Among the auspicious flowers offered in temples are hibiscus, offered to the goddess Kali, and *datura* flowers offered to Shiva. Various plant and animal species are considered sacred on account of their association with different deities. Some animal species are believed to be the *vahanas* or vehicles of the deities and are hence venerated. Important among these are the bull of Shiva, the rat of Ganesha and the lion of Durga.

In India and several other countries, pockets of forests have traditionally been set aside because they are believed to be the abode of a particular god. Over the ages, local communities have protected these areas which are called **sacred groves**. As a result of the protection, these areas are preserved as pockets of rich biodiversity.

### The Indian treasure house

India is one of the world's 12 megadiversity countries. India contains 8.1 per cent of the world's biodiversity on 2.4 per cent of the earth's surface. It is estimated that 47,000 wild species of plants and over 89,450 wild species of animals occur in our country. India has a tremendous range of ecosystem, species and genetic diversity. The location of the Indian subcontinent at the confluence of three biogeographic realms has led to the presence of elements of African, European, and Chinese and Indo–Malayan characteristics in the flora and fauna. The diversity is also due to the fact that India has almost every major type of habitat and climatic condition—from alpine heights to coasts and plains; from areas of the heaviest rainfall to dry deserts.

The Indian subcontinent is known as the Hindustan Centre of Origin of crop and plant diversity. At least 166 species of crops and 320 species of wild relatives of crops are known to have originated here. Within each of these species, the diversity of varieties is astounding.

India is also considered one of the world's eight centres of origin of cultivated plants. It has 51 species of cereals and millets, 104 species of fruits, 27 species of spices and condiments, 55 species of vegetables and pulses, 24 species of fibre crops, 12 species of oilseeds, and various wild strains of tea, coffee, tobacco and sugar cane. India also has significant indigenous livestock diversity, with 27 breeds of cattle, 40 breeds of sheep and 22 breeds of goats. For example, India's eight breeds of buffaloes represent the entire range of the genetic diversity of buffaloes in the world.

These are only the recorded species. A number of biologically rich areas in India, such as the north-east, are not yet fully explored and studied. Who can tell what treasures lie therein?

## EROSION OF INDIA'S BIODIVERSITY

India's rich biological diversity is rapidly eroding. At least 10 per cent of its recorded flora, and possibly a large fraction of its wild fauna, is threatened. Many may be on the verge of extinction. In the last few decades, India has lost at least 50 per cent of its forests; polluted over 70 per cent of its waterbodies; built, cultivated or otherwise encroached upon its grasslands; and degraded many coastal areas.

The cheetah and the pink-headed duck are amongst the conspicuous species that have become extinct. More than 150 of the known species of medicinal plants in India have already become extinct due to unsustainable methods of harvesting. Of the species of

flora and fauna that remain, over 10 per cent of flowering plants, 21 per cent of mammals and 5 per cent of birds are believed to be under threat. India's domesticated biodiversity is also under threat. Hundreds of crop varieties have disappeared, and even their genes have not been preserved.

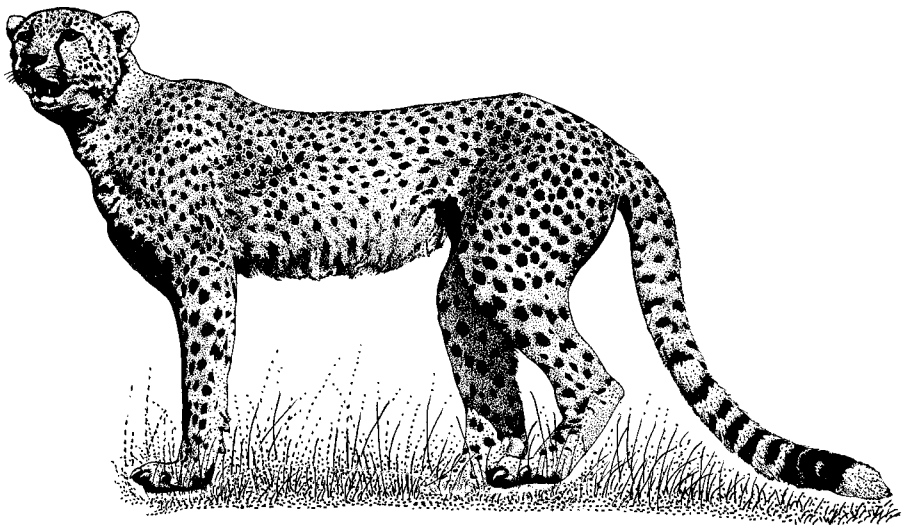


Illustration 3.2 There are no cheetahs left in the wild in India today

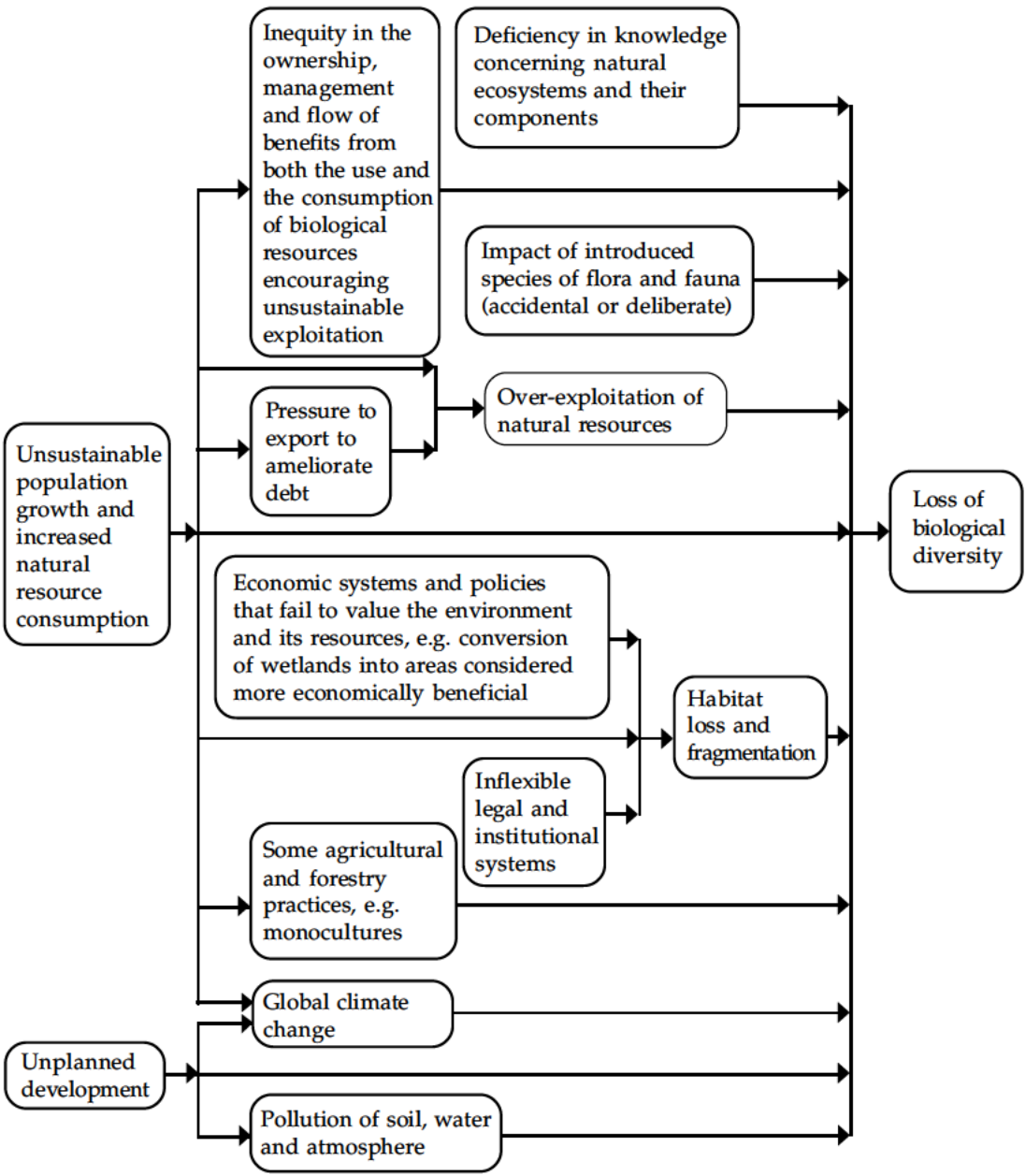
## Loss of Biodiversity: Causes and Consequences

Most causes of the loss of biodiversity can be traced, directly or indirectly, to the way we live. Biodiversity is essential for sustainable development, but finding sustainable ways of living is essential for the conservation of biodiversity. The following are some of the major causes of the loss of biodiversity.

### Unplanned Development and Habitat Destruction

Biologically diverse natural systems and the services they provide are most often undervalued in monetary terms, and as a result, are used for development activities that seemingly have more direct economic benefits. Large-scale development projects such as industrial plants or hydroelectric projects have contributed substantially to the loss of biodiversity-rich areas. Projects such as the construction of large dams not only result in the submergence of large tracts of forests but also introduce human settlements and roads within forest areas. Between 1951 and 1980, 502,000 ha of forest were diverted for

Figure 3.1
Causes and mechanics of the loss of biodiversity




**Source:** Adapted by Seema Bhatt from *Global Biodiversity Strategy* (WRI, IUCN, UNEP, Washington, D.C., 1992).

river valley projects. The enormous demand for minerals in a rapidly industrializing economy has resulted in large-scale deforestation for mining purposes. As many as 70 protected areas, that is, natural areas protected by law and supposed to be free of all destructive human presence, are under threat by ongoing or proposed mining within or adjacent to their borders.

In Goa, nearly 600 mining concessions lie within forest areas rich in biodiversity. Coral reefs, known for their rich biodiversity of marine life, have been exploited for use as raw material in cement manufacture in the country's coastal region.

Large areas rich in biodiversity have been reduced to small pockets due to their conversion to agricultural land or for the construction of roads and housing. Wetlands are filled up to provide space for more housing, large tracts of forests are submerged for hydroelectric projects. This may lead not only to the loss of innumerable species of flora and fauna, but also to the disappearance of entire ecosystems.

## Changing Agricultural and Forestry Practices

Over the ages, farmers have bred and maintained a tremendous diversity of crop and livestock varieties. This broad genetic base provided insurance against pests, diseases and adverse climatic conditions. The Warli tribals of Maharashtra, for example, grow several varieties of rice for different water and soil conditions. These varieties have varying periods of maturity, are resistant to different diseases, and are used during different cultural events.

In the last few decades, changing market forces and the increase in demand for food have prompted farmers to change their traditional agricultural practices. They have moved towards the cultivation of a single crop rather than a mixed crop. This monoculture, which is high yielding, is supported by the excessive use of chemical fertilizers and pesticides. This has led to a severe loss in the genetic diversity of crops.

In forestry, too, mixed stands are being replaced by monocultures of species which are fast-growing and have commercial value. In South India, large tracts of natural forest land have been replaced by commercial monoculture plantations of eucalyptus, wattle, teak and silver oak which are used for timber or pulpwood.

Several parts of the north-east and also parts of southern and western India have seen the replacement of local crops by cash crops like coffee, rubber, cardamom and tea. Indigenous breeds of cattle have been replaced by cross-breeds and exotic breeds for their higher milk yields. So, in the name of productivity, stability and diversity are being replaced by uniformity.

## Invasion by Introduced Species

The introduction of non-native species (also known as invasive, alien or exotic species), deliberately or accidentally, has been a major threat to biological diversity worldwide.

The introduced animals and plants pose a threat to the local species of fauna and flora. For example, the spotted deer *(Axis axis)* was introduced by the British in the Andaman and Nicobar islands. The deer have now proliferated on these islands as they have no predators except crocodiles and humans. Their large numbers seem to be affecting forest regeneration as they over-exploit certain forest species for food. The deer are also causing crop damage in the fields of the islands' settlers. Exotic plants, such as *Lantana camara*, originally introduced as an ornamental plant from Brazil, are spreading rapidly in our forests at the expense of local species.

Exotics such as eucalyptus are replacing native tree species because they are fast growing and commercially valuable. It is estimated that 18 per cent of Indian flora comprises invasive aliens, of which about 55 per cent are American, 10 per cent Asian, 20 per cent Asian and Malaysian, and 15 per cent European and Central Asian species.

## Over-exploitation for Commercial Gain

Many plant and animal species have been over-exploited by humans, sometimes to the point of extinction. Many species such as tigers and elephants are killed or poached for their skin, tusks, claws, etc., which have high commercial value. Others, such as several snake and bird species are caught and smuggled out for their curiosity value for collectors and as pets. Marine fauna are under great threat from over-exploitation, largely as a result of mechanized fishing and increasing international fishing operations in Indian waters.

A rapidly expanding pharmaceutical industry, for which no collection regulations exist, also affects medicinal plants. For example, the forest shrub *Rauvolfia serpentina* (*sarpagandha* or Indian snakeroot) has been used in the country for over 4,000 years to treat snakebite, nervous disorders, dysentery, cholera and fever. About 50 years ago, an extract (reserpine) from this plant became the base for modern tranquillizers. Today this plant is threatened in India due to over-collection.

## Environmental Pollution

Soil, water and air pollution affects the functioning of ecosystems and may reduce or eliminate sensitive species. Several studies carried out in India have clearly traced the effects of pesticide pollution on populations of specific plant and animal species. A long-term study in Keoladeo National Park in Bharatpur, Rajasthan, showed high levels of pesticide residues in Sarus cranes. These toxic residues could lead to a high mortality rate among the cranes and eventually to a decrease in their population. At the Corbett National Park, studies on the effects of DDT on the breeding of the grey-headed fishing eagle show that DDT causes egg-shell thinning, which leads either to the eggs not hatching or to the death of the fledglings.

Water pollution affects aquatic biodiversity. In India, industrial effluents are destroying coral reefs and other marine life. A thin film of oil (from oil leaks) can spread across the water surface reducing the penetration of sunlight. The impermeable oil film reduces the exchange of gases in the water. This can lead to a disruption in the respiration of aquatic organisms, thus killing them.

## Global Climate Change

In the coming years, climate change could also affect global biodiversity. There are several hypotheses about this. Different species of plants and animals may respond in different ways to an increase in global temperature. Many species which cannot adjust to warmer temperatures could become extinct. Species with specialized niches or rare species will be at greatest risk being most sensitive to any atmospheric change. A change in the climate may also result in a change in the characteristics of habitats, thereby affecting the species within those habitats. Some habitats such as islands and coastal systems, which are at risk of flooding and submergence due to rising sea levels, could suffer particularly high losses of biodiversity.

## Loss of Traditional Knowledge

Traditions, beliefs and cultures of traditional communities are closely linked to the diversity of life around them. In India, hundreds of tribal and other communities utilize the products of biodiversity in their everyday lives. They are known to use about 5,000 species of wild plants for many different purposes; for food, fibre, antidotes against insect and snakebite, medicines, and for making hunting, fishing, and farm implements.

The lifestyles of these communities are rapidly changing. A lot of knowledge about medicinal plants and their uses is being lost because the coming generations of traditional medicinal healers are in an education system which alienates them from their tradition, and therefore they are not interested in carrying on their traditional practices. If their traditional knowledge is not recorded, understood and passed on, we are likely to lose it all. In some cases, species may be known locally but the knowledge may die out as traditional lifestyles change. A species may be lost because we did not know it existed at a site that was subsequently developed.

## Nature of Legal Systems

Although laws to protect biodiversity exist, the loss of biodiversity continues. In planning legal enforcements, what is missing is an approach which combines ecological and economic realities and involves the people who will be affected.

Where planning is over-centralized, it hinders the participation of the local people who could contribute valuable local knowledge, experience and insights. Often traditional or community laws have been powerful in promoting sustainable use of biological resources. The Bishnois (meaning twenty-niners), a community living in Rajasthan, have followed, for over five centuries, the 29 principles laid down by Guru Jambaji. These principles emphasize the conservation of plant and animal species.

In the state of Mizoram in north-east India, the traditional land use system is divided into two distinct categories: 'supply forests', from which only regulated harvest of biomass is permitted, and the 'sacred safety forests', from which the removal of biomass is strictly prohibited. These designations are followed even today.

Sometimes, the so-called contemporary legal deterrents may prove to be counterproductive. The Wildlife (Protection) Act, 1972, for example, curtails the rights of local communities to the land in and around protected areas, particularly national parks. For generations, these communities have depended on these forests for many of their basic survival needs. Curtailing their access to fuelwood, food, fodder and many other forest products gives rise to conflicts between park authorities and the local people, leading to more disturbances in the natural and social systems.

### Parks versus people

On 7 November 1982, six people were killed when police opened fire at the Keoladeo National Park at Bharatpur. This 2,200 ha park harbours over 350 bird species. Some 4,000 head of cattle from 14 surrounding villages also used to feed on its grass. In November 1982, the state government decided to ban grazing inside the national park without making any acceptable alternative provision. This led to growing tension between the park authorities who tried to impose the ban, and the villagers who claimed that the park was their only source of fodder. The continuing conflict resulted in tragedy.

Interestingly, the effect of grazing on the park's ecosystem is not clear. A long-term study by the Bombay Natural History Society concluded that grazing might even help in maintaining the current ecosystem. The buffaloes clear the marshes of grass, their droppings provide fertilizer, animals eat up the dry grass thus preventing forest fires and checking weeds from growing, and several birds were found to nest in the footmarks left by cattle.

While the incident at Keoladeo National Park is important from the historical perspective, conflicts still continue in protected areas. Some examples are given below.

At Ranthambore National Park in Rajasthan, poachers are known to employ local Mogya *adivasis* as trackers. The Mogya are expert hunters. This community used to depend on the forests for their food, and survived by gathering fruits and wild roots for their livelihood. The declaration of the park put an end to all that and they started using their skills for poaching.

(For more information on the Bharatpur example, see CSE. 1985. *State of India's Environment, 1984–85*.)

## Nature of Management Systems

The issue of ownership (legal versus traditional), management, and flow of benefits from the use and consumption of biological resources may lead to situations which encourage unsustainable exploitation of natural resources, which leads to the loss of biodiversity.

Substantial areas in India significant for their biodiversity, have been designated as protected areas and have been set aside for conservation. These are legally managed by the state or central government as reserved forests, protected forests, national parks and sanctuaries. In the past, local communities living within or around these areas derived benefits from them. In turn, they acted as the local custodians of the areas. However, with the curtailment of their traditional rights and benefits, the communities living in and around these areas are beginning to wonder who benefits from the protection of these areas and are wary of outside control and management of what was traditionally theirs. This conflict of interests is now being seen in several of lndia's protected areas.

## International Trade

The demands of international markets can affect the status of biodiversity. For example, extensive areas of agricultural land have been planted with monocultures of bananas, sugar cane or pulp trees, to produce commodities on a large scale for export in order to expand the economy (export-led growth). Another example is the global market for prawn and shrimp, which has encouraged several governments in Asia to create policies favouring investment in shrimp farming. Shrimp farming is practised in brackish water. However, it uses up precious freshwater resources. At the same time, the infrastructure for commercial farming pollutes the water that is flushed into estuaries. As a result, mangroves, an important habitat for fish, have been destroyed. The costs of habitat loss are borne not only by the plant and animal species, but also by the local people who depend on the mangrove ecosystem for fish protein, income and forest materials.

## Growing Demands

The unprecedented growth in human population, as well as the materialistic lifestyles of affluent people and countries, has put enormous pressure on biodiversity. Greater demand for food and land, excessive consumption of minerals and other non-renewable resources and gross overuse and waste of energy, have aggravated the problem.

Many of these causes raise the difficult issue of how to balance the demands of development and the need to conserve biodiversity. The concern for economic growth is valid. And yet, this growth cannot be sustained if the resource base upon which development depends is destroyed. Development planning must recognize that its success depends, ultimately, on ecological, social and economic sustainability. The ultimate challenge is to rethink the way we live, and review our own patterns of consumption.

# Conserving Biodiversity

It is now recognized that biodiversity is a global wealth on which no value can be put. It is also evident that this invaluable heritage is being destroyed at an alarming rate. Fortunately, measures are being taken at the international as well as the national level, to tackle this issue before it is too late. Some of the conservation strategies are discussed below.

## National Conservation Strategies

Several measures are being taken at the national level to protect biodiversity.

Legislation: India has several Acts in force, which have a bearing on the conservation of biodiversity.

**The Environment Protection Act, 1986,** relates to general measures to protect the environment, such as restrictions on industrial and other processes or activities in specified areas. It also deals with the prevention of and control over the manufacture, use, release and movement of hazardous substances.

**The Fisheries Act, 1897,** prohibits the use of explosives and poisons for fishing. It also regulates fishing in private waters.

**The Forest Act, 1927,** deals with the setting up and management of reserved, protected and village forests, and controls how selected products from the forest can be sold and at what price.

**The Forest (Conservation) Act, 1980,** primarily focuses on prohibiting or regulating non-forest use of forest lands.

**The Wildlife (Protection) Act, 1972; The Wildlife (Protection) Amendment Act, 1991; and The Wildlife (Protection) Amendment Act, 2002,** deal with the restriction and prohibition of the hunting of animals, and with the protection of specified plants. They also deal with the setting up and management of sanctuaries and national parks, setting up of the Central Zoos Authority, control of zoos and captive breeding. They also control trade and commerce in wild animals, animal articles and trophies.

**The Biodiversity Act, 2002,** which was formulated after a long period of discussions and considerable public debate, is part of India's follow-up of the International Convention on Biological Diversity. The Act provides for a National Biodiversity Authority (NBA), which will screen proposals for the transfer of genetic resources abroad, and set up a system for genetic material from India to be sent to any other country. This is to ensure that there is a record of all genetic material going out of the country. The NBA will also advise the central government on measures for conservation, sustainable use, and benefit-sharing resulting from the use of the biodiversity with the communities who are its traditional custodians.

The National Biodiversity Strategy and Action Plan (NBSAP): This plan was initiated in late 1999 by the Ministry of Environment and Forests (MoEF), Government of India, as part of India's commitment to the Convention on Biological Diversity. The broad purpose of this process was to produce an implementable action plan that would ensure the conservation of India's biodiversity, its sustainable use and equitable sharing of benefits arising from its use—the main tenets of the Convention on Biodiversity. The two prerequisites of this plan are the ecological security of the country or of any region within it, and the livelihood security of those most critically dependent on biodiversity and its components.

The NBSAP has been one of India's largest participatory planning exercises with the involvement of several thousand people in different parts of the country. The attempt of the process at various levels has been to involve all the relevant stakeholders. This was done keeping in mind the fact that there are millions of people in India who use biodiversity and many who are also involved in its conservation. In most planning processes, these people have never been involved. In this case, public participation was sought and encouraged through meetings, workshops, seminars, public hearings and even festivals organized for the purpose. The end result has been a series of action plans. The national plan attempts to build elements from all these.

*In-situ* Conservation: *In-situ* conservation, as defined by the UNEP (United Nations Environment Programme), is 'the conservation of ecosystems and natural habitats and the maintenance and recovery of viable populations of species in their natural surroundings'. This is an effective conservation strategy since it ensures the maintenance of ecosystems and species in their natural conditions. India has taken several steps towards *in-situ* conservation of biodiversity.

India's major attempt to conserve *in-situ* wild biodiversity has been through a network of protected areas throughout the country. Two kinds of protected areas are recognized by the legal system in India; national parks and wildlife sanctuaries. National parks are highly protected by law. No human habitation, private landholding or traditional human activity such as firewood collection or grazing is allowed within the park. Sanctuaries are also protected, but certain types of activities such as collection of firewood and grazing of cattle are permitted within these areas.

The first such initiative was the establishment of the Corbett National Park in 1936. As of 2003, India has 89 national parks and 500 wildlife sanctuaries occupying 156,000 sq km, or over 5 per cent of the country's area. These protected areas have helped in conserving habitats and their biodiversity.

Several special projects have also been launched to save certain animal species which have been identified as needing concerted protection effort. These projects are designed to protect the species *in-situ*, by protecting and conserving their natural habitat. Project Tiger and Project Elephant are two such major initiatives. Other species' conservation projects include Project Crocodile Breeding and Management, which was started in 1976 and now operates in 16 sanctuaries; and the Gir Lion Sanctuary Project in Gujarat, which

aims at saving the Asiatic lion which once roamed over a wide stretch of the northern and central parts of the Indian subcontinent, but is today one of the most threatened species of animals in India.

Many NGOs are also involved in the conservation of wild species of fauna and flora. The WWF–India, for example, has a specific programme focused on the protection of the tiger and its habitat. Operation Kachhapa was initiated in 1998 for the conservation of the Olive Ridley sea turtles in Orissa. It is coordinated by the Wildlife Protection Society of India (New Delhi), and involves government departments as well as NGOs.

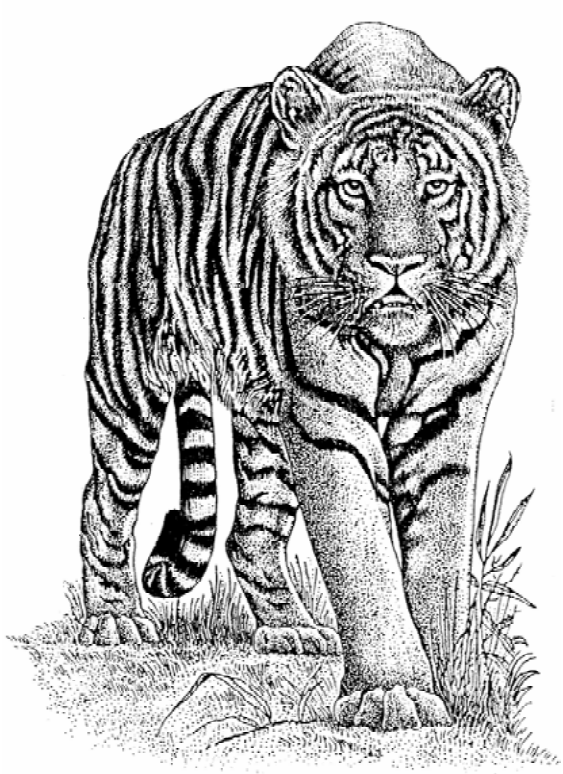


Illustration 3.3 Project Tiger has helped not only to protect the tiger, but numerous other wild inhabitants of India's tiger sanctuaries as well

To conserve medicinal plants, the forest departments of Andhra Pradesh, Karnataka, Kerala, Maharashtra and Tamil Nadu, with the help of the Foundation for the Revitalisation of Local Health Traditions (FRLHTs), have set aside 54 forest patches as Medicinal Plants Conservation Areas (MPCAs) measuring 200 to 500 ha each. These MPCAs represent all the forest types and climatic zones of the region and harbour many species of medicinal plants threatened with extinction.

A citrus gene sanctuary has been established in the Garo Hills of Meghalaya. Its purpose is to conserve both wild and cultivated species/varieties of citrus, such as *Citrus indica* (wild citrus variety), and of other plants that are useful to human beings.

An example of the initiatives taken for the conservation of agricultural biodiversity is the *Beej Bachao Andolan*. This is a movement in the Garhwal Himalayas to save indigenous seeds from being wiped out by the introduction of new, hybrid varieties. It also emphasizes the conservation of seeds and farming practices that traditionally existed in the area. The movement has been successful in conserving, *in-situ*, several hundred indigenous varieties of seed, including those of 40 different crops, oilseeds, medicinal plants, as also vegetables. The movement has now spread to many villages in the area and is an established network.

In India, a number of communities also practise different forms of nature worship. This has resulted in the tradition of providing protection to patches of forest (sacred groves), waterbodies (sacred ponds, lakes, etc.) and even entire landscapes for cultural and/or religious reasons. This customary protection of the habitat over centuries has resulted in the conservation of a range of rare and endangered species in these sacred spaces. Nearly 14,000 sacred groves are reported to exist in India.

*Ex-situ* Conservation: There is a need to conserve species of animals and plants outside natural habitats also and, therefore, the relevance of *ex-situ* conservation. This could be in zoological parks and botanical gardens or through forestry institutions and agricultural research centres. There are many examples of *ex-situ* conservation of plant and animal species.

A number of orchid sanctuaries and orchidariums have been established in orchid-rich habitats, like the foothills of the Himalayas, the Western Ghats, the western coastal region and the southern hill stations.

The Central Council for Research in Ayurveda and Siddha (CCRAS), established in 1978, has promoted the cultivation of medicinal plants at five herbal gardens across the country covering an area of 135 acre.

The pygmy hog is the smallest and rarest wild pig in the world. Very small populations survive in the wild but it is almost on the brink of extinction. A small population exists in the Manas National Park in Assam. The Pygmy Hog Conservation Programme (PHCP), a collaborative programme of the government and international specialist groups, focuses its work on trying to ensure that pygmy hogs are successfully bred in captivity and released in the wild in an effort to save them from extinction.

The Madras Crocodile Bank (MCB) was the first crocodile-breeding centre in Asia. Since its establishment, it has supplied over 1,500 crocodiles and several hundred eggs to various state forest departments for their stocking programmes and to set up breeding facilities.

A lot of effort is underway to collect and preserve the genetic material of crop, animal, bird and fish species by the Government of India. This work is being done by institutions such as the National Bureau of Plant Genetic Resources (NBPGRs), New Delhi, and the National Bureau of Animal Genetic Resources (NBAGRs), Karnal.

## Building on Indigenous Knowledge

The lives of several rural communities are closely interwoven with their environment as they are dependent upon their immediate resources for their needs. These communities have a vast and rich bank of knowledge about local flora and fauna, which is very important for biodiversity conservation. Much of this knowledge is passed on orally from generation to generation. Such indigenous knowledge needs to be recorded and preserved before it is lost. Several organizations have recognized this and are working to record the knowledge and preserve it for posterity.

### People's biodiversity registers

India's Biological Diversity Act formulated in 2002, attempts to address the challenge of how best people's traditional knowledge can be documented and conserved. People's Biodiversity Registers (PBRs) are a step in this direction, where trained scientists along with local community members document the indigenous local flora and fauna as well as the related indigenous knowledge. PBRs are essentially instruments in developing a biodiversity information system. Such documentation requires the collaboration of people with expertise in several disciplines and would include trained modern-day scientists as well as traditional health practitioners, local experts, etc. PBRs are an attempt at organizing the information available in the domain of folk science. Such a system would give due credit to the informants and practitioners who use this knowledge. This system of documenting traditional and local knowledge is already underway, and several thousand PBRs have been made. In some places, college students, too, have been trained and are involved in documenting for the PBRs.

## Community Participation in Biodiversity Conservation

It is being recognized that no legal provision can be effective unless local communities are involved in planning, managing and monitoring conservation programmes. Several initiatives to do this have been started, both by government and by non-governmental organizations.

Joint Forest Management (JFM): JFM has been and continues to be the government's largest attempt at regenerating and sustainably using forests with the support of local communities. This is a forest-management strategy launched in 1990, in which the forest department and the village community agree to jointly protect and manage the degraded forest land adjacent to the villages. They agree to share responsibilities of and the benefits arising from this protection. The village community is represented through an institution which is commonly called the Forest Protection Committee (FPC). In 2003, 27 states had adopted JFM, and through them over 63,000 FPCs were managing around 14 million ha of forest land.

India's Eco-development Project: This project which operates around select protected areas, is an attempt to reduce biotic pressure from grazing and the collection of fuelwood, fodder and various non-timber forest products in the PAs, by providing alternatives to the villagers. The villages are represented in this scheme through their Eco-Development Committees (EDCs). The EDCs decide what kinds of alternatives the villages require, and plans are made accordingly.

It is recognized that for conservation strategies to be successful, they must have the confidence and participation of the local communities. There are several thousand community-conserved areas in India, where communities continue to conserve the biodiversity of the region without any government or legal support.

## Linking Livelihoods with Conservation

In a country like India, where several thousand people still depend on forests, fresh water and marine resources for meeting their livelihood needs, any conservation strategy must ensure that the people continue to benefit from these areas of biodiversity. The government's attempts have been in the form of projects such as JFM and eco-development.

The link between biodiversity conservation and livelihoods still remains weak. For this to be strengthened, several questions need to answered. First, how do we ensure that people will benefit from the area? Second, how do we ensure that if people benefit then the area will be conserved and not destroyed? Third, how do we ensure that people who benefit from these areas will themselves help to conserve them? There have been some attempts to formulate projects where these questions could be answered. (See box, NTFP in the Biligiri Rangan Hills.)

### NTFP in the Biligiri Rangan Hills, Karnataka

At the confluence of the Eastern and Western Ghats lies the Biligiri Rangaswamy (BR) Temple Sanctuary. This area has high floral and faunal diversity and is also rich in non-timber forest produce (NTFP). The sanctuary is also home to approximately 4,000 Soligas, an indigenous tribe. The Soligas, once shifting cultivators and hunter-gatherers, now rely on the limited NTFP they collect from the sanctuary.

A project supported by an international agency called the Biodiversity Conservation Network (BCN), focused on the sustainable extraction and local processing of three different forest products: (*i*) *amla (Phyllanthus officinalis)*, (*ii*) wild honey, and (*iii*) some Ayurvedic preparations from select medicinal plants. The processing and marketing of *amla* (as pickles and jams), honey and some Ayurvedic products has helped to increase the income of the Soligas.

The project is continuing through the Ashoka Trust for Research in Ecology and the Environment (ATREE). This project looks at how the income levels of the Soligas can be raised, how they could be encouraged to ensure that conservation of the forest is taking place, and how they could monitor the harvesting of these forest products in a comparatively non-destructive manner.

## Equitable Sharing of Benefits from Conservation and Indigenous Knowledge

Another big challenge for countries like India is how to ensure that benefits from biodiversity resources do flow to local communities. For many years now, large pharmaceutical companies have explored areas in different parts of the world for plants and animals as sources of medicinal products, very often using local knowledge. They have also produced drugs based on these resources. Unfortunately, local knowledge has neither been acknowledged nor have local communities benefited from the sale of these products. An attempt is now being made to ensure that communities do benefit from the use of their local knowledge. One of the first attempts to do this in India is described in the following box.

### The Kani–TBGRI Model

In 1987, a team of scientists from the Tropical Botanic Garden and Research Institute (TBGRI) was on an ethnobotanical field trip in the Agasthya Hills in the southern Western Ghats. They noticed that the Kanis (a tribe resident in that area) who accompanied them were eating a fruit which energized them. After discussions with the Kanis and an assurance that knowledge about the fruit would not be misused, the scientists took the fruit back for analysis of its properties.

The analysis revealed that the fruit, locally known as *arogyapacha*, did have 'anti-stress' properties. Having isolated 12 active ingredients from the plant, and filed patent applications, a drug named *Jeevani* was formulated by TBGRI. Arya Vaidya Pharmacy (Coimbatore) Ltd, in 1995, was given a license to manufacture this drug. It was decided by the TBGRI that the Kanis would receive 50 per cent of the royalty from the sale of the drug. In 1997, the TBGRI assisted the tribals to register a trust called the Kerala Kani Samudaya Kshema Trust. The 50 per cent license fee received was transferred to the Trust. The Trust could decide what this money would be used for. There have been many hurdles in this benefit-sharing agreement. However, it is the first attempt of its kind in India.

## International Conservation Strategies

Conserving biodiversity is not an issue confined to any one country or community. This is a crucial global concern because what happens to the biodiversity of one country affects another. The forests of one country may help in decreasing the effects of global warming. The cure for AIDS or cancer may lie in the forest or seas of one country but may cure people living in many different parts of the world.

Several international treaties and agreements are in place in the attempt to strengthen international participation and commitment towards conserving biodiversity (see Appendix 2). This is because certain problems can be addressed only if several countries work together. International agreements and treaties help in tackling such problems.

The issue of illegal trade in wild fauna and flora, for example, transcends political boundaries and is best addressed through international agreements. This is, of course, over and above national laws. Some of these international agreement are briefly described below:

The Convention on Biological Diversity: This convention was signed during the United Nations Conference on Environment and Development (Earth Summit) in Rio de Janeiro, Brazil, in 1992. It focuses not only on conserving biodiversity but also on the sustainable use of biological resources and equitable sharing of benefits arising from its use. By signing this convention, member countries are committed to several activities including developing strategies for biodiversity conservation and sustainable use, and incorporating biodiversity issues into national plans, programmes and policies. This is by far the most important convention for the conservation of biodiversity at national and international levels.

The Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES): This convention is an international treaty which is designed to protect wild plants and animals affected by international trade. The treaty, in force since 1975, controls the export, import and re-export of endangered and threatened wildlife. Today, this convention provides varying degrees of protection to more than 30,000 species of animals and plants that are being traded as live specimens, for fur coats, or even as dried herbs.

The Convention on Wetlands of International Importance: This convention also known as the Ramsar Convention, was signed in Ramsar (Iran) in 1971, and came into force in December 1975. It provides a framework for international cooperation for the conservation of wetland habitats which have been designated to the List of Wetlands of International Importance.

Although it originally focused on conserving habitats for waterbirds, the convention now covers all aspects of wetland conservation and wise use. India became a signatory to this Convention in 1982, and till November 2002 had designated 19 wetlands as Ramsar sites. These are Harike (Punjab), Pong Dam (Himachal Pradesh), Ashtamudi Lake, Sasthamkotta Lake and Vembanad–Kayal (Kerala), Chilika Lake and the Bhitarkanika Mangroves (Orissa), Deepor Beel (Assam), Kolleru Lake (Andhra Pradesh), Tsomoriri and Wular Lakes (Jammu & Kashmir), east Kolkata Wetlands (West Bengal), Sambhar Lake and Keoladeo National Park (Rajasthan), Ropar Lake and Kanjili Lake (Punjab), Point Calimere Wildlife and Bird Sanctuary (Tamil Nadu), Bhoj (Madhya Pradesh), and Loktak Lake (Manipur).

The World Heritage Convention: Also the Convention Concerning the Protection of the World Cultural and Natural Heritage, to give this international treaty its full name, is aimed at protecting sites of such outstanding value that their conservation is of concern to all people. Natural or cultural sites, which are nominated by the signatory nations,

are evaluated for world heritage quality as per the criteria given in the convention before being added to the World Heritage List. The treaty was adopted in Paris in 1972 and came into force in 1975. India has a total of 23 designated World Heritage Sites of which five are natural sites. These are: the Keoladeo National Park (Rajasthan), Manas National Park (Assam), Kaziranga National Park (Assam), The Sunderbans (West Bengal), and Nanda Devi National Park (Uttar Pradesh).

It is important to consider what each one of us can do towards the conservation of biodiversity. Conservation of biodiversity is everyone's problem. It needs to be dealt with at various levels. Biodiversity is not only confined to the fields of farmers, forests or waterbodies. It is also found in urban areas, where we live. We need to realize this and see how best it can be conserved.

## I Questions

1. Do you know of any sacred grove or pond in your village, district, state, or anywhere in the country? Is it different from the area around it? Is there any story behind it? If so, what is it?
2. What are some of the factors responsible for India's rich biological diversity?
3. Why and how do 'exotic' species of plants and animals pose a threat to native species?
4. In what way do our changing lifestyles and consumption patterns lead to biodiversity loss?
5. In what way can local communities living in and around biologically-rich areas be motivated to conserve the biodiversity of these areas?
6. Which is biologically the most diverse place you have visited? Why do you rate it so?

## II Exercises

1. Read the following description of the situation in one of India's national parks, and then answer the questions that follow.

   Ranthambhore National Park in Rajasthan is a green island in degraded surroundings. Tiger sightings have become rare in recent years. The census conducted in 1992 showed that the number of tigers, which had been 44 in 1981, was down to 17. Nearly 60 villages surround the park. Villagers depend for their fuel, fodder and timber requirements on the buffer zone. The buffer zone experienced tremendous pressure as soon as a large part of the forest

was declared inaccessible, and today it is severely degraded. Efforts to restock the buffer zone have been negligible, which has further increased the pressure on the national park. Recently, poaching has been a cause for serious concern. A kingpin of the tiger-poaching racket was arrested. Ranthambhore has become an important tourist destination for Indian and foreign tourists. The area which used to belong to the people of Ranthambhore is now not accessible to them, but is open to tourists!

**Problem:**
The first problem is that the people of Ranthambhore were not consulted by the government when it created the national park. Thus, they were cut off abruptly from their traditional resource base. No alternatives were provided, which led to an acute mistrust between the park authorities and the people. The second problem is that of diminishing habitats for endangered species such as the tiger. Citizens and activists alike have serious concerns about the future of such species and their degraded habitats.

**Questions:**

a. The villagers contend that they have been using the local forest resources for generations and so have every right to the forest. But while the population of the people and their cattle has been increasing, the area under forest has at best remained constant, and the productivity of the forest has not increased. If the forest had not been declared a protected area, and the people had free access to it, what would be the state of the forest? Would it continue to be a healthy ecosystem? If yes, why? If no, why not?
b. Who should decide whether local communities should have access to local resources—the government or the people (or both)? Why?
c. If you had to choose between protecting the forest to save the tiger at the cost of the basic survival needs of humans, such as fuelwood, or providing for the needs of the people even if it means that the tiger becomes extinct, which would you choose and why?
d. Is it possible to create a sustainable relationship between the forest and the people which also protects the tiger? If yes, how? If no, why not?

2. Find out about at least five household medical remedies that use plants. What are these used to treat? What part of the plant is used? How is it prepared/administered? There is an increased market for 'Ayurvedic' preparations. Find out more about five such products in the market. What plants do they list as ingredients? Are they the same as those listed in the household medical remedies?

3. Locate the Ramsar sites and World Heritage sites on a map of India. Does your state have any one or more of these?

## III DISCUSS

1. Do you think reviving local health traditions (e.g., Tribal and Ayurvedic medicine) will help conserve the biodiversity of India? Why or why not?
2. Discuss the pros and cons and ethics of encouraging biological collections and dissections as part of school and college syllabi.

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# Chapter 4

# Water

Avanish Kumar and Sarita Thakore

There can be no life without water. Water is an essential component of all living things. All animals and plants need water, and contain large amounts of it. Water plays a key role in determining the weather; it helps to shape the land surface and regulate the climate.

Water has played a predominant role in governing the distribution of humans across the surface of the earth. In fact, the earliest civilizations such as the Mesopotamian, the Egyptian and the Harappan arose on the banks of perennial rivers.

The importance of water and its uses can be briefly summed up as follows:

1. **Sustaining life:** Life began in water and water is a basic component of every living cell. It acts as a medium for important life processes and chemical reactions, and transports food and waste products.
2. **Agriculture:** Water is the basic input for agriculture. All crops and livestock need water. Agriculture is one of the prime users of water.
3. **Industry:** Almost all industrial processes need water. It is needed for the manufacturing or processing of ores, textiles, chemicals, paper, food, etc. Water is needed as a solvent, as a medium, as a cooling agent, as a cleaning agent.
4. **Power:** Almost all modes of power generation require water—from hydel power, where falling water turns turbines to produce power, to thermal and nuclear power, where usually water is used as a coolant.
5. **Domestic use:** Cleaning, cooking, washing, bathing, sanitation, all these require water.
6. **Medium of transport:** Boats, ships and sailboats carry humans and materials from one place to another across bodies of water.

## Water in Nature

About three-fourths of the earth's surface is covered by water. This is the earth's **hydrosphere**. It consists of water in the oceans, lakes, streams, rivers, swamps, on the

surface of the land and under the ground. It also consists of water frozen as ice and snow—in icebergs, glaciers, polar ice, on mountains and in the frozen layers of soil—and as water vapour in the atmosphere.

## HYDROLOGICAL CYCLE

Water continuously circulates from the ocean, to the atmosphere, to the land, and back to the ocean. This never-ending movement from one stage to another is called the hydrological cycle or **water cycle**. Water in the oceans, lakes and streams is heated by the sun and evaporates. Water also evaporates from plants. This is called **transpiration.** All this water vapour rises into the air. As it rises, it cools and condenses and forms little droplets which make up the clouds.

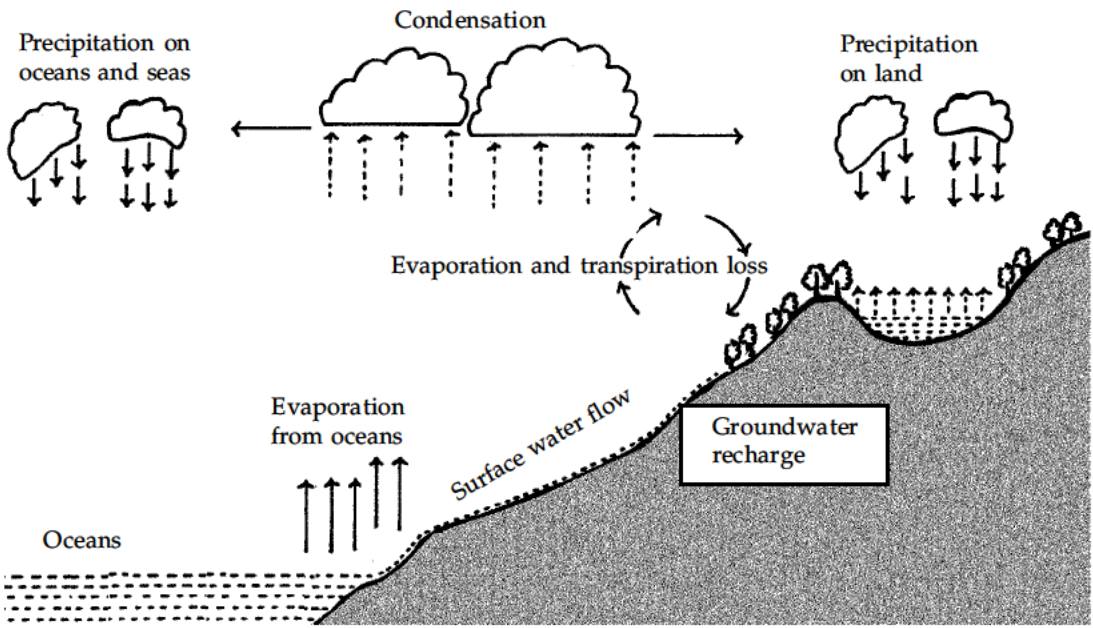



Illustration 4.1 Water cycle is powered by the sun

Water that falls from the clouds is called **precipitation**. Precipitation can occur in the form of rain, snow, hail and sleet. Precipitation occurs when large masses of air laden with water vapour rise, cool and condense to form the tiny droplets that make up clouds. Within clouds, the tiny droplets of water come together to form larger and heavier clouds.

When the air around the clouds cools, the droplets fall as rain, or when the temperature is below freezing point, as snow.

Some of this rainwater seeps through the soil and is stored underground. This is called **groundwater**. Plants absorb water from the soil and return it to the atmosphere during transpiration. Much of the remaining rainwater finds its way into rivers which transport it to the oceans. From the oceans it evaporates again. Thus, a new cycle begins.

Powered by energy from the sun and the gravitational force of the earth, the water cycle recycles and redistributes the earth's fixed supply of water. Several natural processes involved in the water cycle purify the water—evaporation and precipitation act as a natural distillation process, and as the water seeps through the ground and flows through streams and lakes, it is filtered and also purified by biological and chemical processes.

## Sources of Water

If we think of the entire hydrosphere as being made up of 100 l of water, what is actually available to us as fresh water is about half a teaspoonful. About 97 per cent makes up the oceans and is too salty, and the rest is locked up as ice and snow.

The primary source of fresh water is precipitation in the form of rain, snow and hail. Rain is the most important of these.

### The Indian monsoon

India has one of the richest water resources in Asia, with about 14 per cent of Asia's renewable freshwater resource. It receives an average annual rainfall of 1,150 mm. However, rainfall distribution varies widely across the land, both in space and in time. Some areas like parts of the Thar desert receive less than 200 mm annually, while 10 km from Cherrapunji in Meghalaya stands the village of Mawsynram, which holds the world record for the heaviest rainfall of 12,163 mm.

Most of the rainfall in India occurs during the 'monsoon' season. Monsoon refers to the seasonally shifting winds in the Indian Ocean and surrounding regions, which blow from the south-west in summer and from the north-east in winter. A monsoon seasonal change is characterized by a variety of physical mechanisms which produce strong seasonal winds, a wet summer and a dry winter.

In the Indian Ocean monsoon, the land/sea heat differential and intense convection, as a result of orography (the location and orientation of mountains in the area), produce more intense effects than in any other place in the world. The highlight is the 'wet summer' phase from June to September, also called the monsoon season, with prevailing winds from the south-west and heavy rainfall. The failure of the monsoon can result in drought, while heavy rainfall during the season can cause floods.

## Fresh Water

Fresh water is available as part of the vast water cycle in which water evaporates from the ocean and land and falls as rain. It has a low salt concentration—usually less than 1 per cent (1000 mg/l) of dissolved salts. Our freshwater supplies are mainly stored either in the aquifers as groundwater or are available in lakes, rivers and streams on the earth's surface as surface water. Waterbodies on the earth's surface are either flowing **(lotic)**, for example, a river or a stream; or relatively stationary, i.e. still waters **(lentic)**, for example, ponds or lakes which are often fed by rivers.

### Watershed and catchment area

A watershed is a system. It is a drainage basin which guides all precipitation and run-off (water, sediments, dissolved minerals, pollutants and trash) to a common watercourse or body of water. It is an area of land that catches rain and drains it into a stream, river or lake, or seeps it into the ground. Our homes, farms, villages, forests, small towns, big cities and more, are all part of some watershed. The entire area from which drainage is received by a river system is called the **catchment area**.

Watersheds are found in all shapes and sizes. They can vary from thousands of hectares—like the land that drains into the Ganga—to a few hectares that drain into a local pond.

A watershed may be open or closed, depending on where the water drains. In a closed system, like in some ponds, there are no outlets for the water, so it leaves the system naturally by evaporation or by seeping into the ground (becoming groundwater). In an open watershed system, water eventually flows into outlet rivers or a gulf, and ultimately the sea.

Within a watershed there are many different human activities that use water and affect water quality.

## Groundwater

Most of the fresh water on land is not in rivers and lakes. It is hidden underground in spaces between soil and rock particles as groundwater.

As rainwater seeps into the ground, some of it clings to particles of soil or to roots of plants. This moisture provides the plants with the water they need to grow. The rest moves deeper into the ground.

The amount of groundwater that can flow through soil or rock depends on the size of the spaces or pores in the soil or rock and how well the spaces are connected. The total amount of pore spaces determines the amount of water the soil can hold and is referred to as **porosity**. The extent to which the pores are linked, so they can become the channels, determines the ease with which the water can percolate through the soil and is referred to as **permeability**. If a material contains pores that are not connected, groundwater cannot move from one space to another. These materials are said to be **impermeable**. Materials

such as clay or shale have many small pores, but the pores are not well connected. Therefore, clay or shale usually restricts the flow of groundwater. Materials such as sand have large connected spaces that allow the water to flow through and are therefore permeable.

The character of most soils changes with increasing depth. As water percolates downwards, eventually it must reach a layer of impermeable material. This may be closely packed clay or it may be the underlying rock itself. At this level, water does not move downwards but flows around horizontally at the same level. This water which flows over the impermeable layer is called the **groundwater**. It does not flow as in rivers and streams but within the soil material that is saturated. This water-saturated layer of material or bedrock is called an **aquifer**.

Just as the depth of a lake varies from place to place according to the level of the lake bed, the depth of the groundwater also varies from place to place, and it also has an 'upper surface'. This is the **water table**, a somewhat indistinct boundary below which the soil is saturated and above which, although not saturated, the soil is very wet. The level of the water table falls in very dry weather, when the rate at which water is drained out of the soil exceeds the rate at which the rainfall contributes to the groundwater. In very wet weather, the water table rises, and in some places and at some times it may reach the ground level causing waterlogging of the upper layers.

Most usable groundwater occurs up to a depth of 750 m. Groundwater supplies water to wells, springs and even to rivers and streams. Groundwater has a number of advantages when compared to surface water. Groundwater reservoirs do not suffer seepage losses like surface reservoirs, such as streams and lakes. The chances of pollution are also less, and less water is lost due to evaporation.

### Wetlands: Uses and threats

Wetlands are waterbodies—both fresh and saline. They are areas where water is the primary factor controlling the environment and the associated plant and animal life. Wetlands occupy the transitional zone between permanently wet and generally dry environments. Shallow lakes, ponds, abandoned quarries, estuaries, lagoons, mangrove swamps are some examples of wetlands.

Wetlands are amongst the world's most productive environments. They provide a wide array of benefits to human beings, and harbour a great diversity of life forms. They provide food for humans, like fish and other animals, and recreation, like birdwatching, boating, etc. Flood control, water purification, serving as habitat for fish, birds and other wildlife are other functions of wetlands.

Many wetlands are being drained for agriculture, urban expansion and other such purposes. Also, a large number of these are subjected to the inflow of domestic sewage, industrial pollutants and agricultural run-off. Deforestation leading to soil erosion and several unplanned human activities in the catchment area of many wetlands have caused increased sedimentation and the resultant shrinkage of the wetlands. Weed infestation is another problem posing a great threat to the wetlands' ecological functions (*Water Manual*, UNICEF).

# Water Use

Water woes

Some news headlines and stories capturing the state of water problems in the country:

- **Amreli in Saurashtra region of Gujarat goes without water for 18 days**
- **Three people were killed and scores injured in different parts of Madhya Pradesh in 'water riots' in the summer of 2003 caused by an unprecedented drinking water crisis in the state**
- **Parts of Hyderabad get municipal water supply once every three days for about an hour**
- **A part of Chennai's water supply is brought in every day from a distant source by freight train**

The demand for water has been ever-increasing due to the growing population and water-consuming human activities. This has led to the serious depletion and deterioration of available water. The projected increase in the demand for water as depicted in Table 4.1, therefore, presents an alarming picture.

Table 4.1
Sectorwise present and future water requirements: 1990–2050

| | | *Sectorwise water use and future requirements (million hectare-metres)* | | | | |
|---|---|---|---|---|---|---|
| *Year* | *Population (millions)* | *Irrigation* | *Domestic and livestock* | *Industry* | *Thermal power* | *Total* |
| 1990 | 800 | 46.0 | 2.5 | 1.5 | 3.0 | 53 |
| 2000 | 1,000 | 63.0 | 3.4 | 3.6 | 5.0 | 75 |
| 2025 | 1,400 | 77.0 | 5.0 | 12.0 | 16.0 | 110 |
| 2050 | 1,700 | 70.0 | 6.0 | 20.0 | 16.0 | 112 |

**Source:** Anil Agarwal, et al. 1999. *The Citizens' Fifth Report*, Part II: 36.

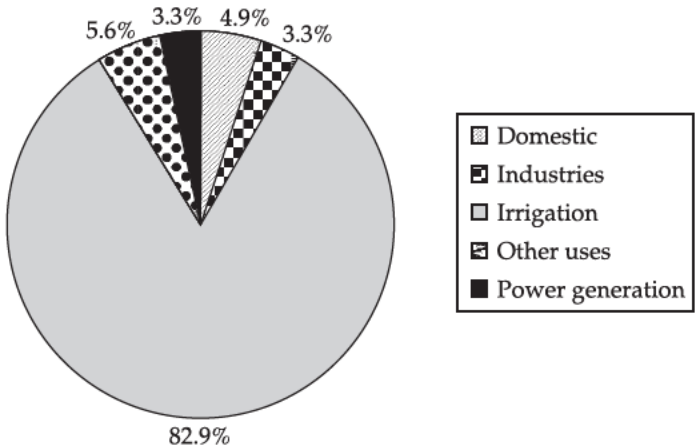
The major sectors of water use in India and their present state are described here.

## Agricultural Use

The agriculture sector is the largest water user in the country, accounting for over 80 per cent of total water use. Irrigation practices in India in the latter half of the 20th century have changed drastically. Taking advantage of the huge government subsidies on water and on electricity for pumping water for irrigation, farmers indiscriminately use groundwater. In states like Punjab, Haryana, Gujarat and Uttar Pradesh, over 85 per cent of the

irrigation is done through groundwater sources. This has resulted in an alarming depletion of groundwater resources. Though it is a well-recognized fact that subsidized electricity and pumps only encourage indiscriminate bore-well extraction, politicians are not willing to reduce the subsidies for fear of losing the vote bank.

Figure 4.1
Sector-wise utilization of total water resource in India (1997)




**Source:** http://wrmin.nic.in/wresource1.htm

The agricultural cropping pattern has changed as more and more farmers are growing water-intensive crops, even in regions where water is scarce. In some areas of Maharashtra, many farmers have switched to sugar-cane farming, which is a water-intensive crop and not suited to the drought-prone region. Excessive pumping of groundwater has also resulted in saline water ingress in coastal areas, affecting the quality of the water resource.

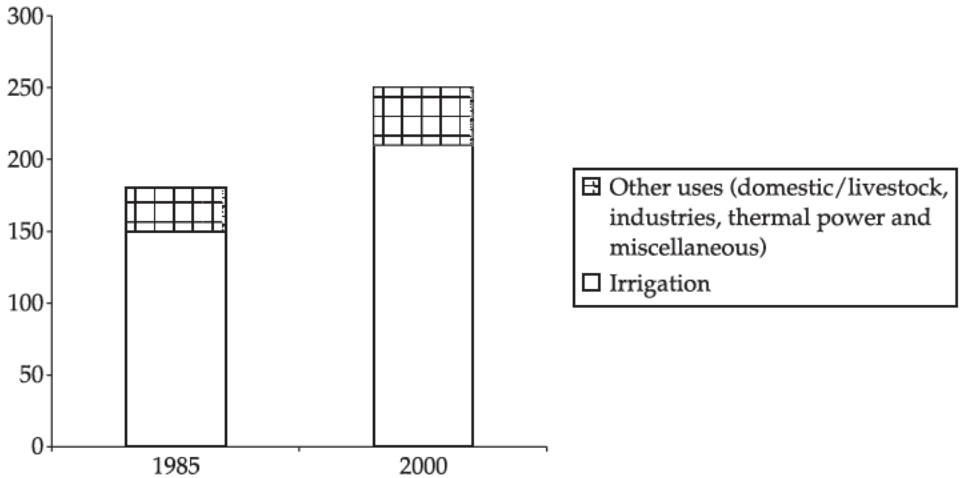
### Water problems in Junagadh, Gujarat

In Junagadh, a district in Gujarat, indiscriminate water pumping has resulted in the water table going down at an alarming level. Anyone who can afford it digs a bore well and there is no limit to the depth of the bore. People connect motors to their handpumps and draw as much water as possible. The amount of water that can be obtained from handpumps has been falling by almost 20 per cent every summer. Women have to travel up to 4 km in search of potable water. Ingress of saline sea water is another problem faced by the villagers: it increases the salinity of both the groundwater and the soil. The occurrence of bone-related diseases is increasing in the region as the hardness of water is well beyond the permissible limits. The problems faced by Junagadh are just one example of a widespread phenomenon that is occurring in several parts of the country.

**Waterlogging** is another problem arising from the excessive irrigation of poorly drained soils. Waterlogging also occurs in areas that are poorly drained topographically. Excessive irrigation (and/or seepage from irrigation canals) eventually raises the water table. The raised water table results in the soils becoming waterlogged. In waterlogged soils, air spaces are filled with water and plant roots suffocate due to lack of oxygen. Waterlogging also damages the soil structure. Farmers generally do not realize that waterlogging is taking place until it is too late.

Waterlogging is already manifesting its disastrous effects in Punjab, Haryana and Rajasthan. The cultivable area as well as the agricultural yields in these states have been going down.

Figure 4.2
Increase in annual groundwater demand (cubic kilometres)




**Source:** *The Citizens' Fifth Report, Part II—Statistical Database*, CSE.

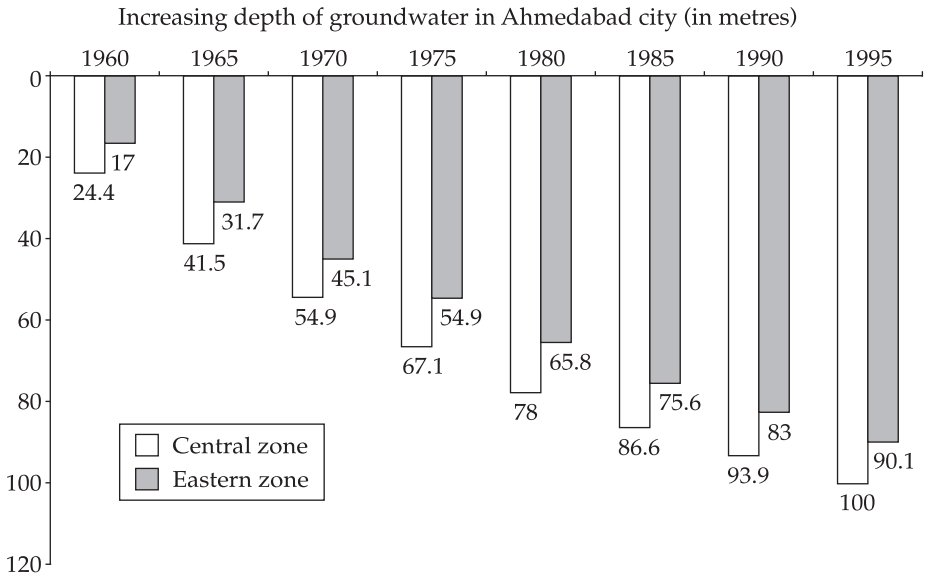
## INDUSTRIAL USE

Though the overall proportion of water for industrial use accounts for only a small percentage compared to that used for irrigation, the impact on water sources due to industrial pollution is considerable. Water is used in a variety of industrial processes. The problem of industrial use of water occurs mainly from the contamination and pollution of groundwater and fresh water by industrial effluents. Industrial wastes are toxic to life forms that consume or live in the water into which they are released. Water treatment facilities are either non-existent/not functional or not up to the mark at most places, and are unable to treat micropollutants like heavy metals and pesticides. Large stretches of the Ganga, Yamuna, Damodar, Tapi, Betwa and Periyar rivers are polluted with both domestic sewage and industrial effluents being drained into them.

## DOMESTIC USE

Domestic use of water includes water for drinking, bathing, washing and other household purposes. This water comes from surface as well as groundwater sources. River water is increasingly becoming unfit for human consumption due to pollution, and this is leading to more and more exploitation of groundwater. There is no regulation on the digging of bore wells; anyone can dig them. As a result, groundwater levels are falling. In parts of Gujarat, they have fallen to around 240 to 275 m, with water levels dropping by 9 to 12 m a year.

Figure 4.3
Rapid drop in groundwater in Ahmedabad between 1960 and 1995




**Source:** 'Reviving Ancient Wisdom', Heritage Cell, Ahmedabad Municipal Corporation.

Domestic uses of water are related to issues of access, scarcity, tariffs and subsidies. In Delhi, on an average a person uses up to 400 l of water every day, whereas in nearby Najafgarh, it is less than 20 l. In metros like Delhi, nearly 15 to 20 l of potable water is used to wash one car. Less than 15 per cent of piped water is used for drinking and cooking purposes. The rest goes down the drain, including much from non-judicious use in toilets and bathrooms. Water amusement parks are mushrooming even where water is scarce.

The domestic water supply in urban areas is hugely subsidized. Studies indicate that just the operational and maintenance costs for water supply in cities are around Rs 15 per cu m. This does not include capital costs which are huge for a watersupply system. Consumers, however, are typically charged around Rs 1.5 per cu m, which is only about

a tenth of the operating and maintenance costs. Moreover, most cities do not have metered supplies of water. The unmetered customers pay an average fixed charge of around Rs 45 per month, while they might be consuming closer to 20 cu m per month, thus paying less than one-sixth of what they ideally should. This subsidy on water has led to non-judicious use of water.

On the other hand, about 40 per cent of the urban poor in India do not use either private or public taps, and hence do not benefit from the subsidy.

## Water Problems

As the examples given above reveal, the problems related with water are essentially those of quantity and quality. Both these problems are also related. For example, as the demand for and the use of water for various human activities increases, so does the generation of waste water. As the quality of water goes down, so does the supply of usable water.

### Water Quantity

The problems related with the quantity of water available are the result of two major discontinuities that have emerged in the management of water since the 19th century. One, the state has emerged as the main provider of water, replacing communities and households as the primary agents for the provision of water. Two, there has been growing reliance on the use of surface and groundwater. With the government taking up the role of providing water, communities have slowly abandoned their water-conservation practices and thus precious rainwater, which could well support the water use, is being wasted. Groundwater exploitation has been ever increasing, especially in the agricultural sector, primarily due to subsidies for power.

Water scarcity is a major problem both in rural and in urban India. Scenes of long queues in front of wells or water tankers and of women making day-long trips to collect water for the day's requirements are everyday stories in many states of the country. More than 70 per cent of the rural population does not have a water source within the house; millions still travel considerable distances to collect drinking water. The situation in drought-affected areas is much worse. In the Dahod district of Gujarat, to get a potful of water, women walk at least 3–4 km to a dry river bed. There they dig more than a metre-deep hole in the river bed. Then a woman is lowered into the hole. There is a long wait before enough water seeps into the hole to fill a small vessel, which is then passed out to the women waiting above. The muddy water is filtered through a fine cloth before being poured into a pot.

Figure 4.4
Drinking water availability in rural areas

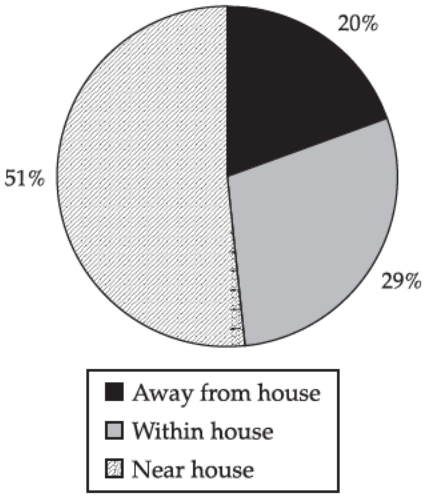
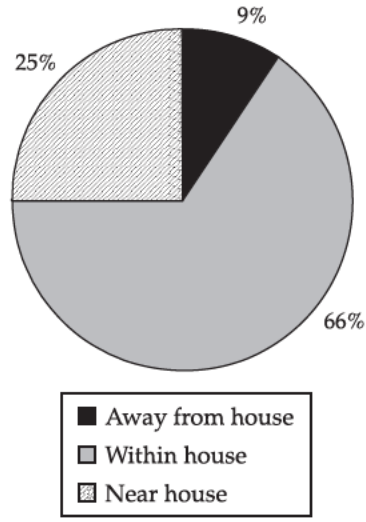



Figure 4.5
Drinking water availability in urban areas




**Source:** *Down to Earth*, Centre for Science and Environment, 31 May 2003.

TOO MUCH WATER—FLOODS: 'Too much water at the wrong place, or more water than can be handled by the drainage of the area' is how a **flood** may be defined. There are several other ways of describing a flood. A simple definition is: 'A flood is when water inundates land which is normally dry.'

Flooding occurs when there is prolonged rainfall over several days, intense rainfall over a short period of time, or an ice or debris jam which cause a river or stream to overflow and flood the surrounding area. Melting snow can combine with rain in the summer; severe thunderstorms can bring heavy rain in the monsoon season; or tropical cyclones can bring intense rainfall to the coastal and inland states.

*Human-induced causes of floods:*

**Deforestation:** The canopy, undergrowth and the root system in forests provide some protection from floods by trapping and absorbing precipitation. When these are cut down, heavy rainfall results in rapid run-off and causes soil erosion. This soil is carried by the water to rivers where it accumulates on the river bed, raising its level. This reduces the water-holding capacity of the river channel. The less water a river channel can hold, the greater the chances of a river overflowing its banks and flooding the surrounding areas. **Flood plains** are the areas bordering a river that are subject to flooding whenever the level of the river rises.

**Urbanization:** With growing population and urbanization, more and more area from flood plains is being reclaimed for the growth of cities. Faulty town planning is another factor in the rise in floods. Housing colonies often come up in low-lying areas which are

easily submerged even with moderate rains. Stormwater-drainage systems are either absent or often not adequately developed or maintained in urban localities, hampering quick clearance of rainwater, especially during heavy rains. In many Indian cities, stormwater drains are usually clogged with garbage, leaving no space for rainwater clearance. With nowhere to go, the rainwater flows onto the roads.

Wetlands (waterbodies like ponds, lakes or small water systems) which store or have huge potential to store rainwater or excess water from the rivers, are also increasingly being encroached upon and reclaimed due to urban growth. With the reduction in the number and extent of wetlands, the chances of floods are increasing.

**Construction of transport networks:** Human activities, such as blocking the natural drainage on flood plains by constructing roads, railways and buildings, increase the likelihood of floods and flood damage.

### Floods in India

India is the most flood-affected country in the world after Bangladesh. Most floods in India occur after the heavy monsoon rains. Rainfall in India is confined mainly to the south-west monsoon months of June to September. The rainfall is not even; it has spatial and temporal variations, causing drought in some parts of the country and floods in others. The all-India annual average rainfall is 1,170 mm, but in a given year, it varies from 100 mm in the western deserts to 11,000 mm in the north-eastern region. Fifty per cent of the precipitation takes place in about 15 days and in less than 100 hours altogether in a year. This means there is a lot of rain in a short period of time. If the rainfall is heavy, coupled with snow melts from the Himalayas, it causes floods in several states.

The seven most flood-prone states in the country are Uttaranchal, UP, Bihar, Jharkhand, West Bengal, Orissa and Assam. The *Rashtriya Barh Ayog* (National Flood Commission) has estimated the flood-prone area in the country at about 40 m ha. On an average, floods annually claim 1,600 lives and 95,000 heads of cattle and damage 1.2 million houses. The annual damage caused by floods is about Rs 13,470,000.

Too Little Water—Drought: Scarcity of water, which occurs due to inadequate rains, late arrival of rains and excessive withdrawal of groundwater, is referred to as **drought**. It is a period of unusually dry weather which persists long enough to produce a serious hydrologic imbalance, leading to crop damage and water shortage. The severity of the drought depends on the degree of moisture deficiency, the duration of the drought and the size of the affected area.

Droughts are classified into several different types. They are:

1. *Meteorological drought:* Occurs when the total amount of rainfall received in an area is less than 75 per cent of the normal rainfall. The departure from normal rainfall is usually defined by comparing the current situation to the historical average of the place,

often based on a 30-year period of record. The drought is said to be severe if the rainfall is less than 50 per cent of the normal rainfall.

2. *Hydrological drought:* This drought is associated with the effects on surface (stream or river flow, reservoir and lake levels) and sub-surface (groundwater) water supply due to less rainfall. It takes some time for rainfall deficiency to show up in the components of the hydrological system such as soil moisture, stream flow, and groundwater and reservoir levels. Thus, there is a lag between the occurrence or the impact of hydrological drought and the occurrence of meteorological and agricultural droughts.

3. *Agricultural drought:* This drought links various characteristics of meteorological and hydrological droughts to agricultural impacts. Overall rainfall shortage as well as the timing of the rain affects agriculture. Reduced groundwater or reservoir levels, less soil moisture, etc., adversely affect agricultural output. Agricultural drought also depends on the susceptibility or tolerance of the cropped plant to deficiencies of water.

4. *Socio-economic drought:* This drought occurs due to a reduction in the availability of food and social security of the people in the affected areas.

A drought can result in famine, which occurs when a large-scale collapse of access to food occurs. Without intervention, this can lead to mass starvation.

While a meteorological drought occurs due to climate and weather conditions bringing less rain, the effects of a meteorological drought are compounded by human activities. Deforestation is a big culprit in inducing a hydrological drought. Trees help in facilitating the percolation and storage of groundwater, and when they are removed, the soil can no longer retain water. This affects the recharge of groundwater and depletes soil moisture, making the land parched and dry.

Low or no rainfall during the cropping season has its adverse impacts on agriculture. But the impact also depends on the cropping pattern. More and more water-intensive crops like sugar cane are now grown even in regions which have a historical record of low to medium rainfall. This heightens the chances of an agricultural drought. Farmers grow high value cash crops to earn more money, but a deficient rainfall may ruin their entire crop, which may have been avoided if the crop had been less water intensive.

### Droughts in India

Nineteen per cent of India's total area is drought prone. Till very recently, the Indian Meteorological Department declared a drought in the meteorological divisions where the annual rainfall was less than 75 per cent of the normal; but since April 2003, the criteria have been revised to declare a drought wherever the rainfall is less that 90 per cent of the normal. Severe drought is declared in years when rainfall is 50 per cent below normal.

The yearly average of rainfall does not always accurately indicate the real situation during different parts of the year. While there may not be a meteorological drought if the average yearly rainfall is good, there may have been less rains during the cropping season, which would result in an agricultural drought. This presents a problem while declaring a district as drought affected, even though the area may be facing the serious effects of drought.

### A good drought!

P. Sainath, an eminent journalist, in his award-winning book *Everybody Loves a Good Drought* quotes the occurrence of drought and the 'drought relief' it bestows upon an area declared as drought-affected as *teesri fasal* (the third crop). Though the relief schemes of the government are meant for areas affected by scarcity and for the poor, it is not they who benefit the most from the schemes. Contractors, middlemen and a number of other functionaries are the ones who get most out of the relief operations.

There is always a hurry and eagerness to declare more and more areas as drought affected, because that would mean more governmental and other supporting schemes coming into play. Some of the top few districts that are constantly reported as drought affected—and for even starvation deaths—are not necessarily the ones which receive below normal rains. For example, Kalahandi in Orissa or Palamau in Bihar or Surguja in MP, are some places that are always in the news for their drought miseries.

Do these districts really receive less rainfall? Most districts in India receive an average of 800 mm rainfall annually, which is more or less sufficient for different uses. The lowest rainfall that Kalahandi has had in the past 20 years is 978 mm. This is well above what some districts get in 'normal' years. Otherwise, Kalahandi's annual rainfall on an average has been 1,250 mm. Besides, the average food produced per person in Kalahandi is higher than the state and national averages. In Palamau also, the average rainfall is 1,200 to 1,300 mm in a normal year. Surguja's annual rainfall seldom falls below 1,200 mm. In some years it gets 1,500 to 1,600 mm.

So inadequate rainfall is not the problem. What is crucial is defining an area as really suffering from drought, and not just 'drought-affected', is the management of the water, along with issues of land use, cropping patterns, the public distribution system, etc.

India has faced droughts in 1966–67, 1972–73, 1979–80, 1986–87, 1996–97 and 2001–02. In each instance, food production fell below the national average. There were large-scale losses due to starvation, depletion of assets and livestock, etc. In 1987, 267 districts and 166 million people were affected by drought.

While food-grain stocks built up over the years have meant that there are no more famines in the country, drought still plays havoc with the livelihoods of thousands of farmers and other workers in rural areas. The government's relief measures like 'food for work' programmes in the drought-affected areas are temporary and provide only interim relief. Long-term programmes for drought-proofing, like watershed management and rainwater harvesting, could help in alleviating the situation on a long-term basis.

### Shortage amongst plenty

Cherrapunji was once the wettest spot on earth. Over the last decade or so, the mixed natural forests in the upper catchment areas have been slowly destroyed. There are no forests to hold water in the slopes and this makes most of the 12,000 mm of annual rainfall quickly run-off downstream, where it causes floods. And in Cherrapunji, soon after the monsoon, the springs and rivers dry up, resulting in drought and even acute drinking-water shortages.

In the Himalayan foothills, three decades of limestone quarrying has destroyed the forests, and perennial mountain streams have either dried up or have become seasonal. In Saurashtra, limestone mining from natural aquifers for the several cement factories has resulted in the ingress of saline sea water as well as an increase in desertification.

## WATER QUALITY

WHAT IS WATER POLLUTION? Water pollution may be defined as the introduction into a waterbody of substances of such character and in such quantity that the natural quality of the waterbody is altered. This alteration impairs its usefulness, affects the health of living organisms or renders it offensive to the senses of sight, taste or smell. Water pollution includes surface water pollution (rivers, lakes, ponds), groundwater pollution and marine pollution. (See chapter on Pollution for a listing and description of some of the common types of water pollutants.)

Contamination of both groundwater and surface water sources due to widespread municipal sewage and industrial pollution is commonplace in the country.

### Eutrophication

The introduction of untreated or partially treated sewage into a waterbody could lead to an increase in the amount of organic matter in it. The decaying organic material provides nutrition for the growth of algae and other aquatic plants. This accumulation of excess nutrients is called eutrophication. Eutrophication also occurs when excess fertilizer nutrients (mainly nitrogen and phosphorus) accumulate in a waterbody. Eutrophication usually results in an overgrowth of phytoplankton (small plant algae). Once these die, they begin to decompose. Their decomposition causes the depletion of dissolved oxygen, which is very important for the life of fish and other aquatic life. This may ultimately lead to the death of fish and other aquatic organisms due to suffocation.

SURFACE WATER POLLUTION: Surface water gets polluted by wastes disposed from human settlements and industries; agricultural run-off; and also natural sources like the addition to waterbodies of soil, plant and animal debris after a heavy downpour. Discussed here are some of the sources of surface water pollution and associated problems.

*Domestic sewage pollution:* Sewage and municipal effluents account for 75 per cent of the pollution load in rivers, while the rest can be attributed to industrial effluents and other sources like agricultural run-off. Large towns and cities situated along the river course discharge millions of litres of sewage into the rivers every day. Treatment facilities are non-existent or inadequate. It is reported by a World Bank study that, in India, out of the 3,119 towns and cities, only 209 have partial and just eight have full sewage treatment facilities.

Domestic sewage leads to biological contamination of the water by a variety of disease-causing micro-organisms. When the source of drinking water is contaminated, it may cause serious health problems, and water-borne diseases, like cholera, gastroenteritis, typhoid, etc., some of which can prove fatal.

Diseases from contaminated drinking water

| Type of organism | Disease | Symptoms |
|---|---|---|
| Bacteria | Typhoid | Diarrhoea, severe vomiting, enlarged spleen, inflamed intestine; often fatal if untreated |
| | Cholera | Diarrhoea, severe vomiting, dehydration; often fatal if untreated |
| | Bacterial dysentery | Diarrhoea; fatal in infants without proper treatment |
| | Enteritus | Severe stomach pain, nausea, vomiting; rarely fatal |
| Viruses | Infectious hepatitis | Fever, severe headache, loss of appetite, abdominal pain, jaundice, enlarged liver; rarely fatal but may cause permanent liver damage |
| Parasitic protozoa | Amoebic dysentery | Severe diarrhoea, headache, abdominal pain, chills, fever; if not treated can cause liver abscess, bowel perforation and death |
| | Giardia | Diarrhoea, abdominal cramps, flatulence, belching, fatigue |
| Parasitic worms | Schistosomiasis | Abdominal pain, skin rash, anaemia, chronic fatigue, and chronic general ill health |

*Industrial effluents:* Industries use water for many purposes, such as processing, cooling, and the treatment of materials at various stages of production. During these processes, the water may become polluted. Sometimes waste water may be a by-product

of the industrial process. Such polluted water released by industries may directly or indirectly reach waterbodies.

All major rivers in the country are being polluted by unchecked industrial effluents being discharged into them. There are norms specified for the treatment of industrial waste water before it is discharged into rivers or other waterbodies: but without enforcement, the pollution continues unabated at most places.

### Deadly Damodar

The 563 km long Damodar river flows through six districts of Jharkhand, before entering West Bengal and joining the Hooghly river. One hundred and eighty-three coal mines, 28 iron ore mines, 33 limestone mines and 84 mica mines draw water from the river and drain into it. A variety of industries—coal washeries, coke-oven plants, the country's major iron and steel plants, thermal power plants, glass and cement plants and fertilizer and chemical factories—seriously pollute the river. A total of about 6,000 mn l of mostly untreated industrial waste water flows into the river every day. This does not include the waste water discharged from mine-based activities and untreated sewage from towns and cities along the course of the river.

Some estimates put the daily outfall of effluents at 60 tonnes of organic load, 2 tonnes of non-metallic toxins and 1.2 tonnes of toxic metal substances. Mining and industrial effluents generally carry high suspended solids in the form of fine coal particles and fly ash. Highly toxic substances like phenol, cyanides and heavy metals are found in these effluents.

The Central Pollution Control Board, in a report in 1998, classified the Damodar under the heavily polluted category. This means that its water is totally unsafe for human consumption and can hardly support much aquatic life. Yet, many of the cities, such as Dhanbad and Jharia, have no other source of drinking water, except for groundwater which is also contaminated.

The problem of industrial water pollution occurs when inadequate measures are adopted for effluent or waste-water treatment. The major water-polluting industries in India include leather, pulp and paper, textiles and chemicals. When these industries dump their wastes without adequate treatment into waterbodies, they introduce a wide variety of pollutants—both inorganic and organic—which are not biodegradable. Various pollutants—solvents, oils, plastics, metallic wastes, suspended solids, phenols, and various chemical derivatives of manufacturing processes—cannot be removed from the water easily with the available technology, thereby making the water unfit for human applications.

Certain metals like zinc, copper, chromium, tin, and particularly heavy metals like arsenic, cadmium, lead and mercury, are widely used in industries, especially in metal-works and in processes related to batteries and electronics. These metals are also used in the manufacture of certain pesticides, medicines, paints and pigments, glazes, inks, etc. The wastes from such industries would usually have a high amount of these materials.

These are extremely toxic as ions. When present in certain water-soluble compounds, they may enter the aquatic food chain. In humans, even small amounts of these can cause severe physiological (including neurological) problems. For example, lead poisoning is known to cause mental retardation, and mercury poisoning causes insanity and crippling birth defects.

The Minamata story

The long-term and indirect effects of chemical pollution are best illustrated by the Minamata story. When people near the Minamata Bay in Japan began suffering from a mysterious disease, the culprit was traced to mercury. A chemical factory was releasing waste products high in mercury into the stream leading to the bay. The mercury accumulated in shellfish and other fishes, which were eaten by the local inhabitants. Over the years, hundreds of people died and many were paralyzed for life. The other effects included impairment of vision and hearing and neurological problems. Prenatal poisoning of foetuses was observed, even when the mothers did not show any visible symptoms.

Another pollutant from industries, especially power plants, is the heat (a by-product of industrial activity) that is released into waterbodies. This heat causes not only direct harm to life forms, but may also catalyze chemical reactions between the various chemicals that are already present in the waterbody. This unnatural heating can also cause disturbances in the natural life cycles of aquatic organisms.

Tirupur, an industrial town in Tamil Nadu heavily engaged in the hosiery industry, is facing a water crisis due to the contamination of its groundwater sources. Its dyeing and bleaching industry uses more than 90 mn l of water a day and then discharges the same amount as effluents, mostly untreated, into the non-perennial Noyyal river. The river has become a cocktail of dyes—red, yellow, brown and black. The groundwater within an estimated 10 to 20 km radius from Tirupur is not potable.

Stories like these abound in the whole country, especially in the industrial zones. In Gujarat, of the total water used by industries, 80 per cent comes from groundwater sources. Most of this is discharged without treatment, polluting fresh water and groundwater sources. Thus, water treatment and the recycling of industrial waste water need to be addressed much more effectively.

Water pollution is mainly due to sewage and industrial wastes. Having a proper sewage-treatment system and the treatment of industrial effluents before they are discharged into a waterbody are a few of the steps that can be taken to reduce surface water pollution.

*Agricultural run-off:* Since the beginning of the Green Revolution large quantities of chemical pesticides and fertilizers are being used to increase the yield of the crops. Excess fertilizers or pesticides remain in the soil. Traces of these fertilizers and pesticides are washed into the nearest waterbody when it rains or with irrigation waters. As

rivers are the primary source of drinking water in most Indian cities, their contamination means contaminated drinking water. River waters have been found to be contaminated with pesticides like DDT, aldrin and dieldrin, which are very harmful for human and ecological well-being. It is important to minimize the use of fertilizers and pesticides, as any kind of treatment is not possible for this non-point pollution.

GROUNDWATER POLLUTION: Water pollution is not restricted to surface water alone. There have been cases where the groundwater is found to be contaminated. Solid-waste dumping is one cause of groundwater pollution. Various kinds of harmful materials (chemicals, metals, etc.) present in the solid waste may get dissolved or leached into the water. The pollutants dissolved in the water percolate down into the soil and contaminate the groundwater. Industrial effluents that are dumped into underground tanks or wells, or allowed to spill on to the ground, can also pollute groundwater. This is a serious problem as groundwater is one of the main sources of drinking water.

### Bichhri's woes

In Bichhri, a tiny village in Rajasthan, during the early 1990s, villagers realized that the water in their wells was brown, coal-like in colour and no longer usable. For more than a decade an acid-manufacturing factory had been dumping its waste near Bichhri. The groundwater became replete with iron salts that had leached down from the dump site years earlier. These gave the local groundwater its peculiar brown tint and made it totally unfit for consumption. In 1997, the Supreme Court shut down the polluting factory and ordered compensation for the villagers. The court also instructed the Ministry of Environment and Forests to assess the damage. But the situation has far from improved because other zinc smelters are also contaminating other wells.

*Natural contaminants of groundwater:* Underground rocks in many areas in the country have high levels of certain metals or compounds. Sometimes a change in the water level, such as by digging deeper for water, can cause the contamination of water by natural sources. One such contaminant in several parts of India is fluoride. Though necessary for humans in small amounts, according to WHO, fluoride can be harmful in amounts more than 1.5 parts per million (ppm). Prolonged exposure to fluoride exceeding this maximum contamination level (MCL ) can cause skeletal fluorosis, a serious and crippling bone disorder. Children exposed to levels of fluoride over 2.0 mg/l for an extended period of time may develop dental fluorosis, a brown staining or pitting of their permanent teeth.

The people of Mandla, a fluoride-rich area in Madhya Pradesh, abandoned conventional shallow wells for bore wells with depths of over 45 m to draw more water. While 10 to 20-m deep conventional wells are safe, the water in bore wells with depths of over 43 m has a high fluoride content. Many of Mandla's children now have symptoms of fluorosis, which include deformed teeth and skeletons. In Rajasthan's Dungarpur

district, drinking-water sources contain 2 to 8.5 ppm of fluoride. Over 93.5 per cent of the people of the 157 villages in the district suffer from dental fluorosis. The disease affects about 100,000 of the state's population.

Another contaminant which has emerged as a major threat to human health, particularly in West Bengal, is arsenic. It may be found in water which has flowed through arsenic-rich rocks. Long-term exposure to arsenic via drinking water causes cancer of the skin, lungs, urinary bladder and kidneys, as well as changes in skin pigmentation and its thickening. In West Bengal, about 1,000 villages in eight districts are affected by the problem of arsenic-rich groundwater. This could mean around 40 million people in the state are drinking arsenic-contaminated water every day. Experts believe that over-exploitation of groundwater has a direct link with the arsenic contamination of aquifers. According to some researchers, as the groundwater level dips, the arsenic-laden subterranean rocks come in contact with air and get decomposed, releasing more arsenic in the process.

Unlike flowing surface water, groundwater is unable to cleanse itself of degradable wastes because groundwater flows so slowly that it cannot disperse or dilute the contaminants effectively. Groundwater is also much colder than surface water and this slows down the chemical reactions that decompose wastes. Groundwater aquifers are also difficult to clean because of their enormous volume and inaccessibility. So the best way to protect groundwater resources is to prevent contamination.

Quality of Drinking Water: The quality of water is an important criterion which influences its use and effects. Drinking-water quality should be such that it is pure, i.e. without any contaminant or pollutant, and wholesome, i.e. it provides the necessary nutrients. Drinking-water sources, both surface and groundwater, are often contaminated. While surface-water pollution occurs due to the discharge of domestic sewage, agricultural run-off and industrial effluents, groundwater can be contaminated naturally or it may also be polluted due to the downward seepage of pollutants from the surface.

Drinking water quality standards or specifications have been established by agencies such as WHO and UNICEF. In India, the Bureau of Indian Standards has specified the criteria for drinking-water quality. Some of the important criteria are given in Table 4.2.

Table 4.2
Specifications for drinking water quality

| *Characteristics* | *Maximum permissible limits* | *Adverse effects beyond permissible limits* |
|---|---|---|
| Colour (hazen units) | 10 | Consumer acceptance decreases |
| Odour | Unobjectionable | |
| Taste | Agreeable | |
| Turbidity (NTU) | 10 | Consumer acceptance decreases |
| T.D.S. (mg/l) | 500 | Palatability decreases, may cause gastrointestinal irritation |

*(continued)*

*(continued)*

| *Characteristics* | *Maximum permissible limits* | *Adverse effects beyond permissible limits* |
|---|---|---|
| pH value | 6.5 8.5 | Mucous membrane affected |
| Total hardness as ) $CaCO_3$ (mg/l | 300 | Encrustation and adverse effects on domestic use |
| Copper as Cu (mg/l) | 0.05 | Astringent taste, discolouration and corrosion of metallic parts |
| Iron as Fe (mg/l) | 0.3 | Taste and appearance affected, promotes iron bacteria |
| Fluoride as F (mg/l) | 0.6 1.2 | Low fluoride cases are linked with dental caries. Above 1.5 p/m causes fluorosis |
| Mercury as Hg (mg/l) | 0.001 | Toxicity* effects |
| Arsenic as As (mg/l) | 0.05 | Toxicity effects |
| Lead as Pb (mg/l) | 0.1 | Toxicity effects |
| **Coliform organisms** | | |
| Coliform bacteria, which inhabit the lower intestines of mammals, while not pathogenic themselves, are taken as an index of contamination of watercourses | Throughout any year, 95 per cent of samples should not contain any coliform organisms in 100 ml<br>No sample should contain more than 10 coliform organisms per 100 ml<br>Coliform organisms should not be detectable in 100 ml of any two consecutive samples<br>No samples should contain *Escherichia coli* in 100 ml | |

**Source:** Indian Standard Specification for Drinking Water IS:105000 1983.
**Note:** *Toxicity here refers to the adverse effects that the high concentration of the metal causes to various body systems and processes.

Many diseases like cholera, typhoid, jaundice, malaria, diarrhoea and dysentery, and many other gastrointestinal problems are directly linked to drinking-water contamination. In India, more than 1,000,000 children died due to diarrhoea and other gastrointestinal disorders in the decade from 1990 to 2000. Water-borne diseases account for nearly one-third of all deaths in the world. Thus, it is very important that the drinking water is clean and pure.

## MEASURING WATER QUALITY

Surface water bodies also support considerable aquatic life, and there are other significant parameters of water quality that influence the biota in the waterbody. The most common and measurable parameters for measuring water quality are biochemical oxygen demand (BOD), dissolved oxygen, coliform organisms, besides the concentration of some other gases and elements in the water. BOD is a measure of water pollution based on the organic material it contains. The organic material provides food for aerobic bacteria which require oxygen to be able to bring about the biodegradation of organic material. The greater the volume of organic material and the greater the number of bacteria, the greater will

be the demand for oxygen. Thus, the BOD value gives an indication of organic pollution levels in water. If BOD exceeds the available dissolved oxygen in the water, oxygen depletion occurs and aquatic organisms suffer.

## Towards Solutions

The best way to deal with the problem of water pollution is to shift from thinking about cleaning up pollution to *preventing* pollution. However, to clean up polluted water to make it fit for drinking, certain technological solutions are commonly in use. Similarly, waste water, whether it is domestic sewage or industrial effluent, can also be treated so as to render it safe for disposal in any waterbody like a river or a lake.

### Treatment of Drinking Water

**Filtration** is the first step in purification. Through this process, suspended particles causing turbidity are removed. Organic and inorganic contaminants are removed by a process called **softening**. Chemicals like calcium hydroxide (slaked lime) and sodium carbonate (soda ash) are used for removing salts dissolved in the water. Softening must be followed by **sedimentation** and filtration in order to remove the precipitates. Water is then disinfected by **chlorination**, to remove disease-causing bacteria. The appropriate dosage of chlorine in the form of sodium hypochloride is administered to the water to disinfect it.

Disinfection can also be achieved through solar radiation. Solar-water disinfection has been found to be effective in treating small quantities of drinking water at the household level. The UV rays in sunlight kill the disease-causing organisms. But as the intensity of radiation decreases with the increase in depth, in order to allow sufficient solar radiation to kill the microbes in water, the depth should be small and should not exceed 10 cm. An efficient, inexpensive and simple method which can be followed by anyone is to place bottles of water in bright sunlight for about 6 hours.

### Waste-water Treatment

Waste-water treatment involves three stages: primary treatment, secondary treatment and tertiary treatment.

**Primary treatment** is the physical removal of floatable and settleable solids present in the waste water. The processes adopted include:

1. Screening—to remove large objects, such as stones or sticks.
2. Grit chamber—a chamber or tank used in primary treatment where heavy, large solids (grit) settle down and are removed.

3. Sedimentation tank (settling tank or clarifier)—settleable solids settle and are pumped away, while oils float to the top and are skimmed off.

**Secondary treatment** involves the biological removal of dissolved solids. It utilizes biological treatment processes in which micro-organisms convert non-settleable solids to settleable solids. Sedimentation typically follows, allowing the settleable solids to settle. In many domestic sewage plants the water is discharged after secondary treatment, but whenever there are more chemicals in the waste water, it must be subjected to tertiary treatment.

**Tertiary treatment** may include processes to remove nutrients such as nitrogen and phosphorus, and carbon adsorption to remove chemicals. These processes can be physical, biological, or chemical.

### River action plans

About one-third of India's population living in urban towns is served by the Ganga waters. The Ganga Action Plan (GAP) initiated in 1985, was envisaged to improve water quality, permit safe bathing all along the 2,525 km stretch of the Ganga from the Himalayas to the Bay of Bengal, and make the water potable at important pilgrim and urban centres on its banks. In Phase I, the main task was to intercept and treat 873 mn l of waste water from 25 cities and towns in the states of Uttar Pradesh (then including Uttaranchal), Bihar (then including Jharkhand) and West Bengal. Phase I was to be completed by March 1997, but it was later extended as GAP Phase II till March 1999 and included 29 towns and cities. Later, the Yamuna Action Plan, the Damodar Action Plan and the Gomti Action Plan were added to include the tributaries of the Ganga. The National River Conservation Plan, launched in 1995, expanded the scope to include all the rivers in the country.

Though the water quality of the Ganga improved due to GAP, it was not enough. Studies indicate that though some parameters like DO and BOD have improved which would not have been possible if there had been no effort to reduce pollution, the programmes have not been able to achieve what they were really meant for. There is not much perceptible difference in the water quality; the dark colour and bad odour are still there and the water can hardly be used without treatment. The plans did not ensure the long-term sustainability of the treatment plants as they did not indicate who would pay for the plants in the long run. In many of the states, power is erratic; the facilities which are power-dependent lie under-utilized. River-cleaning processes are very long term and complex: perhaps the years to come may show the results that were expected from the action plans.

## Conservation and Management of Water

Considering how little water is actually available for use, conservation of water and efficient management of water sources is more critical than ever before. This requires a combination of technology, traditional, modern or both, and good practices. Several parts

of India lie in arid or semi-arid regions, where people over the centuries developed ways of catching and storing every drop of rain that fell on land, and using this precious resource judiciously. Today, many of these traditional systems of water management and use, which were governed by strict codes of conduct, have died out or been eroded. In view of the water crises being faced today, efficient water management requires the revival of some of these systems and practices through the increased participation of people everywhere. The following case study is an example of a community-based effort to revitalize traditional water-conservation practices, as well as to work collectively for new systems of water management at the local level.

## Reviving *Johads*: A Success Story

The Alwar district in Rajasthan is classified as a semi-arid region. It has a meagre average annual rainfall of 620 mm, and drought is a recurrent feature. In the early 1980s, with the pressures of population, increased consumption and overall environmental degradation, the water situation became worse. The district was officially declared by the Government of Rajasthan as a 'dark zone', an area where the groundwater table has receded below recoupable levels.

In 1985–86, a severe drought hit the region adding to the already bleak situation of vanishing livelihoods and mass migration. Into this grim scenario entered a team of dedicated volunteers from the Tarun Bharat Sangh (TBS), a voluntary non-governmental organization. The TBS volunteers were convinced that one of the ways to improve the situation would be to revive traditional practices, especially the *johad* (an earthen bund or check dam to conserve rainwater), that had sustained Alwar and its populace in the past. But initiating a dialogue with the villagers and convincing them to take part in the revival was not an easy task. The volunteers decided that the best way to do this was to practise rather than preach. They themselves started digging to revive an already existing *johad* in one village, Gopalpura. Their hard work and patience paid off. The villagers began participating in discussions and gradually became involved in the process.

The TBS activists evoked a sense of commitment and involvement in the community. To spread the movement in the entire area, the TBS organized *Pani Yatras* (water tours). Every year these *yatras* of about one and a half months would travel extensively, to share the experiences of water harvesting. The goal was to involve at least a hundred more villages in this work. The march carried the message of harvesting rainwater and saving forests by using traditional systems and knowledge. Today, there are more than 4,000 *johads*, which are totally managed by the community and have come to be regarded as community or village property. In many cases, the villagers have contributed around 90 per cent of the total cost. The role of the TBS has been that of a catalyst and motivator.

The perceptible changes brought about by building *johads* have been no less than a miracle. The wells have been recharged and water supply ensured for the entire year to

meet the needs of the people and livestock. The effect has been evident in many areas, in increased food production, in soil conservation and in increased biomass productivity. It has even brought back to life two rivers, the Aravari and the Ruparel. These were once perennial but had nearly disappeared during the drought in the 1980s. Now they are perennial again.

Wastelands that were sparsely cultivated earlier are now cultivated with higher cropping intensity. These efforts have transformed an officially 'dark zone' into a 'water-surplus zone'. The revival of traditional harvesting systems in Rajasthan is one example among several such initiatives undertaken all over the country, especially in the drought-prone regions of Gujarat, Maharashtra, Andhra Pradesh, Orissa and Karnataka.

### Johad: A technological marvel

Technologically, *johads* are simple structures—earthen check dams designed to capture rainwater. But their unique feature is that they have been built entirely with local traditional knowledge and the experience of the villagers. No 'qualified' engineer has been involved in their construction. Starting with site selection, design and execution, they have been managed by *gajdhars* or traditional rural engineers. These *gajdhars* have no formal degree, but are carriers of traditional knowledge and skills, which are so perfect that even modern technologists marvel at their systems. Mr G.D. Agrawal, the former head of the civil engineering department at the Indian Institute of Technology, Kanpur, who assessed the water-harvesting structures in these areas found them not only structurally adequate but also built at very low cost. The *johads* have withstood the test of adverse natural conditions, like intense rainfall, and have not failed, unlike some other structures designed by qualified engineers.

## RAINWATER HARVESTING

**Water harvesting:** This is one of the main techniques of conserving water, one which has great potential to solve the water crisis all across the globe. Water harvesting means the delib-erate collection and storage of rainwater that runs off on natural or man-made catchment areas. Catchments include rooftops, compounds, rocky surfaces or hill slopes or artificially prepared impervious/semi-pervious land surfaces. The amount of water harvested depends on the frequency and intensity of rainfall, catchment characteristics, water demand and how much run-off occurs.

Rainwater harvesting is neither energy-intensive nor labour-intensive, thus making it an eminently feasible alternative to other water-accruing methods, such as desalination of sea water or the contentious, much discussed issue of interlinking rivers.

India has an enormous amount of water that can be captured directly as rainwater or as run-off from small catchments in and near villages or towns. Even if 15 per cent of the total run-off can be captured through rainwater harvesting, tremendous pressure can be

taken off the country's groundwater and surface water resources, and the availability of clean water can be greatly extended.

Rainwater harvesting is an age-old practice. Water harvesting measures were highly developed in ancient Indian civilizations. There is evidence that even during the Harappan period, there was very good system of water management, as can be seen in the excavations at Dholavira in Gujarat.

***Kunds* in Rajasthan:** In many parts of Rajasthan, an ingenious system of rainwater harvesting known as *kunds* or *kundis* had evolved over the centuries. The *kund*, the local name given to a covered underground tank, was developed primarily for tackling drinking-water problems. The *kund* consists of a saucer-shaped catchment area with a gentle slope towards the centre where a tank is situated. Openings or inlets for water to go into the tank are usually guarded by a wire mesh to prevent the entry of floating debris, birds and reptiles. The top is usually covered with a lid from where water can be drawn out with a bucket. The first known construction of a *kund* in western Rajasthan was in AD 1607 by Raja Sursingh in the village Vadi-ka-Melan. During the Great Famine of 1895–96, the construction of *kunds* was taken up on a wide scale. The proximity of a *kund* to the house or village saved time and effort in searching for drinking water. Without a *kund*, households in many parts of the Thar would have had to make a 10 to 15 km round trip by donkey, camel or bullock cart, to meet their water needs.

***Tankas* in Gujarat:** Rainwater harvesting and storage for individual houses is also an old practice. Old houses in Gujarat had water-storage tanks called *tankas*. Rainwater from the roof was drained during the monsoon months and diverted to these underground *tankas*. Water from these *tankas* was then used in the summer months when there was scarcity of water. Although *tankas* still exist in most of the old houses, the practice of storing water is dying out. With most new houses being built without the provision of rainwater harvesting, the traditional wisdom is slowly dying out.

**Temple ponds:** In South India, ponds or tanks were built in temple compounds to store water. During the water-scarce season, water from these tanks was utilized by the community.

With water scarcity being a problem in all big cities today, various methods have been developed and tried out for rainwater harvesting in urban buildings. Rainwater is directed from roofs or other surfaces, such as roads, to an underground tank, well, or percolation pit. The pit carries the water to the aquifer to be recharged.

The potential of water harvesting in meeting household needs is enormous. According to some estimates, there is no village in India which cannot meet its drinking water needs through rainwater harvesting. Some calculations also show that, if rain was captured in the area of Delhi alone, there would be enough clean water to meet the drinking water needs of every individual in India!

### Oceans

Oceans cover more than 70 per cent of the earth's surface. This is why the earth is also called the blue planet. These oceans play a key role in the survival of life forms on earth. They serve as a gigantic reservoir for carbon dioxide, thus helping in regulating the temperature of the troposphere. Oceans provide habitats for about 250,000 species of marine plants and animals which are food for many organisms, including human beings. They also serve as a source of iron, sand, gravel, phosphates, magnesium, oil, natural gas and many other valuable resources. The oceans, because of their size and currents, mix and dilute many human-produced wastes flowing or dumped into them, to less harmful or even harmless levels, as long as they are not overloaded.

**What oceans do for us**

Oceans plays a vital role in the water cycle; they supply us with rain, food, and help to regulate our climate. Oceans help to regulate the greenhouse effect—billions of tiny plants called phytoplankton absorb the greenhouse gas carbon dioxide and release oxygen—thus helping to balance the carbon dioxide and oxygen. But these oceans are threatened by human activities directly or indirectly; by activities that take place on the land and in the water.

**Threats to oceans**

Industries in coastal areas discharge their untreated effluents into the sea through waste water, canals, drains, creeks, etc. Pesticides and herbicides used in the fields contain persistent organic pollutants; their toxic chemicals find way through the washed away silt and irrigation water and finally into the ocean. Sewage contains heavy metals, man-made chemicals and organic wastes, all of which ultimately find their way into the ocean. The toxic chemicals released through all these lead to the problem of biomagnifications, and subsequently the creatures of the food chain are affected.

## GOVERNMENT INITIATIVES

The constraints of water availability and the variety of uses warrant good water management. The Government of India has framed a National Water Policy to address the variety of issues related to water in the country. The water policy states that planning and development of water resources need to be governed by national perspectives. Thus, water allocation is one of the important issues to be addressed. Special attention needs to be given to equitable access to water, with emphasis on the marginalized and weaker sections of the society. Effective water management including conservation and protection of water sources is part of the water policy.

The government has initiated a number of programmes to protect and conserve water. Some of the laws, policies and programmes related to water management are:

**The Water (Prevention and Control of Pollution) Act (1974):** This act establishes an institutional structure for preventing and abating water pollution. It establishes standards for water quality and effluent. Polluting industries must seek permission to discharge effluent into water bodies. The Central Pollution Control Board (CPCB) was constituted under this act.

The CPCB along with the State Pollution Control Boards has set up a water quality monitoring network with 480 sampling stations throughout India. Regular monitoring visits to industries to check pollution are organized by the Pollution Control Boards. The Boards now have the power to disconnect the electricity and water connections of industries which flout pollution standards.

**The National River Conservation Plan (NRCP):** After the Ganga and Yamuna Action Plan in the late 1980s and early 1990s, it was decided that other rivers should be included in such programmes. The National River Conservation Plan was launched in 1995 to cover 18 major rivers in 10 states of the country. Under this action plan, pollution abatement works are being taken up in 46 towns in the states of Andhra Pradesh, Bihar, Gujarat, Karnataka, Maharashtra, Madhya Pradesh, Orissa, Punjab, Rajasthan and Tamil Nadu. About 1928 mn l per day (mn l/d) of sewage is targeted to be intercepted, diverted and treated. A National River Conservation Authority has also been set up under the Chairmanship of the Prime Minister to oversee the river conservation plans.

**The National Lake Conservation Plan (NLCP):** On the recommendations of the National Committee of Wetlands, Mangroves and Coral Reefs, a programme for the conservation of 21 urban lakes was formulated. Large-scale conservation activities have been taken up in selected urban lakes which are highly degraded due to pollution, encroachments and habitat degradation. Apart from these programmes, wetland conservation and watershed management have also been given priority by the government.

**Watershed Management Programmes:** Historically, the Drought Prone Areas Programme (DPAP) and the Desert Development Programme (DDP) have looked into the problems of drought and water scarcity. Both these programmes, along with the Integrated Wasteland Development Programme, were brought under the watershed approach and were included under the Guidelines for Watershed Development from 1995 onwards. These guidelines take a holistic view of the problems of water scarcity and emphasize the development of watersheds on a local scale with local participation. Roof-water harvesting is also being stressed to augment water availability. The authorities in Delhi and Chennai have made it mandatory for new houses to install roof-water harvesting structures.

## TOWARDS A SUSTAINABLE FUTURE

To ensure that we find sustainable solutions to our problems of water availability and quality, in addition to making use of appropriate traditional and modern technologies and practices, government policies and laws, appropriate incentives and disincentives, our emphasis must be on *preventing* water wastage and pollution and ensuring equitable access to water, and the active participation of the community in managing and making decisions about their water resources.

### I QUESTIONS

1. Explain the terms:
   Precipitation
   Transpiration
   Water table
   Aquifer
   Watershed

2. Match the following:

| | |
|---|---|
| A. Meteorological drought | a. affects soil moisture, stream flow, groundwater level. |
| B. Hydrological drought | b. affects output of food |
| C. Agricultural drought | c. affects availability of food |
| D. Socio-economic drought | d. occurs when rainfall received is less than 75 per cent of the normal rainfall |

3. The amount of water on the earth is same as it ever was or ever will be. Is this statement true? If yes, then why are we facing water scarcity everywhere? Are there any threats to the water cycle? If yes, explain.
4. What are the causes and effects of flooding? Does flooding occur in some parts of your town/city? Why? If your region or zone is at risk, what steps will you take to reduce damage and the risk of injury or loss to society?
5. What is the difference between drought and famine?
6. What efforts have been taken to clean up the Ganga? Why have the efforts not been successful? What would you do differently if you were made responsible for cleaning up the river?

## II EXERCISES

1. Study the following table. Which are the most drought-prone parts of the country? Plot them on an outline map of India. What could be the possible reasons for the occurrence of frequent drought in these areas? Which kind/kinds of drought occur there most often, and why? Are any of the areas listed in the table also prone to floods? Which ones and why?

**Periodicity of droughts in different meteorological subdivisions**

| *Meteorological subdivision* | *Recurrence of very deficient rainfall* |
|---|---|
| 1. Assam | Once in 15 years |
| 2. W. Bengal, MP, coastal AP, Kerala | Once in 5 years |
| 3. Bihar, Orissa, North Karnataka | Once in 4 years |
| 4. Eastern UP, Vidarbha, Gujarat, Eastern Rajasthan | Once in 3 years |
| 5. Western UP, Tamil Nadu, Kashmir, Rayalaseema, Telengana, Western Rajasthan | Once in 2.5 years |

**Source:** *Report on the Development of Drought Prone Areas.* 1998. National Committee on Development of Backward Areas.

2. Create an anti-pollution advertisement selling the value of clean water. The ad could focus on persuading people to do something that benefits water, or it could persuade people to avoid doing something that pollutes water. Try out your artistic talents as well as your sense of humour in creating the ad. The ad could be for the print medium (i.e it might appear in a newspaper or a magazine); it could be a script for the radio; or a combination of a script and visual ideas for a TV ad.
3. Conduct a survey of your college to identify how water is being wasted. Report leaking taps and broken pipes, overflowing cisterns or tanks, etc. Find out how long it takes to repair them. Develop a water-conservation strategy for your college.
4. Find out if any traditional methods of rainwater harvesting were, or still are, used in your town or surrounding area. Describe the system. If it is no longer in use, try to find out why. Do you think the system can be revived? If yes, why? If no, why not?

## III DISCUSS

Leonardo da Vinci said, 'Water is the driver of nature.' Discuss what he meant by this.

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# Chapter 5

# Energy

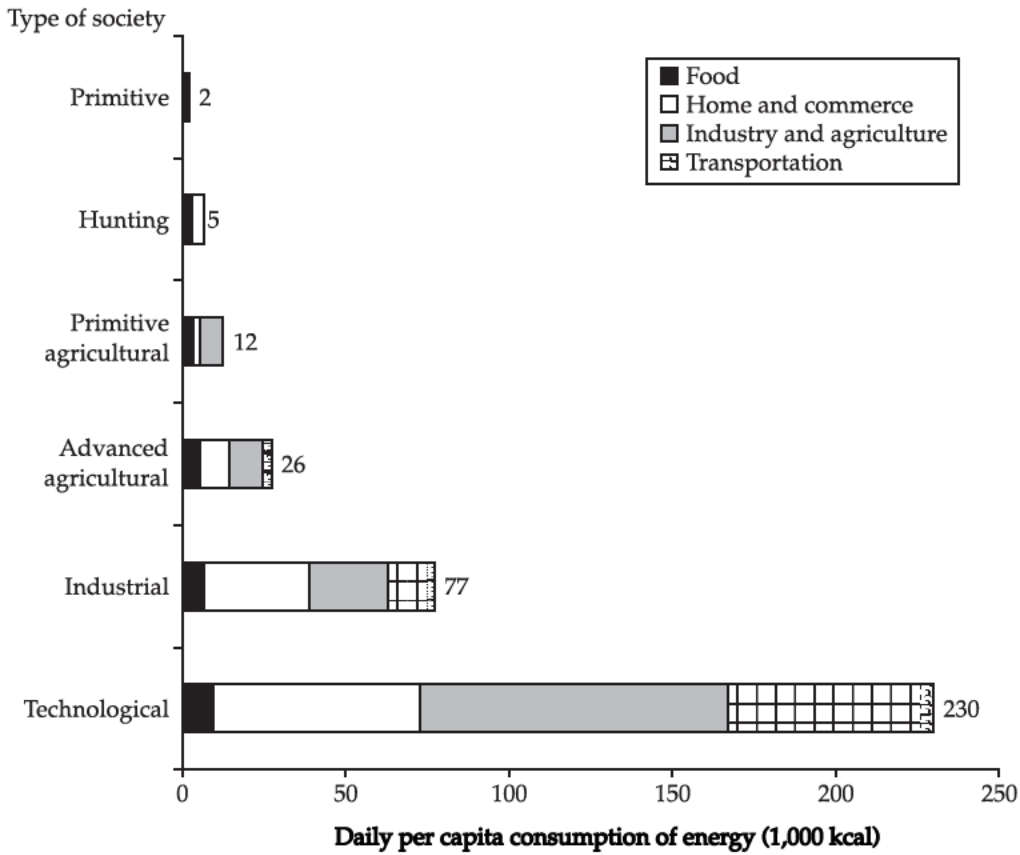
Kiran B. Chhokar

Energy is an essential ingredient of all activity on earth. Human society has progressed because it has learnt to harness and use more and more energy (see Illustration 5.1, 'Consumption of Energy in the Development of Human Society'). Early humans acquired the 2,000 kcal of metabolic energy necessary for survival by gathering and eating plants. About 400,000 years ago, they discovered the use of a new source of energy—fire.

By using wood fires for cooking, keeping warm and protection against wild animals, an early hunter-gatherer probably used not more than 5,000 kcal per day. Over time, humans learnt to use fire to extract metal from ores and to forge tools. The metal tools made settled agriculture possible. Humans also tamed animals to harness their muscle power for agricultural tasks. Technological advances made possible improvement in agricultural productivity and the harnessing of water and wind power. The invention of the steam engine, which was able to convert heat energy into mechanical energy, set in motion a process of rapid industrialization in Europe and the United States. By the mid-1800s, industrializing countries like England, Germany and the USA were using 70,000 to 80,000 kcal per person per day.

Today, the average American commands 250,000 kcal per day, which, in energy terms is equivalent to a hundred persons working full-time. In other words, each American has the equivalent of 100 'energy slaves' to warm, cool, light, transport, cook and manufacture things for him or her. These energy slaves are not people, horses or wood, but mainly fossil fuels and, to a lesser extent, hydroelectric, nuclear and solar power.

While every technological advance in human history has, in a major way, been a result of our increasing ability to harness energy, convert it to useful forms and put it to various uses, the galloping increase in our use of energy has also created problems. Some of these problems are local, some global; some immediate, some looming ahead. For example, the increasing demand for fuelwood in rural and urban areas of India is contributing to the denudation and degradation of forests in some parts of the country. The pollutants released into the atmosphere by the burning of fossil fuels are making the air unsafe to breathe. According to a newspaper report, in Mexico city, the air was unsafe to breathe for more than 300 days in 1990. In New Delhi, the air was so polluted that during the 1996 World Cup cricket series, the Australian cricket team refused to play in the city.






**Source:** Earl Cook. 1971. 'The flow of energy in an industrial society', *Scientific American*, 225 (3): 136.

Illustration 5.1 Consumption of energy in the development of human society

Due to certain gases emitted by fuel combustion trap heat, experts predict that by the year 2100, the average global temperature will have increased by anywhere between 1°C and 4.5°C. So it is important that we take a close look at energy—where it comes from, how we use it, what the environmental impacts are, and what we can do about it.

## SOURCES OF ENERGY

The earth is a vast storehouse of energy. The fossil fuels beneath its surface, the wind and water on its surface, the plants growing on it, the sunlight falling upon it, these are all sources of energy. All energy sources can be classified into two basic categories, non-renewable and renewable, depending on the time period over which they can be replenished. The degree of renewability is determined by the human timescale.

### NON-RENEWABLE SOURCES

Fossil fuels are organic remains which have, through the process of fossilization, over millions of years, become coal, oil and natural gas. They cannot be renewed over time-scales relevant for humans. They are therefore non-renewable resources. Nuclear fuels are also non-renewable sources of energy. Using the analogy of money in the bank, all these sources of energy are our 'capital', which may be extracted at as fast a rate as we want, but once it has been used up, it will be gone forever. The earth contains huge stocks of these sources of energy, but they are in fixed quantities and are being steadily depleted.

### RENEWABLE SOURCES

Renewable sources of energy, or flow sources, rely on natural energy flows and sources in the environment and thus have the potential of being continually replenished. Renewable resources may be likened to a steady flow of interest on money in the bank. If the deposit of money is considered as a resource, as long as we withdraw either less than or equal to the interest which the deposit earns, the resource (deposit of money) can be considered to be renewing itself.

BIOMASS (wood, and animal and crop wastes): Biomass is a renewable source of energy. Biomass resources can, however, be exhausted if their rate of use exceeds the rate at which they are replenished, like money in the bank. Animal and human muscle power are also renewable resources.

Biomass—A renewable resource

Biomass can be defined as the weight of all the living organisms in a given population, area, volume or other unit being measured. Often it is also considered as the weight of the dry matter of living organisms (phytomass of plants and zoomass of animals) at any given time per unit area. Plant biomass provides the primary energy source and acts as the foundation for all life forms. It is an important and major source of food, fodder for livestock, timber for housing and furniture, and many other products needed for human existence.

In India, biomass is a major source of energy. Biomass resources, too, can be exhausted if their rate of use exceeds the rate at which they are replenished.

Most renewable energy sources are powered directly or indirectly by the energy of the sun, and so will last as long as the sun lasts. These include solar radiation, energy from flowing or falling water, and from wind. These sources can however be tapped only at a certain rate. But they can last forever and are therefore also called **perpetual sources**.

Another way of classifying energy sources is as 'non-commercial' and 'commercial' energy.

NON-COMMERCIAL ENERGY: This form of energy includes fuels such as firewood, dung and agricultural wastes, which are traditionally gathered, not bought. These are also called traditional fuels. However, when these sources of energy become scarce, often they too have to be bought. For example, the denudation of forests and the consequent reduction in the availability of wood for fuel has resulted in firewood becoming a marketed product not only in urban areas, but in rural areas as well.

Non-commercial energy has been used by human beings for a long time. We use solar energy for drying grain, clothes, fish and fruits; and the energy of flowing water for grinding grain. Non-commercial or traditional sources of energy also include animal and human muscle power. We use these for transportation, ploughing, threshing, lifting water for irrigation, crushing sugar cane, etc. Unfortunately these are not included in most energy statistics. Nor are the other sources of energy harnessed through traditional means, such as the power of flowing water used by water mills. While these sources of energy continue to be widely used in developing countries like India, we are now becoming increasingly dependent on commercial sources of energy.

Accurate records of the use of non-commercial energy do not exist, but it has been estimated that biomass fuels contributed 41 per cent to India's primary energy supplies in 1998. In India's rural areas, about 95 per cent was supplied by biomass (wood, animal dung and agricultural residues). While the use of dried dung and crop waste as fuel is widespread in agriculturally prosperous regions, wood is still the principal domestic fuel in poorer and less well-endowed regions. Overall, fuelwood is estimated to provide almost 60 per cent of the energy in rural areas and about 35 per cent in urban areas.

COMMERCIAL ENERGY: This energy is also known as industrial energy, and is energy that is bought and sold. By far the most important forms of commercial energy are electricity and refined petroleum products. The primary energy sources such as coal, oil, natural gas, flowing or falling water and nuclear fuels are converted into secondary energy forms, like electricity, which are of greater use and value.

Commercial energy forms the basis of industrial, agricultural, transport and commercial development in the modern world. In industrialized countries, commercial energy is the leading source not only for economic production but also for several household and personal tasks such as washing dishes, drying clothes, shaving and even for brushing teeth.

The production and consumption of commercial energy from conventional sources—fossil fuels, large-scale hydroelectric and nuclear sources—is continuing to rise worldwide. However, efforts are also on to harness commercial energy from alternative renewable resources such as solar, wind, wave, geothermal, small-scale hydro and non-traditional biomass.

## INDIA: CURRENT ENERGY SCENARIO

India's current energy requirement is increasing sharply because of rapid industrialization, mechanization, urbanization, commercialization, population growth, and the changing lifestyles and aspirations of the people. As the supply of energy cannot keep pace with the rising demand, we experience energy shortages in our everyday lives—of petrol, electricity, cooking gas, kerosene, fuelwood.

> In our country, nearly half the energy is consumed not by industry or agriculture, but by households—mainly for cooking food.

A significant feature of energy use in India is the substantial contribution of non-commercial energy—nearly one-third of the energy used in India comes from non-commercial sources. Firewood continues to be the major fuel for cooking energy in the country. Where fuelwood is available, households prefer it to dung or crop residues.

> Energy ladder
>
> When faced with firewood scarcity, the rural poor shift to poorer quality fuels such as cattle dung, crop residues, the woody parts of shrubs, roots, weeds and leaves. All these are less efficient than wood and give off a lot of smoke. At the household level, people often use a mix of fuels depending on the purpose. In urban areas, where firewood is used mainly by

*(continued)*

*(continued)*

the poor, those who cannot afford to buy alternative commercial fuels sometimes turn to non-fuels such as waste paper, discarded tyres and plastic wastes, especially for warmth on cold winter nights.

A strong relationship exists between income and the type of fuel used. This relationship manifests itself in an 'energy ladder'. With an increase in income, people switch to higher quality fuels, i.e. they shift to fuels that are more energy efficient as well as cleaner and more convenient to use. (Fuel efficiency is a function of the proportion of the chemical energy in the fuel which is converted to thermal energy, i.e. heat.)

The normal progression up the energy ladder is from solid to liquid to gaseous fuels to electricity. For lighting, the normal sequence is from vegetable oil to kerosene to electricity. For cooking, from fuelwood to charcoal to kerosene to LPG (liquified petroleum gas).

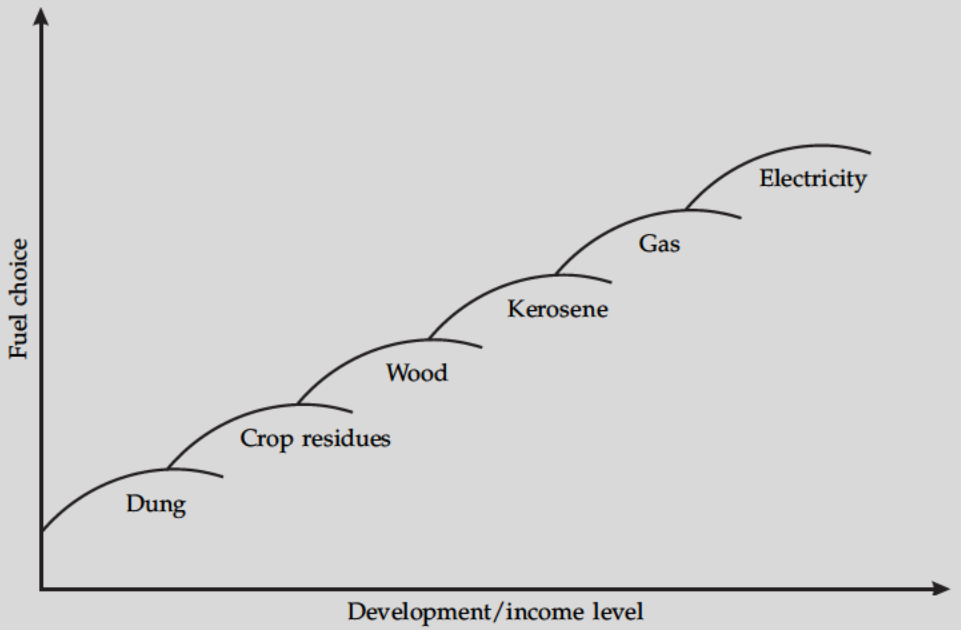



Illustration 5.2 Energy ladder

Energy efficiency of fuels

| *Fuel* | *Amount* | *Units of energy* | *Output (units of energy)* | *Efficiency (per cent)* |
|---|---|---|---|---|
| Cow dung | 1 kg | 2.5 | 0.4 | 16 |
| Wood | 1 kg | 5.5 | 1.0 | 18 |
| Coal | 1 kg | 7.0 | 2.0 | 29 |
| Petroleum based | 1 kg | 12.0 | 7.0 | 58 |
| Electricity | 1 kWh | 1.0 | 0.7 | 70 |

**Source:** *Urjapatra*, January December 1994, p. 19.

Although statistics on commercial energy are easily available, the absence of accurate statistics for non-commercial energy makes it difficult to precisely state how much each category contributes to India's total energy use. The share of commercial energy in India is, however, expected to grow from an estimated 66 per cent in 1990 to 80 per cent in the early years of the 21st century.

COAL: It is the largest of a mix of commercial energy sources India uses. Coal provides 39 per cent of India's total energy requirements and is the source of 56 per cent of its commercial energy. India is the fourth largest producer of coal in the world, and has large coal reserves. Its proven reserves are nearly 68 bn t, but estimates indicate that there may be three times as much. Most of India's coal reserves are in the Gondwana Basin.

OIL: It accounts for 32 per cent of India's commercial energy. The petroleum reserves are mainly in the Arabian Sea in the offshore Bombay High and Cambay basins, and in Upper Assam. India has proven and recoverable oil and natural gas reserves of 3.3 bn t. This is small when compared with the reserves in the recognized oil-producing countries of the world. According to one source, Saudi Arabia has 35.6 bn t while Kuwait has 12.7 bn t.

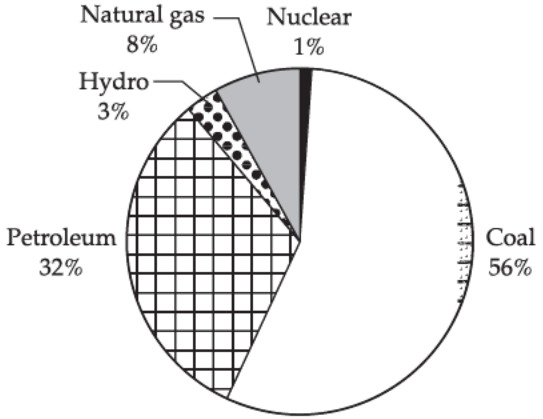
India rapidly developed its oil resources in the 1970s and early 1980s to meet the rising demand and reduce its dependence on foreign oil. Since 1985, oil production has been relatively stagnant. India still has to import half of its requirements of crude oil. Oil imports continue to be a heavy drain on the exchequer.

NATURAL GAS: It supplies 8 per cent of India's current commercial energy needs, but its contribution is growing. Natural gas in India occurs largely in the oil reserves. The current production of natural gas far exceeds the country's ability to transport it to where it could be used. As a result, nearly 40 per cent of the gas produced, valued at Rs 100 million per year, is flared (burned off) at source. However, the country's future energy plans include the use of natural gas in power plants.

HYDROELECTRIC POWER: It supplies about 3 per cent of India's commercial energy and 18 per cent of its electricity. The potential for augmenting this capacity is great, but the high capital costs and the long gestation periods of such projects, as well as the swelling resistance against them on environmental and social grounds, have slowed development. Interstate river-water disputes are another major reason for slow development.

NUCLEAR POWER: It provides 1 per cent of India's commercial energy and 2 per cent of its electricity. India has 14 nuclear reactors at six nuclear power stations producing electricity. The first two reactors were commissioned at Tarapur in Maharashtra in 1969. Subsequently, nuclear power plants were also set up at Rawatbhatta in Rajasthan, Kalapakkam and Kudankulam in Tamil Nadu, Narora in Uttar Pradesh, Kakrapar in Gujarat, and Kaiga in Karnataka.

Figure 5.1
India: Sources of commercial energy (1997–98)




**Source:** State of the Environment, India (2001). UNEP.

## THE PROBLEMS

The commercial energy resources that we currently depend upon are largely non-renewable, making our growing demand for energy, our lifestyles and patterns of energy use clearly unsustainable.

The per capita commercial energy consumption in India is still low when compared to other countries, being less than 4 per cent of a developed country such as the USA. However, we need to look at energy issues holistically and choose a way which, through a mix of policy, institutional, and technological tools, is more sustainable and viable.

This section looks at some of the problems and issues associated with availability and requirement, growing imports, inequitable distribution, inefficient technology, unsustainability and environmental costs.

### SHORTAGES

Like most rapidly developing countries, India suffers from energy shortages. Rising fuelwood prices and the dependence of the poor on low-quality crop residues and cattle dung are indications of the shortage of fuelwood.

Coal is the primary fuel in power generation in India. Over the last decade, coal shortages and therefore electricity have steadily worsened, largely because of the low-energy

prices set by the government, which provide neither adequate returns nor incentives to producers. Until recently the price of coal was lower than its cost of production.

On a countrywide basis, electricity generation is about 10 per cent less than the potential demand. In some regions the situation is much worse. This leads to frequent power breakdowns, voltage fluctuations and planned and unplanned power cuts. Most power companies are inefficient state monopolies. They are neither market driven nor accountable to public or private shareholders. Economic losses due to power shortages are estimated at 1 to 2 per cent of India's national income. Many industries have invested in diesel-driven back-up generators leading to greater demand for imported oil.

## Dependence on Imported Oil

India's demand for oil has been steadily rising. The persistent shortages of coal and power supply have contributed to a more rapid rise in the consumption of petroleum products than had been anticipated. In agriculture, at least 5.5 million diesel pumps are currently in use for pumping irrigation water. The transport sector is a major user of oil. The use of diesel in road and rail transport has increased significantly over the past few decades. The rapid and unconstrained growth of cities, inadequate public transport and increase in income levels have led to a phenomenal growth in the number of privately-owned vehicles, especially two-wheelers. This in turn has led to a significant increase in the demand for petrol and motor oil.

India has met this demand by importing oil as well as by developing its own oil resources. In 1991–92, oil accounted for 25 per cent of India's total import bill. However, if current trends continue, by 2009–10, the oil demand is projected to reach 186 million tonnes, i.e. more than three times the demand in 1992. The import requirement to meet such a large demand could have a disastrous effect on India's foreign exchange situation and its external debt. Besides, India's economy would continue to be vulnerable to the volatility of the international oil market and of the political situation in the oil-producing countries such as Iraq.

## Inequities

India has so far followed development policies that equate development with growth, and economic growth with increased consumption of commercial energy. This approach to energy planning has further magnified the existing inequities between rich and poor, urban and rural, in Indian society. According to Ravindranath and Hall (1995):

> Conventional wisdom in energy planning has led to the neglect of the crucial aspects of the lives of the rural and urban poor, their basic human needs (drinking water and cooking energy), their settlements (villages and slums), their fuels (fuelwood,

crop residues, dung), the end uses (cooking and lighting), and their energy-using devices (cooking stoves, kilns). Instead, the energy supplies of the elite—oil and electricity—are overemphasized.

The decline in the availability of firewood is driving the landless poor, and marginal farmers who cannot get adequate crop wastes from their small landholdings, to depend on cattle dung. But the adoption of domestic biogas plants by many of the larger farmers and cattle owners has deprived the poor of dung which they were earlier free to collect from the streets and fields for fuel. In many parts of rural India, dung and agricultural wastes are increasingly becoming market commodities. This has affected the rural poor.

These inequities also affect men and women unequally as poor rural women have to bear the increased burden of spending longer hours and more energy searching for and gathering fuel. It has been said that millions of poor women in rural India 'are caught in a vicious energy cycle: they eat food to get human energy and then spend all of this energy in producing food and collecting the energy needed to cook it'.

The inequities of access to the various types of fuels exist not just between rich and poor, but also between rural and urban areas. The rising demand for fuelwood by the urban poor who cannot afford or access commercial fuels (for example, if they do not possess a ration card, as is often the case with slum and pavement dwellers) has resulted in a sharp increase in fuelwood prices in urban areas. This has led to truck- and wagon-loads of firewood harvested from forests at ever-increasing distances, and hence increasing costs, being sent to major cities. In some cases this reduces supplies in rural areas where firewood has traditionally been a non-commercial resource. The urban demand has contributed to the depletion of forest cover not only in areas near urban markets but in distant areas as well. Delhi, for example, receives firewood from as far away as Assam, a distance of nearly 2,000 km.

The government subsidizes some products such as kerosene and cooking gas while it taxes others. The price for kerosene is subsidized with a view to protecting consumers, but the benefit of the subsidy is not directed to the poor in particular. As a result, while the relatively cheap kerosene is often used for adulteration in the transport sector, poor consumers are unable to fulfil their total requirements of kerosene from the ration shop. They have to depend in part on supplies from other sources where they pay significantly higher prices.

The scarcity of firewood and other biomass fuels, and the increase in the time spent on gathering them, reduces the time available for other tasks such as cooking. This, in turn, can affect the choice of foods. It has been observed in some urban slums that the shortage of firewood resulted in more nutritious but slow cooking and hence more fuel-expensive cereals such as *jowar*, *bajra* and maize giving way to quicker cooking but nutritionally poorer grains such as rice. The decline in nutritional intake makes people, especially women who traditionally eat the last and the least in the household, more vulnerable to disease. Their poorer nutritional status also makes women more susceptible to diseases

caused by prolonged exposure to indoor air pollution, as they spend four to six hours every day near the cooking stoves.

## INEFFICIENCY

Widespread inefficiency in power generation, transmission, management and use intensifies energy shortages. Some industries and power plants use outdated equipment and processes. For example, the manufacture of steel in India requires twice as much energy as that required in an industrialized country. Poor maintenance of equipment and inadequate monitoring procedures also contribute to inefficiency. Some of the factors responsible for inefficiencies in different sectors are given below.

THE POWER SECTOR: More than 20 per cent of the electricity generated in India is lost during transmission and distribution (T and D). These losses occur because of too many transformation stages, poor quality of wires and equipment, friction and heat loss, and extensive rural electrification, which means carrying electricity over long distances from the source of generation. India's T and D losses are two to three times more than the industrialized countries. In addition, losses because of pilferage, theft and unmetred supply are also significant.

THE TRANSPORT SECTOR: In the transport sector both public and private vehicles are, by and large, poorly maintained, which adds to their energy inefficiency. Ensuring fuel economy is not a priority with automobile manufacturers.

THE DOMESTIC SECTOR: The combination of using inefficient fuels (only a small amount of the chemical energy in the fuel is converted to heat) in inefficient stoves (that transfer only 10 to 15 per cent of the heat to the pot in which the food is cooked while the rest escapes as waste heat) is negative from the standpoints of energy, the health of the cook and the environment. Such a combination requires a greater quantity of fuel for cooking a meal and exposes the cook to more pollutants.

THE AGRICULTURE SECTOR: Subsidies by the central and state governments that keep energy prices artificially low contribute to energy inefficiencies. In 1995, while it cost an average of Rs 1.36 per unit to supply electricity for irrigation, farmers using it were being charged barely 15 paise, and in some states electricity was, and still is, free. Low tariffs on electricity for agricultural pumping continue to be in force as a populistic measure by politicians—those in power and those seeking it. Promising cheap or free electricity for agriculture (mainly for pumping water) is a way of seeking the support of the large vote bank of farmers. But these subsidies have led to the wasteful use of electricity and water, and have resulted in huge losses for the state electricity companies. This has hindered the ability of the utilities to function efficiently.

### Unsustainability

By definition, the use of non-renewable energy sources in the long term is not sustainable. Although biomass is a renewable resource, the current pattern of consumption of biomass fuels is unsustainable. For example, the over-harvesting of forests, partly for timber and other demands, and partly to meet the firewood demand in urban areas, is causing deforestation. India currently uses about 227 mn t of fuelwood energy per year, and this figure is growing with population growth.

Every million tonnes of cut wood requires the cutting of about 8,000 ha of forest. India uses about 227 mn t of fuelwood per year. Even if 10 per cent of the fuelwood comes from felling trees, about 180,000 ha (1,800 sq km) of forest and tree plantations would have to be cleared for fuelwood alone, leading to significant deforestation.

Scarcity of fuelwood has increased the pressure on other biomass resources such as cattle dung and crop residues. The use of these resources as fuel makes them unavailable for other more appropriate uses as fertilizers and mulch.

## Environmental Costs of Energy Use

The use of any of the various conventional energy resources has some adverse environmental consequences at some stage—from its extraction, through processing and transportation, to its end use and waste disposal. Here we look at some examples.

### Biomass

Biomass is a renewable resource; but when it is consumed faster than it can regenerate, biomass denudation (especially deforestation) results in soil erosion, loss of productivity of the soil, disruption of streams and loss of habitats.

Biomass is considered to be a carbon-neutral energy source because green plants absorb carbon dioxide for photosynthesis and give off oxygen, thus establishing an overall carbon dioxide balance. But the burning of biomass-based fuels emits not only $CO_2$ but also other carbon-containing materials, namely, carbon monoxide, methane, other hydrocarbons, and suspended particulate matter like soot and ash. It therefore causes air pollution and contributes to the build-up of 'greenhouse gases' which cause atmospheric warming.

Of more immediate concern is the fact that the carbon monoxide, smoke and hydrocarbons from open wood stoves in poorly ventilated dwellings affect the health of the rural and urban poor, especially the women, who are the main users of biomass fuels. According to one study, the average exposure to biomass smoke in three hours is

equivalent to smoking 400 cigarettes. Even if we consider this to be an exaggerated figure, biomass fuels have nonetheless been found to expose the cook to almost 10 times more particulate matter than kerosene and 20 to 25 times more than LPG.

## Coal

Coal is mined in two ways—underground mining and opencast mining. Both ways of mining have specific environmental effects, but together they degrade forests and land, pollute water and air, and affect the health of miners and people living near the mines. Opencast mines are comparatively more efficient because they permit almost complete recovery of the coal. In underground mines, 40 to 60 per cent of the coal has to be left in place to hold up the structure. Yet, occasional roof collapses and explosions in the underground mines kill miners. The enclosed, coal-dust-laden atmosphere affects the miners' health. Pneumoconiosis, a serious lung disease, occurs with a high frequency among coal miners. Under present practices, opencast mines are safer but destroy, often permanently, the vegetal cover and soil. They also disrupt and pollute aquifers and streams. The coal dust generated by mining pollutes the air for miles. After coal is mined, it is sometimes washed to remove impurities like clay. This uses and pollutes a lot of water.

The worst environmental problem associated with coal is the air pollution generated when coal is burned. Coal is about the 'dirtiest' fuel and produces twice as much carbon dioxide (the main greenhouse gas which leads to global warming) per unit of energy as natural gas and 25 per cent more than oil. In India, coal combustion accounts for 66 per cent of carbon emissions. India's Environment (Protection) Act, 1986, requires emissions from the smokestacks of coal-based power stations to be kept within prescribed limits. However, only 50 per cent of power stations have installed devices like electrostatic precipitators to control emissions, particularly of suspended particulate matter (SPM). Coal use in the country is projected to reach over 600 mn t by the year 2010.

Coal is also the primary source of oxides of sulphur and nitrogen which combine with water vapour in the atmosphere to cause acid rain. The acidic nature of the pollutants causes damage to buildings, monuments, metals, vegetation, animals, aquatic ecosystems and human health. Although the sulphur content of Indian coals is low (1 per cent), in terms of the total pollution load, the large amount of coal combustion in thermal power plants offsets this advantage.

Indian coals contain high amounts of ash (25 to 40 per cent). The disposal of fly ash is one of the biggest solid-waste disposal problems in India. For every megawatt (MW) of installed capacity, approximately 0.04 ha of land is required to pile up the ash 8 to 10 m high. The majority of the thermal power stations in India are of 200 to 210 MW units. So you can work out how much land each coal-based power plant requires just to dump the fly ash!

### Fly ash

Fly ash is a fine particulate, essentially non-combustible material, which is carried out in a gas stream from a furnace as opposed to the ash that remains at the bottom.

In India, over 60 per cent of power generation is coal based, which produces nearly 80 to 100 mn t of fly ash every year. India stands second only to China in the quantum of fly ash generated. Currently, nearly 90 per cent of the fly ash is dumped as slurry in ash ponds, which requires huge amounts of water. It also results in the creation of wasteland and could result in the leaching of heavy metals and soluble salts. Leaching from ash ponds to neighbouring fields and waterbodies can lead to surface- and groundwater pollution.

Efforts are on to develop uses for fly ash. It has been used commercially for making bricks, blocks and as an ingredient in cement. It has also been used to fill up old mines. But at present, only about 3 per cent of the fly ash generated each year is being put to these uses. Research at the University of Calcutta has found that fly ash is an excellent catalyst for treating toxic and non-biodegradable chemicals in effluents from the pesticide industry.

## OIL AND NATURAL GAS

The process of oil and natural gas exploration is very energy-intensive, and so is its extraction. Both exploratory and commercial drilling, even if done with a lot of care, result in the release of some toxic chemicals and in the pollution of water and air. Accidental explosions and occasional leaks occur both during exploration and during production.

Today, all oceans are contaminated to some degree by oil slicks (thick patches of oil floating on water) and petroleum residues. These come from offshore oil wells, ships (from collisions, leaks, and flushing of tanks), and also as run-off from land-based oil facilities and waste oil. When oil spills into a natural ecosystem on land or in water, it kills creatures by cutting-off their air supply, enters the food chain and disperses in the sediments and soils. In the sea, oil is especially harmful to life forms that cannot swim away, such as coral.

### Oil spills and accidents

A major blowout occurred in Pasarlapudi in Andhra Pradesh in January 1995, when a well was being drilled. The fire raged for 66 days before it was finally put out. Besides the damage it caused to drilling equipment and the smoke and other pollutants it added to the air, the fire drove thousands of people from their homes and scorched crops and trees.

The infamous accident of the oil tanker *Exxon Valdez* in May 1989 spilled nearly 42 mn l (equivalent to the contents of 17 Olympic-size swimming pools) off Alaska's coast, along 1,930 km of the coastline. The spill killed at least 100,000 sea birds, 1,000 sea otters and innumerable seals. In June 1989, an oil spill threatened the Indian coast when a Maltese tanker, *MT Puppy*, collided with a British ship, spilling over 5,000 tonnes of oil into the open seas off Mumbai.

Oil is a 'cleaner' fuel than coal, but natural gas is the cleanest of the three. It is composed mainly of methane which is a greenhouse gas that traps ultraviolet radiation more effectively than $CO_2$. Therefore, unusable gas at oil wells is flared rather than being allowed to escape into the atmosphere.

The commercial processing of petroleum products produces solid wastes such as salts and greases. After all the refining and processing, the oil is ready as a fuel. It is then used in vehicles and furnaces. When burned, it produces air pollutants such as sulphur dioxide, oxides of nitrogen, carbon monoxide, and of course, carbon dioxide.

The phenomenal increase in motor vehicles in India—from 11 million in 1986 to nearly 59 million in 2002—has resulted in a corresponding increase in the use of petroleum in transportation. As this increase in vehicles has occurred mainly in urban areas, the air quality in most Indian cities has deteriorated significantly. Smog is now a common feature in many cities. Smog and other air pollutants lead to respiratory and eye problems among urban dwellers. According to a recent World Bank report, every year 40,000 people die prematurely in India because of air pollution.

## HYDROELECTRICITY

About 18 per cent of the electricity produced in India is generated by turbines turned by the force of falling water. Hydropower generation requires the building of dams behind which water is impounded. Although the generation of hydroelectricity does not release any carbon dioxide, rotting vegetation resulting from the submergence of forests, produces methane, which is a greenhouse gas.

Large dams are a controversial environmental issue in India. Vast tracts of valuable forests, wildlife habitats (both terrestrial and aquatic) and biodiversity, as well as agricultural land, are at stake due to submergence. The water table rises and often leads to salinization and waterlogging due to poor management. When that happens on agricultural land, the productivity of the soil is affected. Waterlogging also leads to a rise in various diseases, notably malaria. Thousands of people are often displaced when a dam is constructed. Large dams entail severe and often irreparable social and environmental costs, including the displacement of people, submergence of valuable resources and adverse impacts on downstream hydrology.

Another major concern is the threat of earthquakes, because impounding such large volumes of water causes a build-up of tremendous stresses in the earth's crust. There is evidence of such occurrences all over the world. The Koyna Dam in India is an example. It was built in 1962, in a stable area known neither for geologic faults nor for seismic activity. In 1967, the area was rocked by an earthquake which killed 177 people, injured 2,300 and rendered thousands homeless. The threat of earthquakes in an area which is known to be earthquake-prone is the most contentious issue in the case of the Tehri Dam.

## NUCLEAR POWER

In some respects nuclear power is the 'cleanest' of all energy sources. Its generation and use do not emit any carbon dioxide or other greenhouse gases. Nor does it cause acid rain or urban smog. Yet it is the most controversial source of energy. The basic cause for concern is the possibility of an accident. Although the probability of an accident is low, should it happen, the consequences would be serious.

The accident at the Three Mile Island nuclear power plant in the USA in March 1979 and the explosion at the Chernobyl power plant in Ukraine (which was part of the former USSR) in April 1986, both of which released large amounts of radioactivity into the atmosphere, have intensified the fear that human errors in operation and maintenance could lead to major catastrophes (see box, 'Chernobyl Disaster'). Critics believe that Indian nuclear power plants are poorly maintained and that accidents, mostly unreported, occur almost every year.

Another unsolved problem is the management and disposal of radioactive wastes. Nuclear power plants use radioactive materials and produce radioactive waste. The power plants have a life of 30 to 40 years after which they have to be decommissioned. But they contain a lot of radioactive material. It takes from thousands to millions of years for most of these materials to lose their radioactivity. During this time, humans and other life forms exposed knowingly or unknowingly to nuclear radiation are at risk. Exposure to radioactivity is known to cause cancer, genetic defects, and even death.

Several methods of dismantling ageing nuclear plants and managing the safe disposal of radioactive waste have been suggested. All of them essentially deal with the safe storage of radioactive materials over a geological time span. However, it remains an intractable problem as we still do not know how to handle and dispose of these materials one hundred per cent safely. The proponents of nuclear energy maintain that science and technology have tackled many intractable problems in the past and will find a solution for this one too.

### Chernobyl disaster

'Chernobyl' is a chilling reminder of the far-reaching effects of a nuclear accident and the long-term, insidious nature of its consequences.

On 25 April 1986, the nuclear power plant at Chernobyl in Ukraine suffered a tremendous fire in the nuclear reactor, known as a 'reactor meltdown'. A series of explosions blew up the roof of the reactor building and scattered radioactive dust and debris all over northern Europe and as far away as Canada and USA. The cause of the accident was pinned on the faulty design of the building, poor maintenance, bad management and human error. Ironically, the accident occurred when the engineers of the plant shut down the automatic safety devices in order to conduct a safety experiment.

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While the accident killed about 30 people, millions were exposed to high levels of radiation which subsequently caused several health problems. The worst hit by this accident were children, most vulnerable to radioactive exposure. Surveys in Belarus of children born after the disaster, whose mothers were exposed to radiation, revealed hardly a child not suffering from some immune deficiency disease.

Radioactivity can be passed between forms of life along food chains. In England, sheep which ate the grass growing in affected areas had to be destroyed as their meat was considered unsafe for human consumption. Till 1994, there were reports that lambs in the English Lake District were too radioactive to be sold. Many British farmers therefore lost money as a result of the Chernobyl disaster. In Lapland, thousands of reindeer were affected by radioactive caesium-137 in their food. As they are an important part of the diet of the Saami community living in the area, thousands of reindeer, too, had to be destroyed. Food restrictions were imposed all over Europe as fruits, vegetables and grass for grazing livestock, and consequently milk and milk products, were suspected to be contaminated.

The Chernobyl disaster raises a few questions: should we use this one example of a nuclear accident to discredit the use of nuclear power? What is the track record of the other approximately 500 nuclear power plants in the world? What are the alternatives available to us? How safe and environment friendly are the alternatives?

## OPTIONS FOR THE FUTURE

Although India uses much less commercial energy than industrialized countries, the rapid industrial and commercial expansion, the projected growth of the population and the increasing consumerism leading to greater per capita energy use point to substantial increases in energy use in the future. Estimates predict a fourfold increase, compared to the early 1990s, in commercial energy consumption in India by 2025. In the same period, carbon dioxide emissions could increase sixfold as the use of traditional biomass fuels gives way to greater use of fossil fuels.

To improve our energy future, we need to take steps to increase energy supplies *sustainably* and reduce energy demand through *efficient use*. We need to shift towards renewable energy resources that are more equitably distributed, more affordable and less environmentally destructive than fossil fuels. At the same time, we must recognize that however rapidly we move towards renewable energy sources, we will remain dependent on fossil fuels for several decades to come. We therefore need to reduce the environmental impacts of our current energy resources by finding ways of burning them more cleanly and efficiently.

## Conventional Energy Resources

For long-term sustainable energy planning, it is necessary to move away from our dependence on imported oil and towards greater use of renewable energy sources, environmentally low-impact and efficient technologies, and greater self-reliance. A large-scale shift to low-impact technologies based on renewable energy sources is, however, still a distant goal. In the short term, technologies that will reduce the environmental impacts of current energy sources need to be adopted, such as reducing emissions of sulphur and nitrogen oxides, hydrocarbons and particulate matter. For example, experts believe that by improving the petroleum-distillation process to reduce the levels of sulphur and carbon in Indian petrol and diesel, vehicular pollution could be reduced by 30 per cent.

For the next few decades, fossil fuels will continue to cater to most of India's and the world's energy needs. The Indian government plans to encourage the use of natural gas to generate electricity. India's natural gas supplies are more plentiful than its oil supplies; gas-based electricity plants are cheaper, cleaner and faster to build than coal-based plants.

The government is also hoping that opening up the power sector to private companies will boost the development of hydroelectricity. There is also tremendous potential in the country for tapping small streams and canals to build mini- and micro-hydroelectric plants.

## Recognizing the Potential of Biomass

Energy for cooking constitutes a large proportion of India's total energy consumption. The primary source of energy for cooking for the majority of India's population is firewood. Ninety-five per cent of the rural population and over 60 per cent of the urban poor depend on non-commercial energy resources—primarily firewood, but also cattle dung and crop residues. Firewood for cooking is one of the basic needs, therefore, it must be a focus of development efforts. Biomass has great potential as an energy source if its rate of regeneration can at least keep pace with its rate of consumption. In the case of firewood, this can be done in two ways:

1. by increasing fuelwood production, thereby increasing the supply. This would require increase in the productivity of land, and tree plantations through careful management and afforestation on degraded lands, and
2. by improving the efficiency of firewood use, thereby reducing the existing demand for firewood. This is concerned mainly with increasing the efficiency of wood-burning devices—primarily the wood stoves or *chulhas*. Improvements in the design of *chulhas* seek to improve the heating process, i.e. efficient generation of heat through efficient burning of the wood, efficient transmission of heat to the cooking pot, and retention of heat in the *chulha* and minimization of heat dissipation.

## ALTERNATIVE RESOURCES AND TECHNOLOGIES

The most promising solution for rural energy lies in replacing over-exploited and inefficient traditional biomass fuels and technologies with more efficient and sustainable alternatives. A promising technology that is likely to increase the efficiency of biomass energy are the biogas plants which convert biomass into modern energy forms. A biogas plant provides about 25 per cent more energy than burning cattle dung. In addition, the sludge left behind in the digester can be used as fertilizer which is richer in nitrogen than traditional dung manure.

To reduce the overwhelming environmental burden of our current energy resources and technologies, it is necessary to move towards greater use of renewable energy options. India has been developing technologies for the use of solar energy, biomass, wind energy and hydropower. These alternative technologies include biogas plants, biomass gasifiers, wind energy farms, solar thermal energy and solar photovoltaics, and mini-, micro- and small hydel plants. Experiments on ways to generate electricity from household waste are also underway.

### Solar energy

Bright sunshine over most of the country for a major part of the year makes solar energy a promising energy option. India receives about 6,000 billion MW of solar energy per year. If only 1 per cent of this energy could be tapped at even 10 per cent efficiency, it would amount to about 30 to 35 times India's present electricity generation!

Solar energy technologies convert the sun's radiant energy into heat (thermal conversion) and electricity (photovoltaic conversion). Thermal conversion technologies use reflective mirrors of different shapes and sizes to concentrate the sun's rays to produce low-, medium- and high-grade heat energy. This heat can either be used directly or it can be converted to electricity.

Medium-grade heat (with temperatures between 100°C and 300°C) is used directly for cooking. India has the world's largest solar-cooker programme. Solar cookers reduce the need for fuelwood, thus also saving the time and labour needed to collect it as well as reducing indoor air pollution from smoky fires.

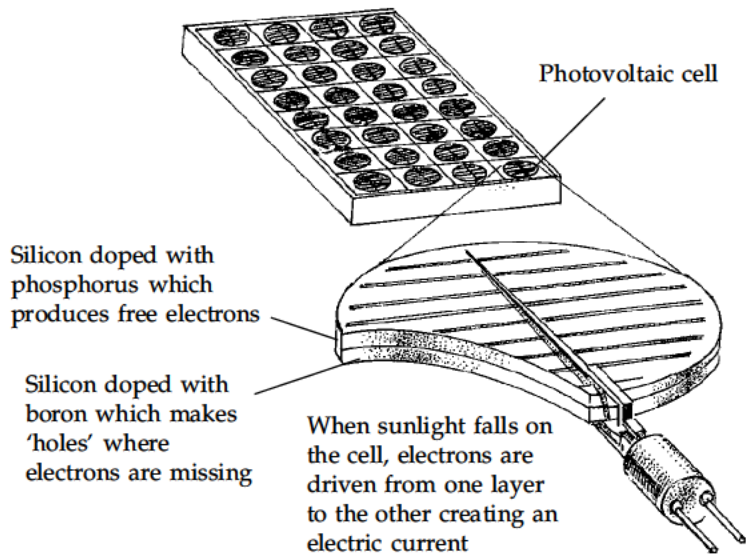
India has also commercialized the manufacture of photovoltaic (PV) or solar cells, which convert sunlight directly into electricity. These cells are made of silicon wafers sandwiched together. Solar radiation dislodges electrons from the silicon in the sequentially arranged silicon cells on solar panels, causing electric current to flow. The current then passes through a regulator into a storage battery where it is stored for future use, or into an inverter which adapts the current for a number of uses. As a single solar cell produces a very small amount of electricity, an array of cells is wired together to form a panel providing between 30 and 100 W. Depending on the requirement, several panels can be used.

The capital cost of solar photovoltaics per kilowatt of generation capacity, however, is still prohibitively high. Therefore, it is not yet an option for large-scale use. Its use is currently economically viable for small loads in remote locations.

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Another question being debated is how environment friendly are solar collectors and solar cells as their production is very energy intensive. According to the proponents of solar energy technologies, using energy and energy-intensive materials to make solar energy systems is a good energy investment as the solar energy produced by these systems is many times greater than the energy used in making them.




Based on *The Dorling Kindersely Science Encyclopaedia* (Dorling Kindersley, London, 1993), p. 134.

Illustration 5.3 Solar panel

Before these new options can be adopted on a large scale, they must be proved to be economically competitive with the conventional alternatives. At present the competition is tilted in favour of the latter. This is mainly because the environmental and social costs that accompany the use of conventional energy are not included in energy pricing. If these **external costs** of the impact on human health, social well-being and environmental damage were to be included in the price, renewable technologies would be found to be more competitive.

The government is encouraging the development of these new technologies both in the private sector and through the Ministry of Non-Conventional Energy Sources (MNES) and the Indian Renewable Energy Development Agency (IREDA) set up by MNES in 1987.

## ENERGY CONSERVATION

Energy conservation means using energy less wastefully and more efficiently. Conservation of energy is an important energy resource because a unit of energy saved is as good as a unit of energy generated. Besides, it is cheaper to save energy than to produce it, and the saved energy becomes available for some other use. In essence, it means 'doing more with less'.

AT THE SECTORAL LEVEL: A few sectorwise examples of energy conservation are discussed below.

*Industry:* The largest consumer of commercial energy in India is industry. Therefore, this sector can make the greatest contribution to energy conservation by using energy-saving equipment and adopting more efficient and sustainable processes and practices. In industrialized countries, a recent focus of the production process has been the 'green' product design and cleaner technologies. Products are being redesigned to use less material or substitute it with new materials which require less energy in their manufacture than traditional materials. Manufacturing processes are being made more efficient. Much more attention is also being paid to **product life cycle**—cradle-to-grave environmental impacts associated with production, use, distribution and disposal of products.

For efficient energy generation and distribution, the installation of cogeneration units where possible is a useful option. **Cogeneration** means the production of two useful forms of energy from the same process. In electricity production in India, at present, nearly three-fourths of the energy input is lost as 'waste heat'. This waste heat from coal-fired and other industrial boilers, which is in the form of high temperature steam, could be run through turbines to generate electricity. About 10 per cent of the electricity requirements of the textile industry could be met if mills that use steam install cogeneration equipment. Agro-industrial wastes such as bagasse are often used for cogeneration of electricity (see box, 'Sugar-cane Power').

### Sugar-cane power

India is the world's largest producer of sugar cane. In 1992–93, India produced 10.8 mn t of sugar and 67.86 mn t of crushed sugar-cane stalks, or bagasse. This waste product is routinely used in 'cogeneration', i.e. it is burned to produce steam and electricity which is utilized by the sugar factories. This is done by sugar factories all over the world, but usually quite inefficiently. The introduction of high pressure boilers and turbogenerators could produce more power from the same quantity of bagasse. This would meet not only the needs of the sugar factories but could also supply between 5 and 10 per cent of India's electricity needs.

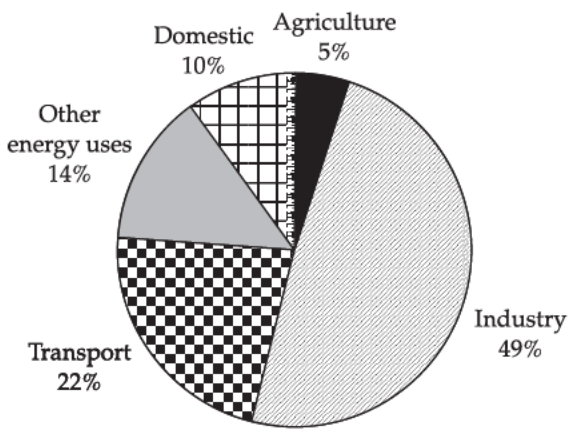
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The Ministry of Non-Conventional Energy Sources (MNES) announced a national programme to support bagasse-based cogeneration in 220 large sugar mills in the country which crush more than 2,540 tonnes of sugar cane per day and have the potential to produce 5 to 20 MW of surplus power. This surplus power can be fed into the grid and supplied to nearby rural areas.

Industry is essentially an economic activity guided by principles that make economic sense. Manufacturers will, therefore, invest in energy efficiency only if it leads to economic benefits by reducing energy or other quantifiable costs. For many industries, innovative technologies that prevent or reduce pollution and lower the cost of complying with anti-pollution laws also tend to decrease energy consumption. The industries that produce the most pollution, such as chemicals, petrochemical, iron and steel, textiles, pulp and paper, also consume the most energy. In the present scenario when the courts are coming down heavily on industries for non-compliance, it would make economic sense to adopt new technologies and improved practices aimed at pollution prevention and waste minimization, which would reduce pollution remediation costs as well as the consumption of energy.

Figure 5.2
India: Sectoral consumption of commercial energy (1999–2000)




**Source:** TERI Estimates http://www.teriin.org/energy/overvw.htm.

*Transport:* After industry, this sector is the largest consumer of energy. While the entire transport system needs major restructuring to make it more efficient operationally as well as in its use of energy, the focus here is primarily on the urban commuter transport system.

Vehicular traffic in cities and towns is the major source of air pollution, noise pollution and road congestion. There is a need to develop energy-efficient motorized vehicles and systems for their proper maintenance, to ensure fuel efficiency and less pollution. Improvements in public transportation, besides reducing pollution and saving energy and money, would reduce the dependence on private vehicles and improve the quality of transportation services available to the average citizen.

*Agriculture:* The efficiency of the water pumps used for irrigation in India, the main consumers of energy in agriculture, needs to be improved. India has over 9 million electric irrigation pumps and each uses 5,362 kWh per year. Studies have shown that 35 per cent of the electricity used by these pumps can be saved simply by replacing the high friction components, such as foot valves, with low friction components. That means a saving of 20,000 MW—the amount of power that it would take nearly 100 thermal power plants to generate!

*Power:* It is the responsibility of power companies and state electricity boards to meet the electricity requirements of their customers. A concept that has great value, especially for the power sector, is **demand side management** (DSM). In this, the power companies, rather than trying to meet the current shortages and also the rapidly increasing demand for more power, help their customers to *reduce* the demand.

The Ahmedabad Electricity Company (AEC) has initiated a pilot project in which energy-efficient water pumps have been installed in multi-storey apartment buildings and more efficient motors in various industries. Several other areas have also been identified which include the replacement of conventional lighting with compact fluorescent light bulbs (CFLs) and energy audits for industry. The AEC estimates that the potential saving through DSM over a five-year period will be 25 MW, or nearly Rs 10 million in the construction cost of new power-generating capacity.

A fundamental problem with the energy sector in India is the pricing policy. Consumers pay much less than what it costs to produce and deliver the energy (electricity, LPG, kerosene) to them. If consumers were to pay a more realistic price, they would use commercial energy less wastefully and more carefully. A more rational energy pricing policy, combined with incentives, would therefore encourage energy conservation.

*Buildings and architecture:* Traditional architecture all over the world uses materials and design features in ways that harness available energy sources such as the sun, wind and water to lower or raise temperatures inside buildings. In both these respects, buildings differ from region to region depending on the local climatic conditions. In addition, local materials are used to avoid transport costs, in terms of energy as well as money. Buildings constructed in recent times, however, ignore these simple strategies. In importing western designs, we disregard the need to adapt them to local conditions. Appropriateness of design detail, such as locating openings in buildings in a way that

allows cross-ventilation, and shading windows with large overhangs to prevent sunlight from directly falling on window panes are means of keeping the interiors cool.

Identifying and using appropriate material is also very important. A modern building constructed with fired bricks for foundations and walls and a reinforced concrete roof uses up to 400 kWh/sqm (or about 280 kg of coal) of energy, from the extraction of raw materials to the manufacture of the building materials. However, the energy used in the process of manufacture of a material varies depending on the technology used and the material to be processed. The use of efficient technologies and low-energy alternatives can bring down the use of energy by 25 to 30 per cent.

According to another estimate, using preventive measures and cutting down on the use of air conditioning, installing efficient ventilation systems, orienting and planning the building in a way that utilizes sunlight and wind direction for heating and cooling, and using appropriate materials for building may make it possible to reduce the energy demand of living in modern buildings by up to 70 per cent.

### Retreat

RETREAT, a residential training facility for executives, is a part of TERI's (The Energy and Resources Institute) Gual Pahari campus, about 30 km south of Delhi. The beautifully landscaped 36-hectare site was barren a decade ago. The topsoil was badly eroded in some places while at others the land was swampy. Today the site is transformed—green, productive, and sustainable.

The facility is designed to be self-sufficient, and independent of any external power supply. It has harnessed both traditional and modern means of tapping renewable sources of energy to offer modern amenities such as lighting, air conditioning, cooking and laundry at substantially reduced costs.

As a model sustainable habitat based on new and clean technologies, the complex makes full use of the most abundant source of energy, the sun, by tapping its energy both directly and indirectly. Twenty-four solar water-heating panels provide up to 2,000 l of hot water every day.

Photovoltaic panels capture the sun's energy and recharge their batteries during the day. The energy generated by the panels is fed into a battery bank, which is the main source of power at night. The source of power for the building during the day is a 50-kilowatt gasifier that uses firewood, dried leaves and twigs, the stubble left in the field after a crop is harvested, and other such forms of biomass fuel.

Specially designed skylights, energy-efficient lights, and a sophisticated system of monitoring and controlling the consumption of electricity, light up the complex with less than 10 kW; a comparable conventionally designed structure would require nearly 28 kW to provide the same level of lighting.

Effective insulation, shade provided by trees, and a network of underground earth air tunnels circulating cool subterranean air throughout the residential block ensure that the temperature in the complex remains more or less even all year round, at 20°C in winter, 28°C in the dry summer, and 30°C in the monsoon. The system has been augmented by adding chillers for dehumidification and additional cooling during the monsoon.

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A bed of reed plants (phragmytes) clarifies 5 cu m of waste water from the toilets and kitchen every day; the recycled water is used for irrigation.

All these technologies help the complex save an estimated 570 tonnes of carbon dioxide emissions per year. The complex saves 40 to 50 per cent in energy costs over conventionally designed buildings at an additional investment of about 25 per cent.

The model sustainable habitat taking shape in Gual Pahari drives home the message to visitors and guests that near self-sufficiency in energy is not a Utopian ideal but a reality cast in brick and mortar.

www.teriin.org/case/retreat.htm.

AT THE INDIVIDUAL LEVEL: Energy can be saved in two ways:

*Using energy-efficient equipment:* Efficiency means getting the greatest possible amount of output with the least amount of inputs—resources, effort and cost. Through efficiency, we can use less energy to do the same amount of work and, in some cases, do even more work; for example, using a pressure cooker, an energy-efficient model of a refrigerator or a *chulha*, or a compact fluorescent light bulb.

Energy-efficient models or products may initially cost more than conventional ones, but they save money in the long run by having a lower life-cycle cost, i.e. initial cost plus lifetime operating costs. And the saving in energy is not a one-time saving because an energy-efficient device goes on saving energy throughout its life. (See box: Energy-efficient Products.) Energy conservation is often the cheapest, and perhaps the largest source of energy available to us.

### Energy-efficient products

'Energy-efficient' products such as compact fluorescent lightbulbs (CFLs) provide the same amount of light as the less efficient incandescent bulbs, but they use less energy in doing so. High efficiency CFLs last about 10 times longer than normal light bulbs, which use one-fourth as much electricity to deliver the same amount of light. While a 75 W incandescent bulb consumes 75 units for running 100 hours, a 15 W CFL, which gives the same amount of light as a 75 W bulb does, consumes only 15 units. CFLs contain Krypton and Argon gases which are safe and do not harm the environment. Many of us are not aware of the range of energy-efficient products available in the market, and even those who are aware may not adopt newer technologies. One of the reasons for this could be the higher initial cost of energy-efficient products. However, using energy-efficient products helps save money in the long run and saves energy throughout the lifetime of the product. According to one estimate, if just 20 per cent of the more than 300 million conventional light bulbs in use in India in 1990, were replaced with CFL bulbs, the country's power requirement would be substantially reduced. India could avoid building 8,000 MW of new power capacity. India could also halve its firewood requirements just by doubling the fuel efficiency of wood stoves.

*Changing energy-wasting habits and lifestyles:* Obvious examples from our daily life include switching off a light when it is not needed, walking or riding a bicycle instead of using a two-wheeler or a car for a short trip, regularly defrosting the refrigerator, or turning off the tap while brushing our teeth—not only does it save water but also the energy used for pumping the water. Such changes in habits do not cost any money.

Equally important is cutting down wasteful consumption in our day-to-day life. All commodities require the input of energy at all stages of production, packaging and transportation. Take a shirt, for example. The production of the fibre (whether natural or synthetic), the yarn, the fabric and the shirt, all require input of energy. So do the plastic bag and the carton in which the shirt is packed. Energy is used to transport all the raw materials as well as the finished products. The shirt therefore has a certain amount of energy 'embodied' in it. So, by not buying a shirt that we do not really need, we will be saving more than just the energy spent on a trip to the store.

It is necessary for individuals in their personal lives and society as a whole, in every sector of the economy, to adopt a combination of the two approaches if we are to meet our energy requirements affordably and with a tolerably low environmental impact.

## THE FUTURE SCENARIO

To improve our energy future, energy supplies have to be increased sustainably and energy demand reduced through efficient use. There is a need to shift towards renewable energy resources that are more equitably distributed, more affordable and less environmentally destructive than fossil fuels. At the same time, though there is a rapid move towards renewable energy sources, the dependence on fossil fuels will remain for several decades to come. Therefore, in order to reduce the environmental impacts of current energy resources, we must find ways of burning them more cleanly and efficiently.

The energy policies of the government aim to ensure adequate energy supplies at minimum possible costs, achieving self-sufficiency in energy supplies and protecting the environment from adverse impacts due to the utilization of energy resources.

### The Energy Conservation Act

The Energy Conservation Act passed by Parliament in 2001, aims at promoting the efficient use of energy and its conservation. It focuses on the enormous potential for reducing energy consumption by adopting energy efficiency measures in various sectors of the economy.

The Act provides measures to establish a statutory authority called the Bureau of Energy Efficiency. The bureau was established to effectively coordinate with designated consumers and agencies for performing functions necessary for the efficient use of energy and its

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*(continued)*

conservation. These functions include recommendations on the norms for process and energy consumption standards for equipments and appliances, recommending the particulars required to be displayed on labels on equipment or appliances and the manner of their display, prescribing guidelines for energy conservation building codes, creating awareness and disseminating information for the efficient use of energy and its conservation, promoting innovative financing of energy efficiency projects, laying down certification procedures for energy managers and preparing an educational curriculum on the efficient use of energy and its conservation.

At the national level, we need to recognize that while India's per capita consumption of energy is low, energy efficiencies are also low. More energy-efficient technologies and advanced fuel systems with near-zero emissions need to be promoted. Promoting clean technologies and reducing energy demand are likely to also minimize local pollution and even reduce carbon emissions.

Experience gained over the last two decades in India in the area of renewables—wind power, small hydropower systems, biomass-fired plants and solar photovoltaic systems—needs to be scaled up to respond to the emerging needs of sustainable development.

## I QUESTIONS

1. Match the following:

| | |
|---|---|
| A. Biomass | a. Non-renewable |
| B. Electricity | b. Renewable |
| C. Oil | c. Renewable |
| D. Coal | d. Commercial |
| E. Wind | e. Non-renewable |

2. Every million tonnes of cut wood requires the cutting of about 8,000 ha of forest. India uses about 227 million tonnes of fuelwood per year. Even if 10 per cent of the fuelwood comes from felling trees, about 180,000 ha (1,800 sq km) of forest and tree plantations would have to be cleared for fuelwood alone, leading to significant deforestation (Ravindranath and Hall 1995). Calculate what this figure means when compared with the area of your town or city.
3. What do you understand by the term 'energy ladder'? Explain.
4. Imagine and describe, in about two pages, your life in a future scenario where there is no oil (petrol, diesel, kerosene).

5. Why is nuclear energy controversial? Do you agree with the concerns voiced by its opponents? Is nuclear energy a viable option for a developing country like India? If yes, why? If no, why not?
6. Government, as part of its development efforts, subsidizes several essential commodities and services. The electricity rates charged by the state electricity boards, for example, are much lower than what it costs to produce the electricity. What are the implications of this policy/practice?
7. Is there a relationship between materials and energy? Explain.
8. What steps do you plan to take to conserve energy in your everyday life?

## II EXERCISES

1. Many types of non-fossil energy sources are already in use—solar photovoltaic, solar thermal heating, wind energy and biogas. What are the alternative sources of energy used in the neighbourhood of your college or home? Which alternative sources of energy are available commercially in your town? Describe the technology/appliance, draw diagrams to explain how it works, state where it is available, what it costs and what are its benefits and drawbacks?
2. Check your Energy IQ. Read the 'Energy Questions' below and state whether each statement is 'True' or 'False'. After you finish marking all the statements, check the score sheet. Read the answers, which explain in detail the scientific principles associated with each answer.

   **The Energy Questions**

   a. On winter afternoons, we should always leave the curtains on all west-facing windows open, to allow the warm rays of the afternoon sun to enter.
   b. We should allow a lot of frost to accumulate in the freezer compartment of our refrigerators, because cold frost cools the air inside the refrigerator faster, thus saving energy.
   c. Small appliances such as hand mixers, *chutney* grinders and juicers generally use less energy for specific jobs than a food processor.
   d. Driving faster uses less energy because operating time is reduced.
   e. Fluorescent light bulbs and incandescent bulbs of the same wattage produce the same amount of light.
   f. On hot summer days, it is a good idea to get that little extra cooling into the room by leaving the refrigerator door open.

g. We will save energy by doing several small loads of wash in the washing machine every day, rather than one large one on the weekend.
h. The freezer compartment of the refrigerator is least efficient when it is half or three-fourths full.
i. It takes less fuel to restart a vehicle than to idle it for more than 60 seconds.
j. The less air in the tyre, the less fuel the vehicle will burn.

**Score Sheet**

Check your answers and rate your Energy IQ:

| | | | |
|---|---|---|---|
| 1. | 9–10 | Correct answers | EXCELLENT! High Energy IQ |
| 2. | 6–8 | Correct answers | GREAT! Above Average Energy IQ |
| 3. | 3–5 | Correct answers | NOT BAD! You still need to learn more about energy conservation |
| 4. | 0–3 | Correct answers | OH NO! Study the answers again. You are probably throwing away money needlessly. |

**Answers**

a. True The energy savings gained by keeping the curtains closed depends on the time of the year. In winter, keep the curtains open and let the sun's rays into the room for extra warmth.
b. False A frosty refrigerator uses more energy than a defrosted refrigerator. Frost acts as an insulator. This is the principle on which igloos are based. Don't let frost accumulate to more than one-fourth of an inch.
c. True Small appliances like hand mixers, *chutney* grinders, etc., often use less energy than a food processor. They are designed to do specific jobs, making the work easier and usually quicker.
d. False All vehicles have an optimum speed at which they give maximum mileage. Refer to the vehicle's booklet to find its optimum range. For example, two-wheelers have an optimum speed range between 40 and 50 km/hr. This is the range in which they are most fuel-efficient. Also, drive the vehicle steadily at the optimum speed. Do not speed and brake often.
e. False Fluorescent and incandescent bulbs of the same wattage do not produce the same amount of light. Fluorescent light bulbs produce about three and a half times more light than incandescent bulbs of the same wattage.
f. False Using your refrigerator is a very costly way to cool your room. When left open for long periods of time, the refrigerator will in fact make the room warmer than cooler!

g. False A large-capacity washing machine saves energy by handling more clothes in one load. It is better to collect clothes for one full-load wash than do small loads of wash every day with fewer clothes.
h. False The freezer is most efficient when filled to capacity.
i. True It takes less fuel to restart than to let a vehicle idle for more than one minute.
j. False Lower tyre pressure increases fuel consumption and also decreases the life of the tyre. Check the air pressure in your tyres regularly and ensure that it is as per specifications.

## III DISCUSS

1. The energy consumption of a citizen of the USA is, on an average, 365 gigajoules (Gj), whereas in India it is 15 Gj per citizen. Why do you think this is so? How do India's wealthy citizens compare with its poor in this regard? Explain whether it would be fair, desirable or practical to expect Americans and affluent Indians to reduce their energy consumption. Is it necessary or desirable for Indians to increase their energy consumption? If yes, why? If no, why not?
2. Read the following statements:

   a. *To encourage the adoption of alternative energy sources, policymakers will need to reduce subsidies, raise taxes on fossil fuels, increase research funding on new energy technologies, and provide incentives to private industry for renewable energy development.*

   **World Watch Institute**

   b. *A society that improves the lot of the poor prudently needs less energy than the one that makes no such dent in poverty.*

   **Reddy and Goldemberg**

   c. *Real wealth is knowing what to do with energy.*

   **R. Buckminster Fuller**

   d. *However carefully it [a nuclear plant] is designed, a piece of mechanical engineering can and will fail; however 'foolproof' the safety system, it cannot be made proof, as the nuclear industry itself says, against bloody fools. The question is not whether accidents can be prevented; they cannot. It is whether the public is prepared to live with accidents like Three Mile Island. It is perfectly prepared to live with air crashes, in which hundreds die, in exchange for mobility.*

   **Nigel Hawkes**

e. *It's not what is in the pot, but what is under it, that worries you.*
**Jodi L. Jacobson** quoting women in a fuel-deficient area of India.

**Now do one or more of the following:**

a. Choose the quotation you like best and write a paragraph explaining its key idea or stating reasons for the choice of that particular statement.
b. Develop a short essay including one of the quotations in it.
c. Write a brief rebuttal to one or more of the quotations provided.
d. Draw a pictorial representation of one of the quotations.
e. Develop a cartoon or poster based on one of the quotations.

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# Chapter 6

# Pollution

Hema Jagadeesan

The word 'pollution' is derived from the Latin word *pulluere*, which means 'to soil or defile'. Any alteration to air, water, soil or food that threatens the health, survival capability or activities of humans or other living organisms, is called pollution. This chapter provides a brief overview of the sources and effects of various types of pollution. As several human activities create pollution, discussion and several examples of different kinds of pollution appear in almost every chapter of this book.

Pollution has been around for a long time—in fact, for as long as humans have been around. In the past it was not a problem. Most of the waste from human activities could be handled by the earth's natural systems. Air and water were able to dilute and disperse pollutants. Much of the solid waste thrown on land, being made of natural materials, decomposed easily. Also, there were fewer people, so the total amount of waste created was not too large.

Gradually, as settlements grew larger and turned into cities with large populations, the wastes too increased. Technological inventions made life easier than before. Factories sprang up and began producing goods in large quantities. But they also began to spew their wastes into the air, into the water, and on to the land. Transportation was revolutionized with the invention of the internal combustion engine, which burned fossil fuels and added to air pollution. More and more synthetic chemicals were invented. Plastics began to replace almost every kind of natural material. Thus the amount as well as the kind of waste generated changed a great deal.

A century ago, people were dealing with pollution which was mainly from animal waste, household waste, and smoke and ash from burning coal and biomass. Today, pollution is generated by many sources—from pesticides, fertilizers, fossil fuels, radiation, and an army of new chemical and synthetic materials, to name just a few. Combined with ever-exploding populations and ever-increasing consumption, pollution has become a threat to the fragile life-support systems of the earth.

Today, almost every human activity—from how we get around, to how our goods are produced, to how we grow our food—creates some type of pollution.

## What Causes Pollution?

Pollutants may be solid, liquid or gaseous. These pollutants enter the system as by-products or as waste in the process of extraction of natural resources (mining), processing of raw materials, manufacture of products, agriculture, generation of energy, etc. Pollution also takes place in the form of the emission of excess noise, heat or radiation. Pollutants may be:

Degradable Pollutants: These are those pollutants that can be broken down or reduced to acceptable levels by physical, chemical or biological processes. Most natural substances are degradable; for example, vegetable waste.

Non-degradable Pollutants: These are those pollutants that cannot be broken down by natural processes; for example, plastics, styrofoam. Once these are released into the environment, it is difficult to get rid of them, and they continue to accumulate.

Slowly Degradable or Persistent Pollutants: These are substances that take a very long time to degrade, for example, aluminium cans, chemical insecticides like DDT, and chemicals like CFCs. These linger on and have long-lasting and far-reaching effects on the environment.

Much of the natural pollution (e.g. from a volcanic eruption) is generally diluted, dispersed or rendered harmless by natural processes. But the pollution caused by human activities (e.g. burning of fossil fuels like coal or petroleum) occurs over a small area (e.g. an urban or industrial area), and so the pollutants become concentrated in the air, water and soil there. The quantity and quality of such pollutants do not allow for their dilution or dispersal by natural processes.

Pollution may come from a single identifiable source such as the chimney of a factory, or the drainage pipe of a mill, or the exhaust pipe of a vehicle. Such sources are described as **point sources**. When the original source is difficult to pinpoint, it is described as a **non-point source**; for example, chemical sprayed into the air, or fertilizer run-off from various fields which enters a river or a lake. Controlling this kind of pollution is not easy as the original source is often difficult to identify.

## What can Pollution Do?

Pollution can affect the very survival of our planet as its effects are felt not only by humans, but by all the life-supporting systems of the earth—air, water, soil, flora

and fauna. The effects of a pollutant may vary depending on a number of factors. These are:

1. The nature of the pollutant, i.e., how active and harmful it is to living organisms.
2. The concentration of the pollutant, i.e, the amount per unit volume of air, water, soil or unit of body weight. When there is too much of a pollutant, or when it is piling up too fast, it starts having harmful effects.
3. The persistence of the pollutant, i.e., how long it stays in the air, water, soil or body.

## TYPES OF POLLUTION

Depending on the component that is being polluted and/or the kind of pollutant, pollution may be classified as air pollution, water pollution, soil pollution, noise pollution and radiation pollution. Let us look at the sources and effects of the various types of pollution.

### WHAT IS AIR POLLUTION?

Air is found everywhere. Air may get polluted by natural causes, for example, volcanic activity, which releases ash, dust and sulphur compounds; forest or grass fires caused by lightning; or by man-made causes such as industrial and vehicular emissions.

SOURCES OF AIR POLLUTION: Air pollution consists of gases, liquids or solids present in the atmosphere in high enough levels to harm humans, other organisms or materials. (See box 'Air Pollutants: Sources and Effects'.)

Pollutants in the air may be in the form of solid particles or gases. The solid particles that remain suspended in the air are called suspended particulates. They may reduce visibility or damage human health. Air can also be polluted by trace metals such as lead, nickel, iron, zinc and copper. There are several types of gaseous pollutants which have different impacts on human health and the environment.

Air pollutants are often divided into two categories: **primary** and **secondary.** Primary air pollutants are emitted or discharged from the source directly into the atmosphere, such as sulphur dioxide and nitrogen oxides from the burning of coal in thermal power plants. Secondary air pollutants are the products of chemical reactions involving primary air pollutants. For example, as the emissions from coal-based power plants are carried away by winds, chemical reactions take place which convert the emissions into secondary pollutants—nitrogen dioxide, nitric acid vapour, and droplets containing sulphuric acid, sulfate and nitrate salts. The acidic chemicals come down to the earth's surface as **acid rain.**

The sources and effects of air pollution are varied and complex. Some sources of man-made air pollution are vehicular emissions, industrial processes and the burning of fuels in homes. Each of these is explained in the relevant chapters of this book.

Indoor air pollution is one of the largest health risk factors in the world. Research shows that about 6 per cent of all deaths each year result from breathing elevated levels of indoor smoke from biomass fuels. Over 80 per cent of the people in the rural areas of India rely mainly on solid biomass fuels for cooking and heating. This produces large amounts of smoke and other air pollutants in the confined space of the home, resulting in high exposures.

Air pollutants: Sources and effects

| Pollutants | Sources | Effects |
|---|---|---|
| Sulphur compounds including sulphur oxides, hydrogen sulphide | Biological decomposition, smelting of sulphide containing ores, combustion of sulphur containing fuels like coal | **Plants:** Death of living tissues; decreased growth and yield<br>**Humans:** Paralysis; damage to lungs; lowering of resistance to diseases like pneumonia and influenza<br>**Materials:** Damage to materials including corrosion |
| Carbon monoxide | Automobile engines, incomplete combustion of fuels in furnaces | **Plants:** Inhibition of nitrogen fixation; premature ageing; inhibition of cellular respiration; initiation of roots, etc.<br>**Humans:** Affects central nervous system; combines with the red blood cells and affects their oxygen-carrying capacity |
| Carbon dioxide | Combustion of fossil fuels | This gas has an insulating effect. Increase in concentration leads to the 'Greenhouse Effect' (See chapter on Climate Change and Ozone Depletion for more information) |
| Nitrogen oxides | Power generators, vehicles, forest lighting, etc. | **Plants:** Stunted growth; fires<br>**Humans:** Nasal irritation; breathing discomfort; pulmonary oedema and in extreme cases, death |
| Hydrocarbons | Vehicles, industries, refineries | **Plants:** Stunted growth<br>**Humans:** Irritation of mucus of respiratory tract; may lead to cancer |

*(continued)*

*(continued)*

| | | |
|---|---|---|
| Particulates | Lead particles from automobile exhaust, soot, fly ash from power stations, from asbestos, fluorides, aluminium metallic dusts, etc., and other natural sources | **Plants:** Inhibits growth (the leaf is covered with a layer of particles which inhibit light penetration thereby reducing photosynthesis) **Humans:** Interferes with maturation of red blood cells, disrupts functioning of cells and organs of the muscular, circulatory and nervous systems by binding with cellular enzymes; lead damages liver, kidneys and gastrointestinal tract and induces abnormalities in fertility and pregnancy; respiratory disorders; asbestos dust leads to lung scarring (asbestosis); fluoride particles may affect teeth, and lead to calcification of bones |

## WHAT IS WATER POLLUTION?

Water pollution may be defined as the introduction into a waterbody of substances of such character and in such quantity that the natural quality of the waterbody is altered. This alteration impairs its usefulness, affects the health of living organisms or renders it offensive to the senses of sight, taste and smell. Water pollution includes surface water pollution (rivers, lakes, ponds), groundwater pollution and marine pollution (see chapter on Water for more information).

SOURCES OF WATER POLLUTION: Some common water pollutants are:

*Disease-causing agents:* These include bacteria, viruses, protozoa and parasitic worms that enter the water from domestic sewage and animal wastes. They are the biggest cause of water-borne diseases, some of which can be fatal.

*Oxygen-demanding wastes:* These are organic matter needing oxygen-requiring bacteria for their decomposition. Large numbers of such bacteria, while oxidizing these wastes, deplete the dissolved oxygen in water, causing fish and other aquatic organisms to die.

*Inorganic chemicals:* These are chemicals which are soluble in water, such as acids, salts and soluble compounds of toxic metals like mercury and lead, make the water unfit to drink, harm fish and aquatic life, affect crops and corrode materials. A large

number of inorganic chemicals find their way into both surface water and groundwater from sources such as industries, mines, irrigation run-off, oil drilling, and urban run-off from storm sewers.

*Inorganic plant nutrients:* Nutrients such as water-soluble nitrates and phosphates cause excessive growth of algae and other aquatic plants. When these aquatic plants die and decay, they decompose. This causes the depletion of oxygen in the water, which is harmful for the life forms in it.

*Heat and warm water:* This water, when released from industries and power plants as part of their cooling processes, raises the water temperature and affects the health and life cycles of aquatic organisms.

*Radioactive substances:* These include the waste from the mining and refinement of radioactive metals as well as the pollution caused by their use. Radioactive isotopes are water soluble and capable of concentrating in food chains and can cause adverse health effects.

*Organic (carbon containing) compounds*: These compounds, found in water, are synthetic chemicals produced by human activities. These include pesticides, solvents, industrial chemicals and plastics. Some organic compounds find their way into surface water and groundwater through seepage from landfills, whereas others, such as pesticides, leach downwards through the soil into the groundwater, or get into surface water by run-off from farms and homes.

*Sediment or suspended matter:* These are insoluble particles of soil and other solids that become suspended in water as a result of soil erosion, run-off from agricultural fields, dumping of debris from building sites, solid wastes, forest soils exposed by logging, degraded stream banks, overgrazed fields, strip-mining and construction, etc. Such particles make the water turbid, reducing light penetration, thus affecting photosynthesis and disturbing aquatic life. The sediments also carry pesticides and other harmful substances into the water.

## What is Soil Pollution?

Soil is polluted through contamination by chemicals, particulates and solid waste, and mining activities. The main sources of soil pollution are agriculture, industrial activities, mining and solid-waste dumping.

### Sources of Soil Pollution

*Agriculture:* In earlier times, agriculture was less intensive. Both in shifting and settled agriculture, land on which the crop was grown was allowed to lie fallow for

different lengths of time, so that the soil could regain its fertility. Now with the increase in population and urbanization and the resulting scarcity of agricultural land, land cannot be left uncultivated for any length of time. The same piece of land is cultivated frequently without giving it time to replenish on its own. Over-cultivation causes the soil to lose its nutrients. Chemical fertilizers are added to increase the fertility of the soil, replenish the lost nutrients and increase the yield. Pesticides are used to kill the plants and animals that are harmful to the crops. The greater the use of these chemicals, the greater their accumulation in the soil and waterbodies. (See chapter on 'Agriculture' for more information on fertilizers and pesticides.)

*Industries:* Power plants produce huge amounts of fly ash, which is one of the major causes of soil pollution in the surrounding areas. Other industries like paper and pulp mills, oil refineries, chemical and fertilizer manufacturing, iron and steel plants,

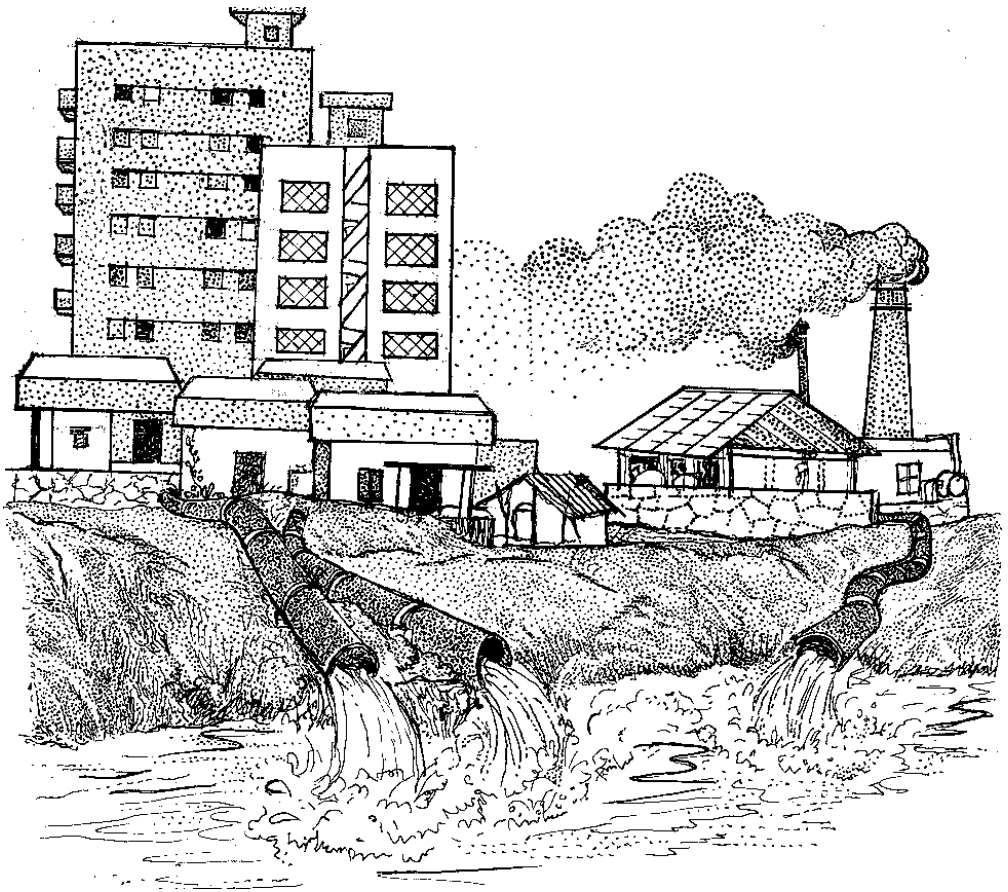


Illustration 6.1 Industrial effluents

plastic and rubber-producing complexes, produce large amounts of solid wastes which are dumped on land. These may contain chemicals which affect the quality of the soil and the life in it.

*Mining:* Mines are another significant source of soil pollution. The area around mines is usually contaminated with metals such as cadmium, zinc, lead, copper, arsenic and nickel, which are toxic to plants and inhibit their growth. Their accumulation in plants makes them unsafe for human and animal consumption.

*Urban solid waste:* Another major pollutant is garbage. In urban areas, most of the pollution is caused by sewage and household garbage. The attitude of 'use and throw' and a disposable culture have increased the quantity of waste and also changed the composition of the waste generated. In urban areas, most of the waste generated in the house is not biodegradable and so it remains on the land for a long time. This waste contaminates the air, water and land with toxins. During the rains, toxic leachates (toxins released from the toxic waste when it comes into contact with water) run-off into near-by waterbodies and also percolate into the groundwater table polluting both sources of water.

The problem of solid wastes can be reduced if the five 'Rs', refuse, reduce, reuse, repair and recycle, are seriously adopted. This will result in less garbage being generated. The excessive use of fertilizers and pesticides can be reduced by educating farmers about organic fertilizers and biological pest control and integrated pest management.

Activities which help generate waste

| **Activities** | **Waste generated** |
|---|---|
| Agricultural | Plant remains, processing wastes, animal wastes |
| Domestic | Paper, plastic, glass, metal, rags, food, fruits, vegetable peels, garden litter, packaging |
| Municipal | Sweepings from streets, schools, colleges, offices, factories, hospitals, clinics, petrol bunks, shops, etc. |
| Industrial | Wastes generated from mining operations, manufacturing, construction work, thermal stations, chemical industries, paper-making units, textile mills, cement factories, factories manufacturing engineering goods, etc. |
| Health care | Health-care establishments generate wastes like needles, syringes and other potentially infectious wastes |

*Biomedical wastes:* These wastes are generated from all types of health-care facilities, such as hospitals, clinics, medical laboratories, nursing homes, dental and veterinary clinics, and are termed as biomedical wastes.

Biomedical wastes include 'sharps' like needles, broken glass, slides; soiled dressings; pathological wastes, which include culture plates, tissue, blood and other body fluids; and chemicals. The proper disposal of biomedical wastes is of paramount importance because of their infectious and hazardous nature.

The Government of India has promulgated the Biomedical Waste (Management and Handling) Rules, 1998. These are applicable to all persons who generate, collect, receive, store, transport, treat, dispose, or handle biomedical waste. They are also applicable to any institution generating biomedical waste.



Illustration 6.2 Biohazard symbol

The biohazard symbol

The Biohazard symbol is used throughout the world to identify biomedical waste. In India, it is a must for facilities involved in the generation, collection, reception, storage, transportation, treatment, disposal or any other form of handling of biomedical waste, to affix the biohazard symbol on the containers. It is mandatory to use the symbol so that it is readily visible on containers of regulated waste (any liquid items that would release blood or other potentially infectious materials like pathological and microbiological wastes); refrigerators and freezers containing blood or other potentially infectious material; other containers used to store, transport, or ship blood or other potentially infectious materials, and bags used to dispose of regulated waste.

These labels should be red, fluorescent orange, or orange-red in colour, and should be affixed in a very prominent manner.

## WHAT IS NOISE POLLUTION?

Noise pollution may be regarded as unwanted sound dumped into the atmosphere without regard to the adverse effects it may have. Noise pollution could occur indoors or outdoors.

Sources of Noise Pollution: The main sources of noise pollution are the many modern electrical gadgets we use in our day-to-day life. Inside the house, we use products like mixers, vacuum cleaners, washing machines, coolers, air conditioners, and play radio and music systems at high volumes. The noise produced by the machinery inside factories is another source of noise pollution and is a major occupational health hazard. Outdoor noise pollution is usually from vehicular horns, festivities with loud bands, loud-speakers, and five-crackers. (See chapter on 'Industry' for more information on occupational hazards.)

Table 6.1
Decibel levels of common sounds and effects of prolonged exposure

| *Sound source* | *Sound level (dB)* | *Effects of prolonged exposure* |
|---|---|---|
| Jet plane at take-off | 150 | Eardrum rupture |
| Live rock music | 120 | Human pain threshold |
| Auto horn, 1 m away | 110 | Hearing damage |
| Busy city street | 90 | Hearing damage |
| Average factory | 80 | Possible hearing damage |
| Conversation in average office | 60 | Disturbance |
| Rustling leaf | 20 | None |
| Breathing | 10 | None |

Noise pollution inside the house can be reduced by keeping gadgets in good working order. Outside, noise levels can be reduced by reducing the use of vehicular horns. Industries should be located away from residential areas, so that the effects of noise pollution as well as air pollution on humans can be reduced.

## What is Radiation Pollution?

Radiation pollution is caused by radioactive substances, either natural or man-made. We are exposed to various kinds of radiation in our day-to-day life. Radiation causes an increase in the occurrence of cancers and other disorders. Apart from direct effects, it can cause genetic defects in living organisms.

Sources of Radiation Pollution: Human beings receive natural radiation from cosmic rays. Other sources are exposure to X-rays, radium-dial wristwatches, television, etc. All these are sources of ionizing radiation, which, from these sources is usually not high enough to cause serious damage to health. The main source of radiation pollution is the nuclear waste from nuclear power plants and other installations related to them. The other potential source is the fallout of a nuclear bomb explosion.

Radiation pollution can be reduced by improving the safety measures taken for storage and to prevent accidents in reactors and storage facilities, and by minimizing nuclear-weapons' testing.

Did you know?

All technicians and radiologists who are constantly exposed to radiation are supposed to wear a lithium badge called the Thermal Luminescent Dosimetry (TLD) badge. The badge absorbs X-rays and measures the exposure level of the individual who wears the badge to X-rays. This badge is sent to BARC (Bhaba Atomic Research Centre) once every three months to monitor the individual's exposure to X-rays. If the person has crossed the permissible limit of exposure, then he/she needs to be shifted out of the radiology section for some time. BARC is the only licensee authorized to provide this badge in India.

## Pollution Due to Wars

Wars and terrorist attacks cause tremendous destruction of property and of the natural habitats of various species. During wars and terrorist attacks, various pollutants, some very hazardous ones, are released into the environment.

A study done by the United Nations Environment Programme (UNEP) on the State of the Environment in occupied Palestinian territories, revealed that war had resulted in the dumping of wastes, pollution of groundwater, loss of natural vegetation and contamination of coastal waters in the region. In Afghanistan, where agriculture is the mainstay of nearly 85 per cent of the population, only 15 per cent of the land is suitable for farming. However, war has affected agriculture because landmines laid on this land prevent its cultivation. Further, 75 per cent of the land where the mines have been laid is actually grazing land, and cannot be used because of the dangers of mine explosions. According to the UNEP study, water resources in Afghanistan are also threatened by contamination from waste dumps and chemicals. The 1991 Gulf War resulted in several oil spills. Three hundred unburned pools of oil left in the desert contaminated some 40 mn t of soil, while 736 burning oil wells gave off huge amounts of carbon dioxide and hydrocarbons (*Gobar Times*, 15 April 2003, p. 68).

# Dealing with Pollution

Pollution clean-up or pollution control in the past has been the primary approach to tackling the issue. This approach looks at ways by which the effects of pollution that has already occurred can be mitigated. The common measures include steps to clean or treat waste water and gaseous emissions from industry, the introduction of emission and effluent standards, etc. Of late, it is becoming increasingly clear that such measures are only

ways of reacting to situations with solutions that are not sustainable. They fail to tackle the root cause of the problem.

Pollution under control

Pollution Under Control (PUC) certificates are required to be obtained every six months for all categories of vehicles. In the case of petrol vehicles, idling CO measurements are taken, while in the case of diesel vehicles, free acceleration smoke is measured. RTOs, and some petrol and service stations, are authorized to issue PUC certificates. These certificates indirectly serve as a guide to the performance of the vehicle and the maintenance needed. If below standard, the vehicles need to be serviced to be brought up to the proper operating level. (Based on www.giteweb.org/iandm/senguptapresentation.pdf.)

## Pollution Prevention

Today, it is being increasingly recognized that 'end-of-pipe' solutions are not adequate. The need is for pollution prevention or input pollution control; that is, reducing or eliminating the release of pollutants and wastes into the environment. Pollution prevention involves changes at many levels in all areas of production—industrial or agricultural, and use—domestic or commercial.

The new strategies focus on the entire production process, examining where wastes are generated and exploring how they can be reduced. This could involve numerous possibilities—changing manufacturing processes, using different raw materials, finding substitutes for hazardous substances, improving the operations and maintenance of units, and recycling and reusing waste materials.

## Environmental Monitoring Programmes

Monitoring programmes are needed to continuously assess the quality and quantity of the pollutants released into the environment. This helps in making informed decisions for pollution control, and also in reviewing the status of pollution in our environment.

## Conserving Ecofriendly Traditional Practices

Often pollution-related problems have cropped up because of a shift from a traditional occupation or practice to a modern one. For example, traditional farming practices did not depend on chemical fertilizers and pesticides. Today, we can see a shift from agriculture dependent on chemicals to organic farming, which is more eco-friendly and

sustainable. Hence, banking on traditional knowledge and innovating to make it suit present needs is one way of preventing pollution.

## TECHNOLOGICAL SOLUTIONS

Technologies often have to be improved for pollution control as well as prevention, which would involve research into problems and finding suitable solutions.

### The importance of biotechnology

Biotechnology is an important tool for improving waste management methods, degradation of toxic pollutants, sewage treatment, etc. Dr Anand Chakraborty, a scientist based in the USA, was successful in synthesizing an oil-eating bacteria. The bacteria can degrade different types of hydrocarbons. This was first used in 1990 for cleaning up an oil spill in the waters in Texas. Technologies like bioremediation can help in cleaning up and converting hazardous waste to non-hazardous or less hazardous waste. For example, a microbe referred to as GS-15 can utilize uranium and can be used in a bioreactor to treat uranium-containing waste from nuclear plants.

## LAWS

The Government of India in its efforts to reduce pollution, has introduced various laws from time to time, depending on the need of the hour and keeping sustainable development in mind. The various Acts and Rules required for the implementation of the laws are expected to make industries more responsible as they are liable to be fined or may even be closed down if they are found to violate emission or pollution standards. (See Appendix 1 'Environmental Laws in India'.)

### Environment acts and rules

**The Environment Protection Act (1986),** is an umbrella legislation put forward by the Ministry of Environment and Forests to create comprehensive legal measures for safeguarding the environment through the framing of rules, notification of standards, notification of environmental laboratories, delegation of powers, identification of agencies for the management of hazardous chemicals, setting up of environmental protection councils in the states, etc.

**The Environment (Protection) Rules (1986),** lay down procedures for the setting of standards for emission or discharge of environmental pollutants. Broadly, there are three types of standards: **source standards** which require the polluter to restrict at source the emission and discharge of environmental pollutants; **products' standards** which fix the pollution norms for new manufactured products such as cars; and **ambient standards** to set maximum pollutant loads in the air, and to guide regulators on the environmental quality that ought to be maintained for healthy living.

## Education and Awareness

There is a vital need to educate citizens about their rights and responsibilities for a pollution-free environment. This awareness will lead to a strong citizen action against erring industries or persons and may, in the long run, help create a pollution-free environment. It will also lead to each and every citizen playing his/her role in reducing pollution.

Some types of pollution can be controlled by individual action, for example, reducing vehicular pollution or garbage dumping. There are others which would need many instruments (policies, laws, financial, technological) and the involve-ment of various sections of society including policy makers, industrialists, etc.

The effective implementation of pollution-control measures requires the cooperation of different people and agencies. It has to start at the policy level. Once the government's policies are in place, laws are made. Implementing the laws is the next step. The challenge is also to find ways to make the implementation economically viable.

Every action towards controlling pollution is like a drop in the ocean ... and every drop counts.

### I Questions

1. What is the difference between primary and secondary pollutants?
2. How do natural processes take care of pollution?
3. 'Dilution of pollution is the only solution'. Do you agree? Why or why not?
4. Why is biomedical waste a cause for concern?
5. Name five ways of dealing with pollution?
6. What are the different types of standards for the setting of which the Environment (Protection) Rules (1986) lay down procedures?

### II Exercises

1. A. Identify and name five polluting units—workshops (e.g. automobile garage, carpentry workshop, electrical workshops, etc.), kiosks, shops (tea stalls, restaurants, grocery stores), etc.—in your neighbourhood.

   a. _____
   b. _____
   c. _____

d. _____
e. _____

B. Record the type of waste being generated by each type of establishment: (e.g. automobile garage would generate waste engine oil, lubricants, petrol, diesel, etc.). Also, estimate the quantity of waste being generated by each unit and the total waste generated by all the units present in a 1 $km^2$ area around your house. Note these in the table given below.

| Type of Establishment | Types of Waste Generated | Quantities of Waste Generated | No. of Establishments in 1 $km^2$ Area |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

C. Identify the health impacts of some of these pollutants. You may need to carry out library research to get this information.

| **Name of the Pollutant** | **Health Impacts** |
|---|---|
| Engine oil | |
| Smoke | |
| Sawdust | |
| Kitchen waste | |

2. From your local State Pollution Control Board, or the Central Pollution Control Board data (posted on the Internet or published), find out the ambient air quality of your town or city, or of the city located closest to you, based on the following parameters: sulphur dioxide, nitrogen dioxide and suspended particulate matter. Is it within the permissible level as per the Environment Protection Act? How does the data compare with the national averages? Plot the data available for the last 10 years. Do you perceive any trend?

Also, collect information on
a. the number of vehicles registered in your town/city; and,
b. respiratory health problems reported at the local hospitals.

Is there any relationship of either one with the air quality data?

## III DISCUSS

1. *There is no pollution if there are no environmental laws or regulations that establish specific environmental quality standards.* Discuss this statement.
2. *Turning the corner on air pollution requires moving beyond patchwork, end-of-pipe approaches to confront pollution at its sources. This will mean reorienting energy, transportation and industrial structures toward prevention.*

**Hilary F. French**

Do you agree with this statement? What are some of the steps that would be necessary in each of the three sectors mentioned, towards the prevention of pollution?

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# Chapter 7

# Agriculture

Kalyani Kandula

From a nation once dependent on food imports to feed its population, India today is not only self-sufficient in food-grain production, but has also built up substantial reserves. The progress made in agriculture during the last four decades has been one of the biggest success stories of independent India. Agriculture and allied activities are the single largest contributor (almost 33 per cent) to the gross domestic product (GDP). About two-thirds of the workforce in the country depends on agriculture as a means of livelihood.

## Evolution of Agriculture

It is generally believed and accepted that agriculture originated in the river valleys of the subtropical regions of the world. The earliest known domestication of crops occurred in the river valleys of the Tigris and the Euphrates in Mesopotamia (now Iraq), the Nile in Egypt, the Huang Ho in China, and the Indus in ancient India. Small human groups settled in compact areas with access to water and fertile soil, where food could be grown and some animals domesticated. Over time, with assured food supply, these clusters of settlements evolved into villages. The surplus food that could be produced in these favourable locations supported the growth of urban centres, and led to the establishment of early civilizations.

Agriculture flourished in ancient India in the Indus valley. It supported the development of ancient urban centres such as Harappa and Lothal. Among the ruins at Harappa are huge granaries which indicate that surplus food was produced by agriculture during that time.

While agriculture may be defined as the practice of cultivating the soil, harvesting crops and raising livestock, the process involves a complicated, interwoven mesh of factors—soil, plants, animals, implements, human labour, other inputs and environmental influences. Over time, a variety of agricultural systems developed throughout the world.

## CLASSIFICATION OF AGRICULTURE

Agricultural systems may be broadly classified as **traditional** and **modern**.

### TRADITIONAL AGRICULTURAL SYSTEMS

There are two main types of traditional agriculture: traditional subsistence agriculture and traditional intensive agriculture. **Traditional subsistence agriculture** produces enough crops or livestock and livestock products for a farm family's survival, and a surplus to sell or put aside for hard times; and **Traditional intensive agriculture** involves increased inputs of human labour, fertilizer, and water to get a higher yield per area of cultivated land to produce enough to feed a farm family and a surplus for sale.

In traditional agriculture, the control over farming lies with the farmers—they collect the seeds, decide which crops and which varieties to grow, what and how much of the produce to keep for themselves, and what and how much to sell.

Traditional systems can be further classified as irrigated agriculture; forest-based agriculture; livestock-based pastoral systems; and, crop-based livestock-rearing systems.

IRRIGATED AGRICULTURE: This form of agriculture originated in the river valleys. It can be subsistence or intensive (or productive) agriculture. The crops grown are basically food crops, but some cash crops are also grown.

FOREST-BASED AGRICULTURE: From the river valleys agriculture spread to forest areas. It was not easy to practise agriculture in areas covered by dense jungles. Agriculture, therefore, developed a new form known as shifting, or slash and burn, agriculture. The crops grown are basically food crops. This form of agriculture is known as subsistence agriculture.

#### Shifting agriculture

Shifting agriculture is a system of agriculture in which the land cultivated is rotated. A patch of forest land is cleared and cultivated for one or a few seasons, after which it is vacated and allowed to lie fallow for several years, while the cultivator shifts to clear and cultivate another plot of land for the next season's planting. This pattern of farming is continued till the farmer returns to the original piece of land, when its fertility has been restored.

This type of cultivation has also been called 'slash and burn' agriculture because it involves chopping down trees or bush cover, and setting fire to the fallen vegetation. The burning of the vegetation releases nutrients that can be used by crops for one or two years before the soil is exhausted. The return of the natural vegetation prevents erosion and repairs the damage done by temporary agricultural use.

*(continued)*

*(continued)*

This traditional method was practicable when populations were small. With the increase in populations the pressure on land also increases; the rotation cycles shorten as farmers return to a patch of land without allowing it to adequately regenerate. As a result, this form of cultivation is not practical any more. This method of agriculture is still practised in parts of north-east India where the rotation cycles have come down from approximately 20 years to three to four years.

LIVESTOCK-BASED PASTORAL SYSTEMS: A large number of animals were domesticated around the grasslands of West and Central Asia. These were mainly herbivorous species that ate grass: sheep, goat, cattle, horse and camel. In these areas, because of the climate and physical environment, crop farming was risky and uncertain, but raising livestock proved a suitable alternative. Early cattle, sheep and goat rearers were largely migratory, who herded their animals from place to place in search of grasslands. When the pressure on grasslands became excessive they moved out in search of fresh pasture or invaded fresh territory. Breeds selected by these herders were essentially those that could withstand the stress of migration, drought and periodic food and nutritional shortages. This form of agriculture is still practised in parts of India; for example, by the Rabaris in Gujarat, and the Gujars in Jammu & Kashmir and Himachal Pradesh.

CROP-BASED LIVESTOCK-REARING SYSTEMS: A major revolution in livestock farming took place many centuries ago when crop farming and livestock rearing were brought together under the mixed crop-livestock farming systems. Under these systems, by-products from agriculture, namely crop residue and straw, could be used to feed the animals. In exchange the animals could be put to work on the land, and animal waste, namely, dung, could be used to fertilize the field. The main products from agriculture (grain, seed and fruit) and livestock (milk, meat and wool) were used for human consumption. It was this great revolution that led to the generation of food surpluses and helped societies go beyond the level of mere subsistence.

## MODERN AGRICULTURAL SYSTEMS

Modern systems of agriculture use large amounts of fossil-fuel energy, water, chemical fertilizers and pesticides to produce huge quantities of crop or livestock. The different kinds of modern agriculture include mechanized and chemical-based farming, commercial farming, contract farming, and genetic farming using biotechnology.

MECHANIZED AND CHEMICAL-BASED FARMING: In this kind of farming, animal power, manure and traditional methods of pest control are replaced by mechanization and chemicals. While the original intention was to enhance food production, with increased water availability, people shifted to cash crops and monocropping.

COMMERCIAL FARMING: Under this form of agriculture, farmers grow cash crops to cater to external markets. Monocropping is the norm. This kind of farming is mechanized and uses chemical fertilizers and pesticides.

CONTRACT FARMING: This form of agriculture includes horticulture and floriculture. The demands of the market determines what crops are to be grown. To that extent, farmers lose control over what they can grow on their own land. Markets also dictate and determine price in addition to what should be grown.

GENETIC FARMING USING BIOTECHNOLOGY: The propagation of plants in this form of agriculture takes place in laboratories. All control is in the hands of corporations or scientists. Farmers are dependant on external agencies for seed, growing technology, markets, etc.

## AGRICULTURE AS A PRODUCTION PROCESS

Like any other production activity, agriculture, too, has three basic components: the inputs, the processes or the technology used, and the outputs and consequences. The inputs include all things that are necessary to make production possible. In agriculture, the inputs usually are seeds, water, fertilizers, pesticides, human labour and energy (for running tractors, irrigation pumps, etc.).

The processes refer to the pattern of agriculture. For example, do farmers raise three crops each year or do they leave the land uncultivated for a certain period of time to allow it to regenerate? Do farmers cultivate only one kind of crop or do they grow a mix of different crops?

The outputs and consequences are the things that result from the production process. These will include: (*a*) the desired outputs, which in the case of agriculture are food grains, fruits, vegetables, etc., and (*b*) the related outputs and consequences, which include wastes.

Certain wastes are unavoidable in the production process. For example, when crops are grown for oilseeds, only the seed may be the desirable part of the plant. Some parts of the plant such as the leaves may be used as fodder. But some other parts of the plant, the stem, the roots, etc., do not have direct utility and may have to be disposed of as waste. Certain other wastes are created by the production process. For example, if the farmer applies excessive quantities of fertilizer, some of it may not be absorbed by the plant, and may remain in the soil. This may find its way through run-off to nearby waterbodies and affect their well-being as well as that of the organisms that inhabit or depend upon them.

The scientific and technological developments of the 20th century brought about major changes in the way food is grown. Chemical fertilizers, for example, made possible

massive increases in the amount of grain that could be produced per unit area of cultivated land. Chemical pesticides and weedicides ensured that plant and animal species harmful to crops were killed. The use of machines made it easy for large tracts of land to be brought under cultivation. Building dams and reservoirs, constructing canals and diverting river waters brought more land under irrigation and made it suitable for cropping.

## Post-Independence Agriculture in India

Agricultural practices have probably changed faster in the past 200 years than ever before. Modernizing agriculture in the country has successfully made India self-sufficient in food grains. This was made possible by the improved productivity of high-yielding varieties. In 1996, Indian farmers harvested more than 60 mn t of wheat, as compared to 6 mn t at the time of Independence.

This revolution in agricultural production is popularly known as the Green Revolution. Spanning the period from 1967–68 to 1977–78, it changed India from a nation deficient in food to one of the world's leading agricultural nations.

### The Green Revolution in India

The Bengal Famine of 1943 was the world's worst recorded food disaster. An estimated 4 million people died of hunger that year alone in eastern India (including what is today Bangladesh) under British rule.

Achieving food security was a paramount item on the agenda of the newly independent India. Until 1967, efforts were largely concentrated on expanding the farming areas. But deaths due to starvation and a population increasing at a much faster rate than food production were some of the factors that called for drastic action to increase the yield. The action came in the form of the 'Green Revolution', a term coined by Dr William Godd of the US in 1968, when India brought about a great jump in wheat production by taking up the cultivation of high-yielding varieties of seeds.

Dr M.S. Swaminathan, often referred to as the 'Father of the Green Revolution', made a significant contribution to the introduction of the dwarf Mexican varieties of wheat into India. These varieties had been developed by agriculture scientist, Dr Norman Borlaug, as part of a programme to increase crop yields in Mexico. He produced high-yielding wheat varieties by adopting some new concepts in plant breeding. The most important concept was that of an efficient plant type that would expend less energy in growing tall stalks and use the free energy to produce higher yields. To achieve this he cross-bred a dwarf variety of wheat from Japan with Mexican and Colombian wheat varieties. The newly developed dwarf varieties were released in 1962. By 1965, Mexican

wheat production showed a per-acre yield increase by as much as 400 per cent as compared with the yield levels in 1950.

The three basic elements of the Green Revolution in India were:

1. **Continued expansion of farming areas:** Expansion of land under farming was continued, but this was not enough to meet the rising demand for food. While this was not the most striking feature of the Green Revolution, the expansion of cultivated land continued.
2. **Double-cropping of existing farmland:** Double-cropping was a primary feature of the Green Revolution. Instead of a one-crop season per year, a practice which depended on the monsoon which brought rain in one season of the year, a shift was made to two crops per year. This was made possible by setting up huge irrigation facilities. Several large dams and canal systems were constructed to impound and distribute water for irrigation, and also to generate hydroelectricity.
3. **Using genetically improved seeds:** The Indian Council for Agricultural Research developed new strains of high-yield variety (HYV) seeds, mainly of wheat and rice and also of millet and corn. The most noteworthy HYV was the K68 variety of wheat. The credit for developing this strain goes to Dr M.P. Singh who is also regarded as a hero of India's Green Revolution.

The impacts of such interventions yielded the desired result of increasing food production; but there were also some unanticipated and undesirable consequences. The latter, including environmental impacts, however, became known only later. For example, hybrid seeds require intensive irrigation and the use of high quantities of inorganic fertilizers and pesticides, which, over time, have resulted in the depletion of soil nutrients, contamination of surface and groundwater, increasing cost of production, and disintegration of the economic and the social conditions in rural communities (see section on Environmental and Social Consequences). There are also health impacts of using chemical fertilizers and pesticides—both on the farmers and on the consumers of such crops.

There were other impacts too. It is believed that the nutritive value of crops (protein, vitamin, minerals, etc.) grown using such practices is less than that of crops grown by traditional methods. However, not much scientific research related to this problem has been done.

Some Environmental and Social Consequences: The Green Revolution's environmental and social consequences are increasingly becoming known as these have been clearly manifested in Punjab, which was the seat of the Green Revolution in India.

*How green was the revolution? The story of Punjab:* The Green Revolution was essentially based on a seed and fertilizer package. Since the inception of the Green Revolution, fertilizer consumption in Punjab has increased thirtyfold because the new

seeds were bred to be high consumers of fertilizers. After some years of bumper harvests in Punjab, crop failures at a large number of sites were reported, in spite of liberal applications of NPK (nitrogen-phosphorus-potassium) fertilizers. The fact is that plants need more than just NPK. They need micronutrients such as zinc, iron, copper, manganese, magnesium, molybdenum, boron, etc. Zinc deficiency is the most widespread of all micronutrient deficiencies in Punjab. As a result, increased NPK application has not shown a corresponding increase in the output of rice and wheat. In fact, the productivity of wheat and rice has been fluctuating and even declining in most districts in Punjab.

The Green Revolution has also resulted in soil toxicity caused by an excess of trace elements in ecosystems. For example, fluoride toxicity is an unintended consequence of irrigation in various parts of India. In some places, large-scale groundwater extraction for irrigation caused water levels to drop and hit fluoride-bearing rocks in the aquifers, leading to a rise in the fluoride content in the water to levels higher than those considered safe for human consumption.

*Change in land-use patterns:* In Punjab, a very rapid change in the pattern of land use took place. Since the start of the Green Revolution, the area under wheat has nearly doubled and the area under rice has increased five times. During the same period, the area under pulses (legumes) decreased by half. Wheat and rice are considered soil-depleting crops, while pulses are considered soil-building crops. Reducing the cultivation of leguminous crops means depriving the soil of a natural fertilizing agent. Repeated cultivation of wheat and rice crops means draining the soil of nutrients.

*Loss of genetic diversity:* Traditional agricultural systems encourage diversity in crop breeds. The Green Revolution displaced genetic diversity in two ways. First, it brought in monocultures of wheat and rice which replaced the existing mix and rotation of diverse crops like wheat, maize, millets, pulses, and oilseeds. Second, even with rice and wheat, the Green Revolution encourages growing single varieties derived from exotic dwarf varieties, to maximize grain production. This is at the cost of the diverse native varieties of rice and wheat that are suited to the different soil, water and climatic conditions. It is dangerous to depend only on a couple of crop varieties to meet the food supply of hundreds of thousands of people. All the wheat and rice varieties grown in Punjab since the beginning of the Green Revolution are derived from the genetically narrow base of the Borlaug wheats and the International Rice Research Institute (IRRI) rice. This makes the crop more vulnerable to outbreaks of disease and other adverse natural conditions.

The cropping pattern in Punjab has witnessed a major shift towards wheat in the *rabi* season and rice in the *kharif* season. Wheat has spread at the cost of gram, barley, rapeseed and mustard, which were usually sown as mixed crops along with traditional wheat varieties. Similarly, the area under rice has increased at the cost of maize, *kharif*, pulses like *moong* and *masoor*, groundnut, green fodder and cotton. While this practice deprives the rice crop of the nitrogen-fixing capacities of the displaced leguminous crops, it

demands artificial fertilizer inputs for the cultivated paddy. In addition, it narrows the availability of different foods with different nutritional benefits.

*Irrigation-related problems:* Intensive irrigation is a major component of the Green Revolution. The Green Revolution increased the need for irrigation water at two levels. First, it prompted a shift away from crops which require less water, such as millets and oilseeds, to monocultures and multi-cropping of wheat and rice, which require water inputs throughout the year. Second, the crop varieties promoted by the Green Revolution need much more water than indigenous varieties. High-yielding varieties of wheat, for example, need three times as much irrigation as traditional varieties.

The demand for water has put a lot of pressure on Punjab's groundwater resources. Ninety per cent of Punjab's groundwater extraction is for agriculture. This is 20 per cent higher than the national average. Research shows that for every 3 l of groundwater used for agriculture, only 1 l is replenished.

Irrigation without proper consideration for the drainage of excess water can be dangerous. Land gets waterlogged when the water table is within 1.5 to 2.1 m below the ground surface. The water table rises if water is added at a rate greater than the rate at which it can drain out. Waterlogging is associated with another problem–salinization. In regions of scarce rainfall, the soil contains a large amount of unleached salts. Excessive irrigation brings those salts to the surface and leaves behind a residue when the water evaporates. It can also cause unleached salts to accumulate in the upper layers of the soil. This excessive salt build-up in the soil is called **salinization**. Salinization diminishes the productivity of the soil and, in extreme cases, ruins it forever. Both these conditions, waterlogging and salinization, can lead to desertification. The rich alluvial plains of Punjab suffer seriously from desertification caused by the introduction of excessive irrigation water to make Green Revolution farming possible.

*Intensification of inequity:* The Green Revolution type of agriculture requires intensive inputs and technologies as, for example, new seeds, more fertilizers and pesticides, tractors and other agricultural machinery, and irrigation. Traditionally, access to many agricultural inputs was free, or was locally traded in non-monetary ways, or was available at prices affordable by most farmers. But when such inputs had to be necessarily bought from the market, poorer farmers could not afford them. So the existing inequities grew.

The Green Revolution technology also demanded landholdings of a substantial size, to make the use of these inputs and technologies viable. For instance, employing a tractor is not economically viable on small landholdings. Due to these factors, farmers with smaller landholdings and less capital were unable to compete with farmers with larger holdings. For example, small farmers with land up to 5 acres constitute 48.5 per cent of the cultivating households in Punjab. In 1974, each small farmer in Punjab was annually running at a loss, whereas farmers with land between 5 and 10 acres made a profit. Unable to maintain their landholdings, many small farmers sold their land to larger farmers. Between 1970 and 1980, there was a 25 per cent reduction in smallholdings in Punjab

due to their economic non-viability. Some of the newly landless farmers became agricultural labourers working for the more affluent farmers.

Looking back, it seems that the gains from the Green Revolution were not spread evenly across society. Only particular crops, regions and farmers actually benefited from the Green Revolution because of the requirement of large landholdings, irrigation facilities, high inputs of fertilizers and pesticides, and intensive irrigation. Rather than a boon for all, the Green Revolution intensified inequities in rural society.

Recent studies and research at the International Rice Research Institute (IRRI) show that the growth in rice yield has slackened, and is failing to outpace population growth in many countries. Cereal productivity in yield per hectare has been declining: it went down from 2.2 per cent per year in 1967–82 to 1.5 per cent per year during the 1980s and early 1990s. These trends, combined with rapid population growth and environmental degradation, have already affected 40 per cent of cropland, and cleared 20 to 30 per cent of forests. It is clear that agriculture must be made more productive and its adverse impacts must be reduced.

## Agriculture and Environment

Some facts

- About 60 per cent of India's cultivated land area suffers from soil erosion, waterlogging and salinity problems.
- It is estimated that between 4.7 and 12 bn t of topsoil is lost each year as a result of soil erosion.
- About 30 mn ha of fragile land now under cultivation is progressively degrading.
- Our livestock requires 932 mn t of green fodder and 750 mn t of dry fodder annually. But only 250 and 414 mn t, respectively, are available. Inadequate fodder affects the productivity and health of livestock.

The inputs, processes and outputs associated with modern agricultural systems have influenced our environment in many ways. Some of the factors that impact the environment are discussed here.

### Fertilizers

Fertilizers are used to increase the fertility of the soil by adding nutrients which help in plant growth. Fertilizers are of many different kinds and give different kinds of nutrients to the soil. They are divided into broad two groups—organic fertilizers and chemical fertilizers.

**Organic fertilizers** are natural fertilizers; for example, cow dung and compost. They are made up of natural components which are biodegradable. Organic fertilizers are used in traditional agriculture.

**Chemical fertilizers** are essentially chemicals produced in factories, and are sold in the market. These fertilizers are beneficial in increasing crop yields, but their prolonged usage can have a detrimental effect on soil health. Excess fertilizer from agricultural fields finds its way into ponds, lakes and rivers through run-off water from the fields. These run-off fertilizers speed up the growth of algae in the pond, lake and river waters. When these algae die they begin to decompose and their decomposition causes depletion of the dissolved oxygen that is very important for aquatic life. This depletion may harm or even kill aquatic life, including fish. This phenomenon is known as eutrophication. Chemical fertilizers also create nitrate pollution in groundwater when they dissolve in water and seep into the soil.

### Biofertilizers

Intensive use of chemical fertilizer is not only costly but has [a] detrimental effect on the natural resources like rivers and soil. Agricultural run-off pollutes water as well as soil. Hence, there is [a] need to find alternatives. Biofertilizers are one such alternative. They are efficient nitrogen-fixing, phosphate solubilizing (dissolving), cellulose-decomposing micro-organisms, which when applied to seed or soil, enhance availability of nutrients to plants and offer an eco-friendly, economically viable and socially acceptable means of reducing external input of chemical fertilizers. These include Rhizobium and Azotobacter.

Rhizobium are the most important biofertilizers which fix atmospheric nitrogen by forming nodules on legume plants which convert nitrogen into ammonia. Azotobacter are non-symbiotic micro-organisms. They produce growth-promoting substances and chemicals which are inhibitory to certain root pathogens. The response of Azotobacter depends upon the amount of organic matter in the soil. (*Indian Farmers Digest*, May 2001.)

## PESTICIDES

Pesticides are used with the intention to kill certain species or control populations of unwanted fungi, animals or plants because they harm the crops. For example, some insects that feed on crops are pests; others, like bees, are beneficial as they help to pollinate plants. Unwanted plants are generally referred to as weeds. Pesticides can be divided into several categories based on the kinds of organisms they are used to control.

Insecticides are used to control insect populations by killing them. Unwanted fungal pests that can weaken plants or destroy fruits are controlled with fungicides. Mice and rats are killed by rodenticides. Plants' pests are controlled with herbicides.

A perfect pesticide kills or inhibits the growth of only the specific pest organism (target organism) that causes the problem. However, most pesticides are not very specific and

kill many non-target organisms as well. For example, most insecticides kill both beneficial and pest species; rodenticides kill other animals as well as rodents; and most herbicides kill a variety of plants, both pests and non-pests. Less than one out of 1,000 kinds of insects is a pests but insecticides kill indiscriminately. Pesticides also adversely affect other species such as frogs, snakes and birds, which are natural pest control mechanisms. They destroy earthworms which are highly beneficial to agriculture. Also, exposure to pesticides over long periods can harm the health of humans and animals. Thus, pesticides do not just kill pests, they can also kill a large variety of living things, including humans.

### Pesticide pollution

Recovering from the euphoria of the Green Revolution, India is now battling the residual effects of the extensively used chemical fertilizers and pesticides in the soil.

The decade from 1980 to 1990 alone saw the area under pesticides in India increase a whopping twentyfold, from 6 mn ha to 125 mn ha. After a high annual consumption of nearly 75,000 MT reached in the early 1990s, interventions in the form of Integrated Pest Management (IPM) practices have only now started to show a declining trend in the use of pesticides in India.

Interestingly, India's consumption of pesticides per hectare is low when compared with world averages—0.5 kg/ha against Korea's 6.60 kg/ha and Japan's 12.0 kg/ha.

Yet, despite a comparatively low use of pesticides in India, the contamination of food products in the country is alarming. About 20 per cent of Indian food products contain pesticide residues above the tolerance level compared to only 2 per cent globally. No detectable residues are found in only 49 per cent of Indian food products compared to 80 per cent globally. (http://www.teri.res.in/teriin/news/terivsn/issue31/pesticid.htm.)

The effectiveness of a pesticide is found to go down when it is used over a period of time. There has been an alarming increase in the number of cases of resistance to pesticides in insects, plants, pathogens, vertebrates and, to some extent, in weeds. For example, resistance in insects has risen from seven species resistant to DDT in 1938 to 447 species which are now resistant to almost all the principal classes of pesticides.

In India, of the 133 pesticides for regular use, 34 are those that are either banned or restricted in some other countries but are still used here. Some of the hazardous pesticides, like DDT and benzene hexachloride which are proven carcinogens (cancer causing), even though they are banned in India for agricultural use, still continue to be used and also find their way into waterbodies. It is believed that one of the effects of the accumulation of high levels of pesticides such as DDT is that the shells of birds' eggs are much thinner than normal. When the parent birds sit on the eggs to incubate them, the eggshells break, killing the chicks developing inside. Hawks, eagles and other fish-eating birds are especially affected by such pollution.

Pesticides from agricultural lands run down with rainwater and enter local streams or lakes. People who use this water for bathing, washing, etc., are obviously affected.

Pesticides affect the health of farmers who use them. They can enter the body in small quantities through the skin and eyes, or through the nose and mouth. In Punjab, where high quantities of fertilizers and pesticides were applied in the fields, breast-milk samples collected from the women in the area were found to contain high levels of pesticides.

### Biopesticides

Biological Pest Control is a method of pest control in which pests are suppressed by their natural enemies such as birds, spiders, mites, fungi, bacteria, viruses or plants, some examples of which are discussed here.

Farmers plant bamboo stalks in paddy fields so that predatory birds can use them as supports while they pick and eat insect pests from rice plants. Farmers in Telangana, Andhra Pradesh, light bonfires in fields during *Deepawali* and *Sankranti* to attract and destroy flying insect pests. Neem contains several chemicals, including *azadirachtin*, which affect the reproductive and digestive processes of a number of important pests. Neem also acts as a repellent and antifeedant, and its oil is effective against leaf folders/borers, aphids and bollworms. In addition to being environmentally safe, neem is effective against a wide range of pests. About 200 species of insects are known to be controlled by neem.

Biological control is sensitive to external factors like climate, type of crop, size of the plot, etc. Biological control is not new to agriculture. Even the earliest farmers practised it by rotating their crops and fertilizing them with organic manures. These and many other traditional practices provide effective disease control by giving enough time and opportunity for the biological destruction of disease organisms.

## GENETIC DIVERSITY

Agricultural practices affect and are affected by the genetic diversity of the crop plant and of the livestock. This diversity refers to the number, variety, and variability of crop plants and livestock. These include traditional and modern varieties of crops and livestock, their wild relatives and other wild species that can be used now and in the future for food and agriculture. Genetic diversity is vital for the maintenance and improvement of agriculture.

VALUE OF CROP GENETIC DIVERSITY: Only about 30 crops feed the world. These are the crops that provide 95 per cent of the dietary energy (calories) or protein. Wheat, rice and maize alone provide more than half of the global plant-derived energy intake. A further six crops, sorghum, millet, potatoes, sweet potatoes, soybean, and sugar (cane/beet), bring the total to 75 per cent of the energy intake.

While the number of plant species which supply most of the world's energy and protein is relatively small, the diversity within such species is often immense. For instance, within the rice species (*Oryza sativa*), there are an estimated 100,000 distinct varieties. Rice

originated in India and then spread throughout Asia. Rice grows in many places where other food crops are difficult to grow. This is possible because the rice plant has a very flexible genetic make-up and the ability to adapt to the local environment. According to Dr Richharia, a well-known rice scientist, 400,000 varieties of rice existed in India during the Vedic period. Even today, 200,000 varieties of rice exist in India. This means that even if a person were to eat a new rice variety every day of the year, he could go on for over 500 years without reusing a variety! That is the genetic diversity within one species.

Table 7.1
Diversity of agricultural crops in India

| *Groups* | *No. of species* |
|---|---|
| Cereals and millets | 51 |
| Fruits | 104 |
| Spices | 27 |
| Vegetables and pulses | 55 |
| Fibre crops | 24 |
| Oilseeds | 12 |

With this astounding diversity of crops, it helps to classify them on some basis. Generally, crop varieties can be classified into modern varieties and farmers' varieties. Modern varieties are the products of plant breeding by professional plant breeders in private companies or publicly-funded research institutes. These varieties are sometimes called high-yielding varieties (HYVs). They typically have a high degree of genetic uniformity. Farmers' varieties, on the other hand, are products of breeding or selection carried out by farmers over many generations. Farmers' varieties tend not to be genetically uniform and contain high levels of genetic diversity. Because of this genetic diversity, farmers' varieties are the focus of conservation efforts.

Genetic diversity provides stability for farming systems. It enables farmers to adapt crops suited to their own ecological needs, culture and traditions. It also provides self-sufficiency and security during difficult times. Losses due to the failure of a particular crop or variety are compensated for by the yield of other crops or varieties. Genetic diversity is an insurance against future adverse conditions. While we may not be aware of the potential use of genetic resources today, they may in future provide useful characteristics, such as resistance to new diseases, or adaptability to changed climatic conditions.

Genetic diversity represents a treasure chest of potentially valuable but as yet unknown resources. This is the reason for maintaining both the wild ecosystems and the traditional farming systems, as plants in these habitats are likely to contain and develop new and valuable genetic characteristics. For example, in India, cassava yields have increased up to 18 times with the disease resistance provided by the genes from the wild Brazilian cassava.

Table 7.2
Diversity of domestic livestock breeds in India

| *Groups* | *No. of species* |
|---|---|
| Cattle | 30 |
| Sheep | 40 |
| Goats | 20 |
| Camels | 8 |
| Horses | 6 |
| Donkeys | 2 |
| Poultry | 18 |

LIVESTOCK GENETIC DIVERSITY: The focus of modern farming is on increased productivity. This single focus has led to the selection of a few breeds of animals disregarding several other significant characteristics of other breeds. This narrow genetic base selected for a particular trait may be completely unsuited to other local conditions such as the ability of a breed to withstand drought, or to emerging future problems such as diseases. A wide genetic base makes possible sustainable livestock farming under diverse conditions.

Genetically Modified Organisms (GMOs): A bane or a boon to Indian agriculture?

Ever since the Agreement on Agriculture of the World Trade Organization (WTO) began to be debated in India, increasing agricultural productivity and improving food quality are being tossed [about] as the only solutions for farmers' survival. One way being promoted is the improvement in crop productivity through genetically modified organisms (GMOs).

GMOs can be a boon to Indian agriculture in many ways. Crop damage can be significantly minimized with the development of genetically reprogrammed seeds designed to resist disease attacks (while minimizing or eliminating costly and hazardous pesticides), and adverse abiotic factors. Since the arable land available for agricultural expansion in India is limited, enhancing stress tolerance in crop plants will permit productive farming on currently unproductive lands. Also the shelf life of fruits and vegetables can be prolonged. Human and livestock health can be improved through genetically modified crops with enhanced nutritional quality traits and through the production of edible vaccines and other pharmaceutical products.

GMOs are, however, also perceived as possible threats to human health and the environment. The concerns raised about the safety of genetically modified crops must be taken very seriously. Reports from Cornell University have shown that butterflies fed on pollen from genetically modified corn showed retarded growth and very high mortality. Swiss scientists have also shown that insects useful in agriculture as biocontrol agents for pest management were damaged seriously in areas where transgenic corn was being grown. The culprit in both cases is Bt corn, a genetically engineered variety of corn using the same system of disease resistance as used in the notorious Bt cotton planted by Monsanto in India.

The incorporation of GMOs into the human food chain is a major issue and needs to be discussed in a common forum of scientists, researchers, policy makers, non-governmental organizations, progressive farmers, industrialists, and representatives of the government.

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Two major questions that need to be debated are:

1. Are genetically modified organisms (GMOs) safe for humans and the environment?
2. Will GMOs help Indian farmers to improve the productivity and take them out of the cycle of poverty?

(www.envirodebate.net as viewed on 8 December 2003.)

## WHAT IS SUSTAINABLE AGRICULTURE?

Agriculture is sustainable when it is ecologically sound, economically viable, socially just, culturally appropriate and based on a holistic scientific approach. Sustainable agriculture integrates three main goals—environmental health, economic profitability and social and economic equity.

Sustainable agriculture implies:

- incorporation of natural processes such as nutrient cycling, nitrogen fixation, and pest–predator relationships;
- minimization of the use of external and non-renewable inputs that damage the environment or harm the health of farmers and consumers;
- participation of farmers and rural people in all the processes of problem analysis, technology development, adaptation and extension, and monitoring and evaluation;
- more equitable access to productive resources and opportunities;
- greater productive use of local traditional knowledge, practices and resources;
- incorporation of a diversity of natural resources and enterprises within farms;
- increase in self-reliance amongst farmers and rural communities; and,
- economic viability of farm operations.

Some elements of sustainable agriculture are:

### PROPER SELECTION OF SITE, SPECIES AND VARIETY

Preventive strategies adopted early on can reduce inputs and help establish a sustainable production system. For example, in a dry region, where rainfall is scarce and uncertain, crops like *bajra* and *jowar* which require little water are suitable. Bringing in extensive irrigation in such areas may make it possible to grow water-intensive crops like rice or cotton, but this may lead to other problems such as waterlogging and salinization. Similarly, choosing pest-resistant crop varieties reduces the need for applying external pesticides.

## Diversity

Farms with more diversity are more economically and ecologically resilient. Monoculture cropping is advantageous in terms of short-term efficiency and ease of management. But the onslaught of a pest or a disease could wipe out the entire crop any one year, and could put a farmer out of business and/or seriously disrupt the stability of a community dependent on that crop. When several varieties of crops are grown in the field at one time, even if one or two fail, the impact is not as severe. Also, practices such as crop rotation, i.e. growing different crops on a particular field over a period of time, can suppress weeds, pathogens and insect pests that depend on and affect specific crops.

## Soil Management

Healthy soil is a key component of sustainability. Healthy soils produce healthy plants that have vigour and are less susceptible to pests. Crop-management systems that impair soil quality often also need greater inputs of water, nutrients, pesticides, and/or energy for tillage to maintain yields. In sustainable systems, the soil is viewed as a fragile and living medium that must be protected and nurtured to ensure its long-term productivity and stability. Methods to protect and enhance the productivity of soil include using compost and/or organic manures, reducing tillage, avoiding traffic on wet soils, and maintaining soil cover with plants and/or mulches. Regular additions of organic matter or the use of cover crops can increase soil aggregate stability, soil tilth, and the diversity of microbial life in the soil.

## Efficient Use of Inputs

Sustainable agriculture relies heavily on natural, renewable and on-farm inputs. It also places equal importance on the environmental, social, and economic impacts of a particular farming practice. But this does not mean that the use of inorganic inputs is completely forbidden in sustainable agriculture. A judicious combination of organic and inorganic inputs may be used, to ensure that this strategy is the least toxic and least energy-intensive, and yet maintains productivity and profitability.

An interesting example of sustainable agriculture, which illustrates the use of several of the principles discussed here, is described below.

## Save Our Seeds

Jardhargaon is a typical Himalayan village in the Tehri Garhwal district of Uttranchal state. After the Green Revolution of the 1960s in India, farmers in these hilly regions also

started using high input-intensive techniques of farming to increase productivity. New improved seeds of high-yielding varieties were introduced, along with a range of pesticides, fertilizers and other external inputs. In the race for modernization, the farmers began to rapidly lose their traditional systems of sustainable agriculture. Ironically, despite increasing investments and inputs, soil fertility, and hence land productivity, began to gradually decline. This realization initiated a movement away from the new methods and a return to the traditionally more sustainable ways of farming. The movement, known as the *Beej Bachao Andolan* (Save the Seeds Movement) is not only about conserving traditional seeds but also about promoting agricultural biodiversity, sustainable agriculture and local traditions.

It has not been easy. Several indigenous practices and seeds had already been lost. One of the key needs was to revive these. This was the basis of the Save the Seeds Movement. A group of villagers, led by farmer and social activist Vijay Jardhari from Jardhargaon, began visiting remote villages in search of varieties of traditional seeds. After intensive travelling, the group collected as many as 250 varieties of rice, 170 of kidney beans and many others which had been presumed lost in the region. In the course of this search, a wealth of information was documented for the first time. For instance, during their search, the *Beej Bachao Andolan* activists found that in the valley of Ramasirain, farmers grew a distinctive variety of red rice called *chardhan* (four grains). The rice was nutritious and did not require huge external inputs. The farmers also grew other indigenous varieties of rice, known locally as *thapchini, jhumkiya, rikhwa* and *lal* basmati. Agriculture was totally free from the use of chemical fertilizers and pesticides, yet good yields were obtained.

Another remarkable traditional system of cropping which came to light was *baranaja* (literally meaning 12 grains), where 12 crops are simultaneously grown in the same field. This not only avoided monoculture, but also helped restore soil fertility and ensure food security. In the *baranaja* system of traditional mixed farming, there is intercropping of 12, or sometimes more, crops. A combination of cereals, lentils, vegetables, creepers, and root vegetables is grown. The 12 crops are those that can grow in harmony with each other. The creepers of legumes use the stems of grain plants as a natural support, while the roots of the plants grip the soil firmly, preventing soil erosion. Due to their nitrogen-fixing abilities, legume crops return nutrients to the soil, which are used by other crops. No external chemical inputs are given, and pest control is achieved through the use of the leaves of the walnut and neem, and the application of ash and cow's urine. This system of biofarming helps maintain the ecological balance and enables the farmer to benefit from certain varieties even if there is damage to some crops. Moreover, the diversity of crops also provides for nutritional security. Millets are rich in calcium, iron, phosphorus, and vitamins, while legumes are a rich source of proteins.

## The Challenge Ahead

In a scenario of shrinking land available for cultivation and depleting water resources, the challenge is to increase biological yields to meet the increasing demands for food, fibre, etc., of the ever-growing population without destroying the ecological foundation or compromising the long-term well-being of the environment. Some measures towards this system are:

1. Agricultural systems should be designed so as to match the environmental characteristics (soil, water, climate and pest populations) of the region. For example, water-demanding crops should not be grown in arid and semi-arid areas. Also, in such areas livestock grazing should be limited. Water conservation should be encouraged by using irrigation systems that minimize water wastage and prevent salinization.
2. Whenever possible, relying on locally available, renewable biological resources and know-how, and using resources in ways that preserve their renewability are good agricultural practices, for example, using organic fertilizers from animal and crop wastes (green manure and compost), building simple devices for capturing and storing rainwater for crop irrigation, and cultivating crops adapted to local growing conditions.

Good agricultural practices also include:

- maintaining the vegetative cover on cropland;
- using organic fertilizers, crop rotation and intercropping, which increase the organic content of soils;
- maintaining a diverse mix of crops and livestock, instead of monoculture;
- reducing the use of fossil fuels in agriculture by using locally available, perpetual and renewable energy resources such as the sun, wind, and flowing water, and by using more organic fertilizers instead of energy-intensive chemical fertilizers; and,
- emphasizing biological pest control instead of chemical pesticides.

Government policies that encourage farmers to grow food for local consumption instead of encouraging the export of cash crops, which reduces the food available to local people, and provide incentives to farmers for adopting responsible practices would help to promote sustainable agriculture.

Today, with the impacts of the highly mechanized, heavily artificial input agriculture becoming evident, there is a growing realization that agricultural processes and practices need to be rethought. In the words of Dr M.S. Swaminathan, ‘what is needed is an Evergreen

Revolution, one that achieves sustainable productivity, and is rooted in the principles of ecology, economics, social and gender equity, and sustainable livelihoods.'

## I QUESTIONS

1. What were some of the gains of the Green Revolution?
2. What were the problems caused by the Green Revolution?
3. What are the alternatives to chemical fertilizers? What are their advantages?
4. Why is it desirable to maintain genetic diversity in agriculture?
5. What is Sustainable Agriculture? What are its major components?
6. What are the essential differences between the livestock-based pastoral system and the crop-based livestock rearing system? Which of these evolved first?

## II EXERCISES

1. Given below is the comparative analysis of the output of paddy in a half-acre area in Kalpvruksh Farm in Umargaon, using two methods: Method A: Crop grown using organic inputs and through sustainable agricultural practices; and Method B: Crop grown using chemical fertilizers and pesticides.

Table 7.3
Paddy output from a half-acre plot

Using organic inputs (Method A) and chemical fertilizers and pesticides (Method B)

| | *Method A* | *Method B* |
|---|---|---|
| Gross production | 50 kg | 100 kg |
| Gross income | Rs 50 | Rs 100 |
| Cost of production | | |
| a. Chemical fertilizer | Rs 0 | Rs 15 |
| b. Water (irrigation using electric pumps) | Rs 6 | Rs 25 |
| c. Pesticide and weeding expenses | Rs 4 | Rs 40 |
| d. Total cost | Rs 10 | Rs 80 |
| Net profit | Rs 40 | Rs 20 |
| Taste | Sweet | Bitter |
| Proportion of toxic substances in paddy | None | High |

**Source:** Kalpvruksh Farm, Bhaskar Save, Umargaon.
**Note:** The result is applicable to a particular case and may vary with conditions.

Based on Table 7.3 answer the following questions:

a. The gross production in Method B (i.e. using chemical fertilizers and pesticides) is more than that of Method A (i.e. organic farming). But the net profit by Method A is more than that of Method B. Why?
b. On an average, a 25 per cent subsidy is available on fertilizer and 80 per cent on electricity. The figures given in the table include these subsidies. Assuming that there is no subsidy either on fertilizers or on electricity, calculate the cost of production and the net income using both methods. (See answer below.)
c. Find out the cost of leasing land in your area. If this is included as part of the cost of production, what would be the net income?
d. The calculation assumes that the market price of the crop grown by both methods is the same. But wherever there is awareness regarding the health and environmental benefits of organic crops, its market price is around 1.5 times that of crops grown using chemical fertilizers. If the crop is marketed in such a market, what would be the net income from organically grown paddy? (See answer below.)
e. If you were a farmer, which method would you like to adopt and why? You need not restrict your answer only to the factors discussed above.

**Answers:**

2b. In method A, the cost of water would increase to Rs 30 and the total cost to Rs 34. This method would thus result in a profit of only Rs 16. In Method B, the cost would increase to Rs 20 for fertilizer and Rs 125 for water. Thus, the total cost would increase to Rs 185, thereby incurring a loss of Rs 85.

2d. The selling price of crops grown organically (Method A) would increase to Rs 75. Thus, even without government subsidies for fertilizer and electricity, the profit would be Rs 41.

2. Read the story given below carefully and answer the questions that follow.

**Maganbhai's Story**

In the 1980s, Maganbhai, a farmer in the Saurashtra region in Gujarat, was engaged in growing *babario*, a local variety of *bajra*. He used seeds from his own farm. He used no chemical fertilizers or pesticides and very little irrigation. He used the by-products of the crop as fodder for cattle, and as fuel, thatching material and organic manure. The taste of the *bajra* was sweet. The ears of *bajra* were of the open type—exposed, without any natural cover. Lots of birds were seen on the farm feeding on the ears. The birds ate some of the grain, but also ate the insect pests that could damage the crop. This

acted as a natural pest-control measure. The crop left over after the farmer had put away enough for his family's consumption for the year was sold in the local market.

***Five years later***

Following what other farmers in the region seemed to be doing, Maganbhai bought seeds of a hybrid variety of *bajra* from a private company. The cultivation of this variety required expensive inputs such as chemical fertilizers and pesticides. It also needed intensive irrigation. The total grain production increased. But as it was a dwarf variety, it did not produce much biomass. So, in addition to having to buy the pesticides and the chemical fertilizers, which he now needed instead of the organic manure, Maganbhai also had to buy fodder for his cattle, fuelwood and thatching material from the local market, all of which he could earlier get as residue from his crop.

Because the ears of grain were of the closed type, birds could no longer feed on the grain and so were rarely seen on the farm. So there was no natural mechanism to keep the pests under control. As the total production was higher than that of the local variety that he had been cultivating for years, Maganbhai was happy at first. But at end of the year of slogging in the field, he did not have any savings.

***Now imagine ...***

Maganbhai has been growing the hybrid now for 10 years. What do you think would have happened to Maganbhai in these 10 years, and why?

***What actually happened to Maganbhai in ten years?***

Maganbhai has been growing the hybrid for 10 years now. Last year, the entire crop was destroyed due to the spread of disease and pests on his farm.

He had borrowed a huge sum of money to buy a variety of pesticides, weedicides and fertilizers. But these inputs did not help as the pests had become immune to the chemicals.

Maganbhai also borrowed money last year to buy fodder, fuel and thatching material, as now he did not have enough crop residues to use for these purposes.

He had thought that he would clear all his debts when he got a good crop yield. But it was his bad luck; he could not even repay the interest on the borrowed money.

While applying chemical insecticides and pesticides in the field, Maganbhai would also inhale some amount of the chemicals. This resulted in headache and nausea. But he does not have any money to pay the doctor's fee or to buy medicines.

This year, Maganbhai was seen sowing the local *bajra* variety *babario*, but as a daily-wage labourer on the farm which once used to be his own.

***Now think ...***
What can Maganbhai do to improve the situation? How many years do you think it would take him to come out the tangled 'hybrid net'?

(Exercise developed by Ramesh Savalia and Gopal Kumar Jain)

## III Discuss

1. Discuss the pros and cons of GMOs, which are increasingly becoming a part of modern agricultural practices. Should foods manufactured from genetically modified crops be labelled as such?
2. What are the major economic and ecological advantages and disadvantages of pursuing traditional agricultural practices and trying to save traditional knowledge?

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# Chapter 8

# The Urban Environment

Vivek S. Khadpekar and Sunil Jacob

The earliest humans depended on hunting and food gathering for their survival. They moved in small groups in search of food. Over time, they found that food could be cultivated and some animals domesticated. This discovery, assuring survival in a fixed place, marked the beginning of human settlement and built shelter.

The early villagers fulfilled most of their survival needs through their own efforts, growing food, building shelter, hunting, and making the implements needed for these activities. As they prospered, some of them started producing surpluses, which they could exchange and trade with other communities. This offered a greater choice of things to use and consume.

With the variety of goods available through trade, it was no longer important for each village to produce everything it needed. An important development followed: some villages which were located centrally emerged as **markets**. Their main activity was not agriculture, so their land could be intensively put to non-agricultural uses and could support high densities of population.

## Advent and Evolution of Urban Places

Thus began urban places or towns. With bigger populations, diverse occupations and many visitors, they became important as places of exchange of goods and commodities, of contacts with a wider world, and of ideas, information and knowledge. They became centres of wealth, power, enterprise, patronage and opportunity.

Towns consumed more material and energy than villages, leading to more waste. In rural areas, there was space for wastes to be disposed of and to decompose, getting assimilated back into the natural environment. Not so in towns, which needed special efforts to manage waste. They also needed facilities for the storage and security of their wealth. From this evolved the institutions to regulate and protect people, their possessions

and commerce—policing and taxation. Specialized occupations which emerged with the first settlements now became more complex and numerous.

These essential features of urbanization—the process by which a society acquires urban characteristics—have survived over a few thousand years, but their scope, pace and complexity have increased. The early towns were relatively small. Over time, some centrally or strategically located towns grew in size and complexity to become **cities**.

Sizeable hinterlands with a range of material and human resources were needed for cities to emerge and survive. Therefore, cities developed at locations easily accessible from these hinterlands, usually at important junctions on trade routes, or at places where rivers could be easily crossed. Assured water availability was crucial for cities. The earliest great civilizations arose on the plains of major rivers, which provided adequate water and deposited silt during floods, which made the land fertile. Such civilizations flourished along the Nile (Egypt), the Tigris–Euphrates (Iraq), the Huang Ho (China) and the Indus (Pakistan and India) between 4000 and 1500 BC. Each of them produced an urban culture, with outstanding artistic and technological achievements.

The Indus Valley Civilization was the first to address the environmental problems of managing urban sanitation and hygiene. Harappa, Mohenjo-Daro, Lothal and other cities, dotting a vast area across today's Pakistan and north-western India, had covered drainage channels along their streets to remove waste water and sewage from houses. This is a key contribution of that civilization. But it also teaches another environmental lesson. Some scholars believe that its decline was due to the excessive exploitation of forests—mainly for wood to fuel kilns that produced huge amounts of building bricks—leading to deforestation, loss of wildlife, and irreversible environmental degradation. This opinion may be debatable, but there is evidence that 4,000 years ago, this area had high rainfall, forests and abundant wildlife. Today it is largely semi-arid or arid.

In the 3,000 years after the decline of the Indus Valley Civilization, civilizations and big cities emerged in different parts of the world, shaped by forces as varied as religion, trade, the advent of nation states, empire-building, and colonization. Each made cultural, economic and technological contributions to civic life, some of which survive to this day.

After the 15th century, colonization by Europe played a major role in shaping cities and patterns of urbanization in the colonies, the influences of which still survive. Britain had the largest empire, including India where, by the late 18th century, it had established new cities such as Madras (Chennai), Calcutta (Kolkata) and Bombay (Mumbai), on sites where there had been no previous urban settlement.

Many considerations determined the location of these new cities. They had to serve as points of control over vast areas of land and sea; as ports for global trade; and as warehouses for large quantities of goods in transit. The British needed local people to handle some aspects of their trade. In due course they also encouraged the setting up of small and large industries for various utility items, shipbuilding and textiles, among others. All this attracted migrants from the hinterland in search of business and employment, and the cities had to provide for their needs too.

## Urban Growth Picks Up Pace

These developments set a pattern of urban growth in India that has continued at a quickening pace to this day, not only in the 'new' British cities but also in extensions of important old urban centres such as Delhi, Ahmedabad, Hyderabad and Pune. Worth special mention here are two events that caused major spurts in Delhi's growth—the shifting of the capital of British India from Calcutta to Delhi in the early 20th century, and the influx of refugees from Pakistan after Partition in 1947. The latter, in fact, affected several cities, but its effect was most pronounced in Delhi.

The critical issues in urban areas accompanying their growth since the mid-19th century, have been the steady increase in crowding and congestion; problems of sanitation, drainage, water availability and supply, and solid waste management; pollution of water, air and soil leading to environmental health stresses; problems of traffic and transport; degradation and loss of public open spaces, greenery, wooded areas, waterbodies and other natural environmental assets; growth of crime and violence; emergence of the informal sector of the urban economy and of slums, and many more. Before embarking on a discussion of these issues, let us examine what the terms 'Urban', 'Urban Growth' and 'Urbanization' mean in today's context, particularly with reference to India.

## Classification of Urban Places

Different disciplines have their own ways of categorizing and classifying urban places. The most widely used across disciplines, is that of the Census of India. This defines as 'Urban' (*a*) all places with a municipality, corporation, cantonment board, notified town area committee, etc., and (*b*) all other places with a minimum population of 5,000; at least 75 per cent of the male working population in non-agricultural occupations; and a population density of at least 400 persons per square kilometre.

Urban places are grouped into six classes based on population size:

| ***Class*** | ***Population*** |
|---|---|
| Class I (city) | 100,000 or more |
| Class II | 50,000–99,999 |
| Class III | 20,000–49,999 |
| Class IV | 10,000–19,999 |
| Class V | 5,000–9,999 |
| Class VI* | Less than 5,000 |

**Note:** * Class VI includes places which, despite a population less than 5,000, qualify as urban by virtue of the occupations of the majority of the working population, density, etc. They include townships in remote areas, evolved around manufacturing, power generation, mining or other similar activities.

Besides the above classes, the Census also lists Urban Agglomerations—cities which, together with the areas adjoining them, accommodate spillover urban land use and functions from the formally designated urban area, or areas in which two or more adjacent cities have merged to form, for all practical purposes, a large, single urbanized spread.

Terms not used by the Census of India but employed by some official agencies include metropolis (population of 1 million or more) and megacity (population of 4 million and above).

## Urbanization and Urban Growth

The terms 'urbanization' and 'urban growth' are often erroneously used interchangeably. In fact, although the two are generally interrelated, their dynamics are distinct from each other. Urbanization is the process by which a society becomes urban in terms of occupations, land use, population density, etc., graduating from primary sector (agriculture, animal husbandry, hunting, etc.) to secondary sector economic activities (manufacturing) to **tertiary sector** occupations supporting them (provision of services such as trade, banking, transport, etc.). Urbanization is expressed as the percentage of the total population of a large area such as a country, or one of its divisions, living in urban areas.

On the other hand, if we say that a particular city—or cities collectively in a country or region—increased in population over a number of years, we are referring to urban growth, not urbanization. Urban growth can happen in one of basically three different ways:

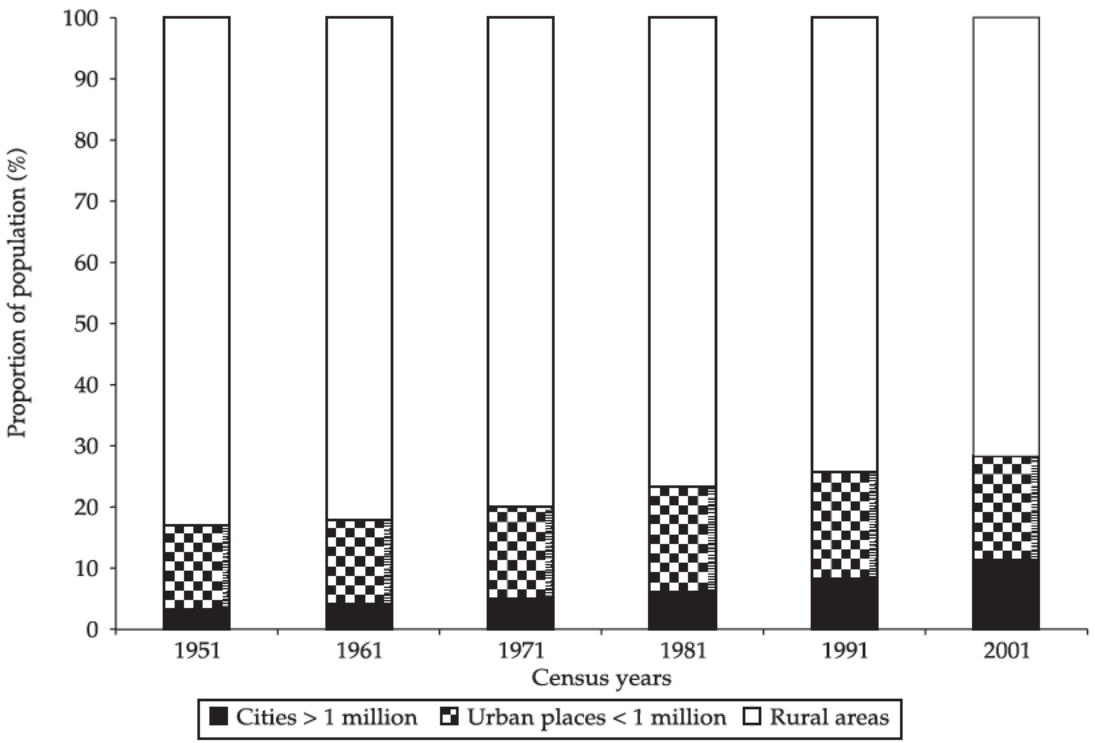
1. by net natural increase (excess of births over deaths in the resident population);
2. by net migration (excess of people migrating into the city over the number migrating out of it); and
3. by reclassification of city limits (the inclusion in them of contiguous populated areas with urban characteristics, which previously lay outside), or of rural places becoming urban.

Urban growth is possible without accompanying urbanization; but for urbanization, urban growth is a must (except in the far-fetched scenario of a calamity selectively decimating the rural population without affecting the urban). To understand this difference quantitatively, let us see how India grew between the censuses of 1991 and 2001. In that decade, the combined rural and urban population increased by 21 per cent to cross 1 billion. The urban population increased 31 per cent (urban growth). But the urbanization of India as a whole grew by just two percentage points, from about 26 per cent to 28 per cent. The absolute growth in the urban population during the decade was 67 million—more people than the entire populations of major countries such as the UK, Italy or France. In relative terms, it was negligible for a large developing country such as India.

The overall increase in urbanization levels over the decade was not dramatic, but the distribution of the population across urban places of different sizes is significant. In 2001, about 38 per cent of it lived in cities of populations of more than 1 million. The remaining 62 per cent lived in some 3,600 small and medium towns in the population range of 5,000 to 100,000. Of the former 38 per cent, nearly 15 per cent lived in three Urban Agglomerations (UAs) of over 10 million each, about 9 per cent in five UAs in the range of 3 to 6 million, and nearly 15 per cent in cities or UAs of 1 to 3 million. This has been a persistent trend since the 1950s, as is evident from the following chart, which shows that the share of metropolitan centres in both the urban and total population has been growing at a higher rate than that of small towns and cities with populations of less than 1 million.

Thus, India's urban growth and urbanization are increasingly due to large cities. Small and medium towns are declining in relative importance and stagnating. Most of them cannot function adequately as central places to their hinterlands, which would ensure

Figure 8.1
India: Population distribution in rural areas, urban areas, 1951–2001




**Source:** Tata Service Limited, 1982 83, 1993 94, 2002 03, *Statistical Outline of India*. Mumbai.

their own prosperity and growth. On the other hand, large cities are growing more rapidly than they can cope with, straining civic amenities and services. In both cases, the net result is the degradation of the urban environment. The small towns suffer from neglect; the cities suffer from overload.

## Migration into Cities

To go back to early urban growth in the British period, it was driven not only by the presence of opportunities in the cities (the pull factor) but also by their absence in rural areas and small towns (the push factor). Colonial trade policy was mainly to procure raw materials from India for processing in British factories into finished products (for example, cotton from India was converted to yarn and cloth in England), to be sold all over the world including India. Being mass-produced, many of these products, even after adding costs of raw material, transport, processing, duties, commissions and other charges, were cheap in India compared to those produced locally by cottage industries. Rural artisans facing diminishing sales and income were forced to migrate in search of livelihoods, for which cities with growing economies offered options. Small farmers, at the mercy of poor yield from land, uncertain rain, or exploitative landlords, also migrated to cities to improve their chances of survival.

Such migration of the rural poor increased with the rise in manufacturing industries in cities. Those lacking skills needed for urban employment took up the most menial jobs. They continued to be poor, but with a degree of assurance of survival and hope of a better future. Unlike better-off urban dwellers, they had no security of shelter. They built their own crude shelters, often lacking even basic amenities. Thus they created what is a very misunderstood and maligned part of urban environment, the *slum*, typically overcrowded, with a degraded environment, inadequate sanitation, and lack of basic amenities—conditions that diminish the quality of life of its inhabitants. Slums play a key role in the 'informal sector' of the urban economy.

## The Informal Sector and Slums

Slums normally develop on low-lying or marginal land unfit for legally acceptable building, or neglected by its owners, in locations near places of potential gainful employment. By building slums, the urban poor provide their own shelter which is low on costs of construction and travel to work. Often situated near or in wealthy localities, they have no share in this wealth, even though they participate in creating some of it.

In India, owing to low incomes, high rents, lack of affordable housing of prescribed standards and increasing costs of living, the slum population is growing four times faster than the growth of the country's population. Already, in India's large cities, nearly a third of the population lives in slums, and this proportion is growing (see Table 8.1). According to Census of India 2001 estimates (which are more recent than the figures given in the table below), nearly 49 per cent of Mumbai's population lives in slums!

Table 8.1
Slum population of selected million plus cities, 1991 and 2001

*(In million)*

| | *1991* | | | *2001 (estimated)* | | |
|---|---|---|---|---|---|---|
| *City* | *Total population* | *Slum population* | *Percentage of total population* | *Total population* | *Slum population* | *Percentage of total population* |
| Greater Bombay | 12.60 | 4.32* | 34.30 | 17.07 | 5.86 | 34.30 |
| Calcutta | 11.02 | 3.63* | 32.93 | 13.11 | 4.31 | 32.90 |
| Delhi | 8.42 | 2.25 | 26.70 | 12.22 | 3.26 | 26.70 |
| Madras | 5.42 | 1.53 | 28.13 | 6.98 | 1.96 | 28.10 |
| Hyderabad | 4.34 | 0.86 | 19.78 | 6.30 | 1.25 | 19.80 |
| Bangalore | 4.13 | 0.52 | 12.50 | 6.36 | 0.79 | 12.50 |
| Ahmedabad | 3.31 | 0.67* | 20.23 | 4.36 | 0.89 | 20.31 |
| Pune | 2.49 | 0.41* | 16.44 | 3.53 | 0.58 | 16.30 |
| Kanpur | 2.03 | 0.42 | 20.55 | 2.49 | 0.51 | 20.60 |

**Source:** Central Statistical Organisation (1997), *Compendium of Environment Statistics,* M/o Planning & Programme Implementation, GOI, New Delhi.

**Note:** * Based on the percentage identified slum population of 1981.

In the urban informal sector, slums are beehives of activity. They provide important but undervalued services to the city: cheap labour beyond the scrutiny of labour laws; services such as garbage collection, small-scale repair of appliances, washing and ironing of clothes, and many more. They also manufacture a fair amount of utility items of daily use—from handkerchiefs and shirts to room coolers and steel almirahs—occasionally sub-standard but usually much cheaper than branded versions. With training for skill upgrading and quality control, the informal sector has also demonstrated its ability to produce and assemble components of sophisticated engineering and other products for large, formal-sector industries. Many of these, such as some upmarket readymade garment manufacturers, routinely outsource part of their manufacturing operations to ancillary units in the informal sector, saving themselves high overheads.

Slums are often seen as parasites on the fabric of a city, the habitats of people who exploit urban resources and amenities without paying for them. In fact, slum dwellers do pay indirect taxes (e.g. octroi or entry tax, levied on most of the basic necessities of life entering a city) which, as a fraction of their low earnings, can be substantial. In return, they normally do not get even a fraction of the minimum civic services due to them as citizens (assured water supply, sanitation, health services, education).

By building their own shelter, slum dwellers indirectly help to save public funds. They effectively reduce the burden the government might otherwise have to bear to provide them with housing. Moreover, it has been observed in many cities over several decades that if slum dwellers have a reasonable, implicit assurance that they will not be arbitrarily evicted from the lands they occupy—even a notional security of tenure—they do progressively invest their own resources in improving the quality of their shelter as and when they can afford to. What is beyond their capacity is to provide infrastructural services such as sewerage, drainage and water supply. This is the area in which the city really needs to intervene and invest.

A common perception is that slums grow because the rural poor migrate to cities. This was true in the early stages of urban growth which accompanied industrialization (roughly from the mid-19th to the third quarter of the 20th century) in large cities such as Kolkata, Mumbai and Chennai. Today, the growth of slums is due more to a natural increase in the local population than it is to migrants. This must be remembered by citizens, administrators or politicians who advocate permits for people (implicitly the poor) entering cities.

It is not possible to visualize cities without slums in the foreseeable future. As emerging market trends, with their emphasis on outsourcing, reduce secure jobs with steady incomes, more and more of the self-employed may move into the informal sector. Future slums could house people from classes and occupations that hitherto lay outside their scope. Their economic importance will continue to be significant. Hence, urban policy must accord high priority to the environment and management of slums, recognizing the value of their contributions, and integrate them into the planning and management of urban services.

## Implications of Present-day Urbanization in India

From the viewpoint of quality of life, several aspects of the urban environment—pollution, crowding, high energy use, social and psychological tensions, conflict—may be seen as disadvantages that outweigh the advantages. Cities draw heavily, directly or indirectly, on resources such as water, forest, fuel and land, which they return to the environment as waste and pollutants. Unsustainable development with rapid urbanization adversely affects both the immediate and the remote surroundings. The implications of this impact for the environment and the people must be given adequate consideration. Urban congestion not only creates unhealthy living conditions, it also trains the infrastructure. The urban environment in general is deteriorating rapidly. The crucial supports for healthy environment and living conditions—air, water, and land—are degrading.

The above arguments do not seek to deny the merits of urbanization. India still has a long way to go before it can fulfil the basic development needs of its people. To that end,

urbanization is necessary. But the path it takes does not have to be the same as that taken by the already developed countries. A different course of development may also signify a new kind of urbanization and urban growth. This requires a review of the critical issues in our urban environment, and of our urban planning and management practices.

## Issues in Urban Environment

The key issues of urban India today have to do with the quality of life of the people. Several factors are involved—health (both physical and mental), education, nutrition, livelihood security, protection from exploitation, fulfilment of cultural and creative aspirations, social justice, harmony and peace, and what are commonly seen as basic democratic freedoms and human rights. In principle these are guaranteed to all Indians. In practice, however, there are several aberrations regarding which of them are available to whom. They afflict both rural and urban society, but the urban environment brings them into closer contact and confrontation. Some of these aberrations and issues are discussed below.

### Increasing Resource Consumption and Waste

With economic growth, the purchasing power of the people increases, leading to higher consumption of resources. While the urban population is smaller than the rural, it corners more resources. This is starkly evident in big cities such as Delhi and Mumbai. City dwellers consume more per capita, and generate more waste. Today, many of these wastes are non-biodegradable. Nature's mechanisms to break down degradable organic wastes are less effective in cities due to the reduction of soil cover—and the micro-organisms it contains—with most of the space taken up by buildings, roads, etc.

### Pressures on Infrastructure

Population density in urban centres has been increasing more rapidly than the infrastructure and services needed to sustain it, such as housing, water supply, garbage disposal and sanitation. This has led to polluted, overcrowded and unhealthy living conditions for many urban dwellers, and it affects the quality of life of rich and poor alike. The poor may be more vulnerable to disease due to poor sanitation, but if the disease becomes an epidemic, it does not recognize the boundaries of economic class. Thus, if sewerage is provided only to those who can pay and denied to those who cannot, everyone suffers.

## PUBLIC SPACES AND ASSETS

People living in densely inhabited areas need spaces to which they can go without having to pay, for recreation, exercise, meetings, peaceful contemplation, or even simply to get away from the hustle and bustle of crowds and noise. To serve these needs, cities have public spaces and assets such as parks and gardens, wooded areas, waterbodies, wetlands and several others. They also provide valuable ecological services such as recharging groundwater. With the increasing demand for land, many such assets face the threat of conversion to commercial use. Protecting them is a critical issue in the urban environment, its planning and management.

## LOSS OF CULTURAL HERITAGE

Cultural heritage, both material (such as monuments, crafts, landmarks) and non-material (such as cuisine, festivals, institutions), is an important aspect of people's identity and self-esteem. Rapid urbanization often tends to erode it. The built heritage—an integral part of a city's identity—is sacrificed in favour of new, commercially 'viable' developments, depriving citizens of the cherished symbols of civic pride. The original functions for which old buildings were designed are often replaced by new uses. For example, when single-family houses in *pols* in the walled city of Ahmedabad are replaced by high-rise flats, or converted into warehouses, the fabric of the *pol* gets disrupted by the increase in people and vehicles which these changes attract (see box *Pols*). An environment originally meant for a culturally homogeneous community to live in safety and neighbourly bonding, gets destroyed. Many old urban neighbourhoods that have evolved a distinct lifestyle and cultural identity face this threat with the onslaught of mindless urban development lacking in appropriate conservation measures.

### *Pols*

A *pol* is a typical built neighbourhood in the old walled city of Ahmedabad. Its residents are generally of one community, often related to one another, and share social and cultural values and practices. Unlike modern neighbourhoods in which the residents are usually from similar classes by income, *pols* have residents with diverse levels of wealth. The less affluent, in times of need or crisis, are helped by community trusts or similar other mechanisms endowed by the better-off members.

Neighbourhoods similar to *pols* are common in hot arid areas. The streets and alleys are shaded from the scorching sun through most of the day by the houses lining them, which typically have long shared side walls and narrow fronts with shading devices such as *jharokhas*, *chhajjas*, overhanging storeys and balconies to minimize the entry of heat. Internal courtyards keep the interiors cool by removing the warm indoor air by convection.

## AIR POLLUTION

Polluted air is a growing problem in cities and a major cause of respiratory ailments. This is mainly due to the exhausts and emissions from motor vehicles and industries which do not conform to the prescribed pollution-control standards. Poor maintenance and adulterated fuels aggravate the pollution. People such as traffic police and industrial workers, whose occupations involve sustained exposure to such pollution, are at particular health risk (see Table 8.2).

Table 8.2
Level of air pollution in selected cities

| | *Range of levels of air pollution (micrograms/$m^3$)* | | | | | |
|---|---|---|---|---|---|---|
| *City* | *$SO_2$* | | *$NO_x$* | | *SPM* | |
| NAAQ standards | 15.0 | 80.0 | 15.0 | 80.0 | 70.0 | 360.0 |
| Mumbai | 6.1 | 111.7 | 5.4 | 115.8 | 60.6 | 473.2 |
| Calcutta | 6.0 | 122.0 | 6.0 | 73.1 | 77.3 | 833.3 |
| Delhi | 10.1 | 85.1 | 20.1 | 104.5 | 145.3 | 929.8 |
| Hyderabad | 5.1 | 70.7 | 7.5 | 124.1 | 59.3 | 458.0 |
| Ahmedabad | 5.4 | 110.9 | 3.6 | 70.0 | 72.4 | 575.4 |
| Pune | 17.1 | 29.0 | 10.1 | 34.0 | 112.0 | 166.5 |
| Kanpur | 8.2 | 22.4 | 7.7 | 63.0 | 233.7 | 809.2 |

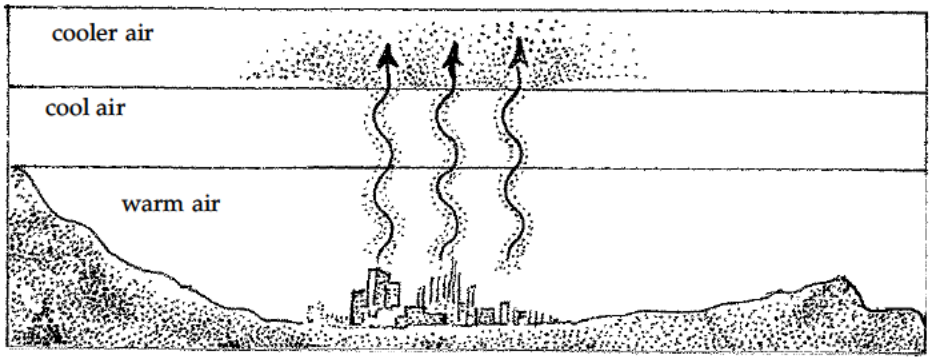
**Source:** *Indian Economic Survey (1998–99), A Pre-budget 1999–2000 Document,* Special Supplement No. 1 of 1999, News from Govt. Gazettes, GoI, New Delhi.
**Notes:** *NAAQ–National Ambient Air Quality.*
*$NO_x$–Nitrogen Oxides (as $NO_2$).*

A second, often neglected, fact is indoor air pollution in the homes of the poor arising from the use of imperfectly combustible 'dirty' kitchen fuels (coal, biomass residues and, in extreme cases, even plastic and rubber wastes) and the poor ventilation of the houses. It is not easy to quantify the extent to which this contributes to overall urban air pollution, but it is a major health hazard for the women who spend considerable time in such kitchens, and for their infants who have to be with them under constant care and attention.

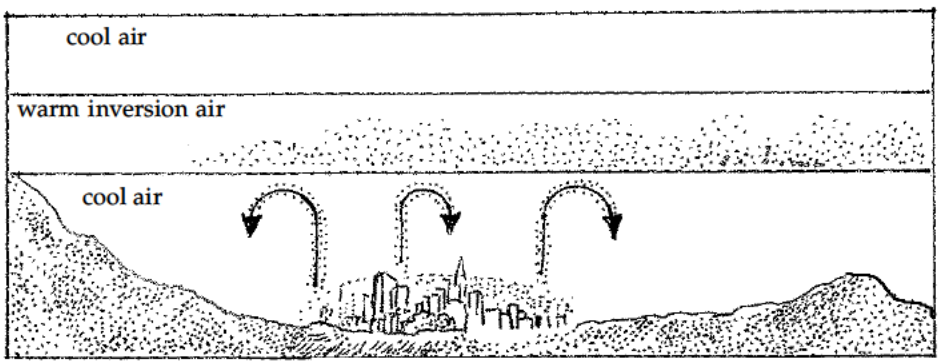
Some kinds of air pollution are due partly to natural phenomena, but get aggravated in urban areas by man-made pollution. These include **respirable suspended particulate matter**—dust and other particles in the air from vehicle exhausts and industrial activities—which are minute enough to enter the respiratory tract past its natural filtering mechanisms (hair, mucus, etc.).

Thermal inversion, a phenomenon which often occurs in winter, is another cause of air pollution. Cold air, unable to rise by convection, settles near the ground after sunset, especially when there is no breeze. In urban areas, where there is more polluted air, it forms a smog which causes eye irritation, running noses and, for some people, breathing

difficulties. In Delhi, the number of people, especially children, suffering from respiratory diseases has registered a significant increase. A study conducted in 2000 revealed that 11 per cent of the schoolchildren in the city suffer from asthma. Another study estimated that in 1995, Kolkata alone suffered monetary losses worth Rs 9.59 billion as a result of premature deaths and sickness due to suspended particulate matter!




Normal pattern




Thermal inversion

Illustration 8.1 Thermal inversion

## WATER AVAILABILITY AND POLLUTION

Access to safe drinking water is a problem in most urban areas. Rivers running through many large cities with high population densities and industrial activity carry untreated sewage and industrial effluents in concentrations which inhibit the natural biochemical processes that cleans flowing water. The Ganga, regarded as the holiest of Indian rivers, has the longest stretch (1,760 km) that is polluted in terms of biological oxygen demand (BOD). As the Yamuna flows through the city of Delhi, 15 drains discharge waste water into it, turning it into almost a sewage drain.

About 135,000 polluting industries in India generate about 13,000 mn l a day of waste water of which only 60 per cent generated from large and medium industries is treated. Most of the rest finds its way into the rivers. The most important pollution source contributing pathogens, the main source of water-borne diseases, is domestic sewage. In the absence of adequate or proper methods of treating or handling it, sewage stagnating within the city provides breeding grounds for mosquitoes. Domestic sewage also contaminates groundwater, the only source of drinking water in many cities. Because of the corrosion of underground lines over time, piped drinking water, too, is often contaminated by the sewage leaking into it. The release into the domestic sewage system of untreated chemical wastes by industries hastens the corrosion and adds to the pollution of water-bodies and soil.

With water becoming scarce, huge amounts of energy are used to transport it from great distances or lift it from underground sources. Piped supply by local government bodies cannot keep pace with urban growth. Tube wells sunk arbitrarily and excessive lifting from underground sources is rapidly lowering water levels over large areas. In the western parts of Ahmedabad, the water table went down from 20–25 m in 1965 to 80–90 m in 1990. It is now declining at an average of 3 m per year. As buildings and paved roads dominate cities, the percolation of surface water to recharge groundwater has reduced to negligible levels. Rainwater is lost as surface run-off, and causes further problems by flooding low-lying areas.

## Solid Waste

Unplanned garbage disposal is a major cause of pollution in urban areas, with serious public health implications. The economic growth of a place is reflected in the kind of waste it generates. Earlier, the waste from human settlements was mainly organic and biodegradable (leftover food, vegetable and fruit peels). Today, there is more waste and it includes high proportions of non-biodegradable materials (plastics, fused materials such as tetrapacks and *paan masala* pouches in which more than one material—plastic and paper or paper and aluminium—are combined), toxic substances, etc. These remain in the environment for a long time, and can contaminate the air, water and land. Table 8.3 gives a partial picture from a period when increasing consumerism, though well underway, was not as overwhelmingly evident as it is today.

What the table reveals in terms of the ratio of compostable to inert (i.e. non-biodegradable) waste generated between large and small cities is even sharper today, eight years down the line. It is equally important to note that large cities generate more waste per capita than small cities and towns (Table 8.4).

Solid waste disposal is a challenge for urban authorities. New landfill sites are needed as old ones get filled up over time. The new sites are usually far from the city. The waste has to be transported longer distances, using more fuel and adding to vehicular air pollution. There is also the possibility of spillage en route. More critically, this method merely transfers the pollution and its consequences to human habitations outside city limits.

Table 8.3
Physical characteristics of municipal solid wastes in Indian cities

| *Population range (lakh)* | *1–5* | *5–10* | *10–20* | *20–50* | *>50* |
|---|---|---|---|---|---|
| No. of cities surveyed | 12 | 15 | 9 | 3 | 4 |
| Composition (% on wet weight basis) | | | | | |
| Paper | 2.91 | 2.95 | 4.71 | 3.18 | 6.43 |
| Rubber, leather & synthetics | 0.78 | 0.73 | 0.71 | 0.48 | 0.28 |
| Glass | 0.56 | 0.56 | 0.46 | 0.48 | 0.94 |
| Metal | 0.33 | 0.32 | 0.49 | 0.59 | 0.80 |
| Total compostable matter | 44.57 | 40.04 | 38.95 | 56.67 | 30.84 |
| Inert material | 43.59 | 48.38 | 44.73 | 40.07 | 53.90 |

**Source:** NEERI (1995). Strategy Paper on SWM in India (August).

Table 8.4
Indian cities: Waste generation per capita

| *Population range (in lakhs)* | *Average waste generation (gm./capita/day)* |
|---|---|
| 1 5 | 210 |
| 5 10 | 250 |
| 10 20 | 270 |
| 20 50 | 350 |
| >50 | 500 |

**Source:** NEERI (1996). Strategy Paper on SWM in India (February).

The waste is not segregated at source and its mixed composition inhibits degradation. Often, when it rains, toxic substances from waste, which come in contact with water leach into and contaminate surface and underground waterbodies. The impact of such pollution on the quality of food crops using the contaminated water for irrigation, and on human and animal health, may be felt even at places far away from its source.

## Noise Pollution

The increasing numbers of vehicles on the road, the proliferation of industrial activity within the city, and the use of loudspeakers at religious, public, and social events are some factors resulting in the increasing ambient (i.e. general, not point-specific) noise levels of the city. Noise intensity is measured in decibels (dB). On this scale, each one-dB rise indicates a tenfold increase in intensity. Thus, a rise in sound intensity from 1 to 3 dB means a hundredfold increase in noise. Noise levels in some major Indian cities vary from 60 to 90 dB. The maximum levels legally allowed in the daytime (6 a.m. to 10 p.m.) are 55 dB in residential areas, 65 in commercial areas and 75 in industrial areas. At night, they are, respectively, 10 dB lower for the first two area categories and 5 dB for the third. Continuous exposure to high levels of noise leads to both mental and physical health problems. Some of the effects are irritability, aggressiveness, rise in blood pressure,

headache, insomnia, hearing loss, etc. (See Table 6.1 in the chapter on pollution for the intensity of sound levels from different sources.)

### Change of Land Use

As they grow, urban areas spread out into adjacent rural areas, consuming cropland for buildings and roads. Thus, agricultural lands, dynamic by nature due to their reusability, get converted forever to static urban use. It is not only the land which changes; even the livelihoods and lifestyles of the inhabitants are disrupted as an area urbanizes. With agriculture becoming more difficult, farmers tend to sell their land. Once the quick money thus earned is used up, they are left without gainful employment. Lack of a water and sanitation infrastructure in the newly urbanized areas causes health problems. The quality of the environment, and of life, of both old and new residents, gets degraded.

Often, natural waterbodies such as wetlands and lakes are reclaimed for building projects, resulting in the permanent loss of catchments for rainwater and natural sinks for surface run-off. This in turn causes floods in the cities in heavy rains. Such reclamations also disrupt a vital means of groundwater recharge. Along with the wetlands, ecosystems which harbour a host of life forms—mainly resident and migratory birds that have to find new areas for nesting and breeding—are lost. The change can also drastically affect the lives of the people in different ways. For example, the reclamation of 4,000 ha of wetlands in east Kolkata resulted in an annual loss of some 25,000 tonnes of the fish catch, jeopardizing the livelihoods of fishing communities and depriving the city of a major source of inexpensive nutrition. The city also lost a major chunk of two important civic amenities provided by nature—storm-water sinks and natural oxidation ponds for sewage.

### Vegetation

Shrubs, grasses, trees and other forms of natural vegetation are usually the first victims of urbanization. Vegetation is crucial for absorbing air pollutants, releasing oxygen, cooling the air as water evaporates from the leaves, mitigating noise pollution, providing habitats for wildlife, and enhancing environmental aesthetics. It also helps to reduce soil erosion.

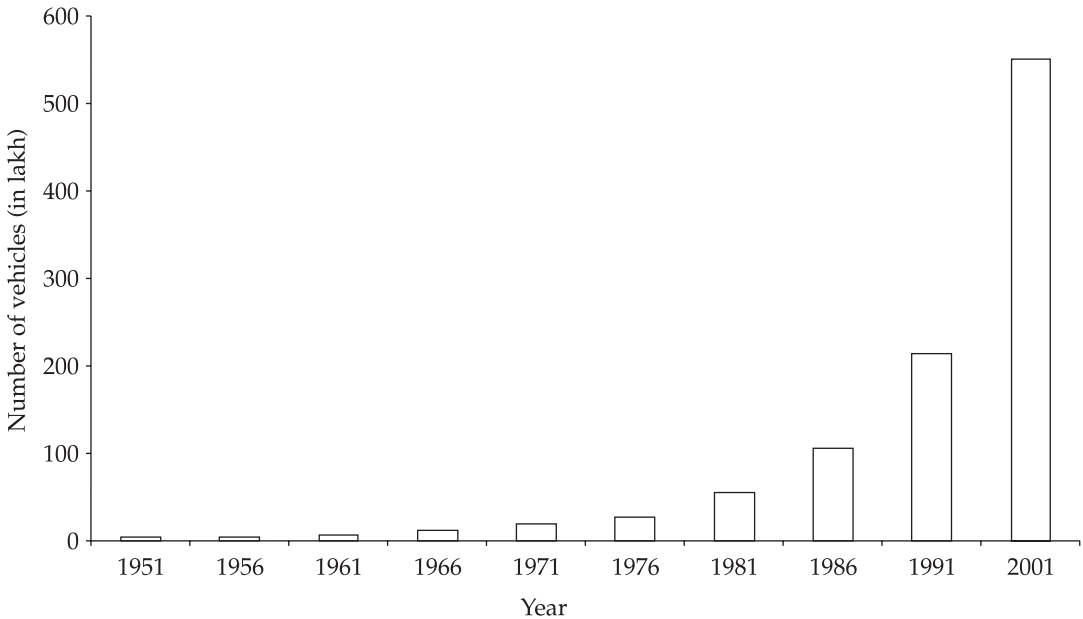
## Planning for Urban Areas

Unregulated and rapid urban growth causes unintended and undesirable environmental conditions which cannot be remedied by a firefighting approach. Comprehensive planning is crucial to make urban areas more liveable and sustainable. Traditionally, urban

planning consists of developing master plans which lay down broad guidelines on aspects such as land use (residential, commercial, industrial, institutional, recreational, etc.) and densities (number of households or persons per unit area). Assuming that these guidelines will be followed exactly, the plans provide for infrastructure such as roads, main lines for water supply and storm-water drainage, and for sewage and its end-of-the-line treatment. In recent years, the management of urban solid wastes has also begun to rate greater attention than before.

There are limitations to the efficacy of such physical planning. It does not directly address what already exists (beyond minor modifications), nor the details of transport, waste collection, or the provision of particular civic amenities. These are generally treated as add-ons—either as details to be looked into after the master plan has been frozen or as ad hoc decisions to be made as and when problems arise. Thus, if the number of private vehicles shoots up to more than what is projected (which has happened in India since the 1990s), their movement and parking becomes a major problem. The space allocated for vehicle parking in urban residential and commercial areas is no longer adequate for the number of vehicles now in use. Parked vehicles occupy space meant for pedestrians, who then risk their lives by walking on carriageways meant for vehicular movement. A major challenge for urban planning and management is to find a solution to this problem.

Figure 8.2
Total number of motor vehicles in India (1951–2001)




**Source:** Government of India, Ministry of Road Transport and Highways <http://morth.nic.in/motorstat/>.

### Planning urban transport

As cities grow, transport assumes a pivotal role and often becomes the key tool in shaping the face of the city. The natural shift from simple non-motorized modes to motorized vehicles fuels the demand for wider and newer roads and other infrastructure, like flyovers and parking lots, which in turn encourages further growth of auto vehicles on the roads.

The real purpose of transport is to move people in adequate numbers, at affordable cost, in reasonable time with minimum adverse impact on the environment of the city. It is not to encourage more and more auto vehicles to drive at faster and faster speeds.

Only when we refocus on the mobility of people rather than of vehicles can we see the futility of the approach that relies unduly on expensive infrastructure (roads, flyovers parking lots) as a solution to traffic problems such as road congestion, air pollution and road accidents.

We need to recognize that the purpose of traffic planning is to improve and increase the mobility options for the majority of the citizens, so that they can travel in minimum discomfort to their place of work, education, shopping, recreation, etc., without excessive delays, costs and danger to their health. Presently, auto vehicles contribute to over 65 per cent of the total air pollution in our cities, which threatens the health of citizens exposed to auto emission, road rage, driving stress and road accidents. Auto-vehicle dominated traffic also threatens the natural and built environment of the city, as roads, flyovers and parking lots devour open areas, natural sites and heritage structures which inevitably come into conflict with road-widening plans.

Auto-vehicle dominated traffic planning depends on building more and more roads and widening the existing ones. Unfortunately, road widening is very often accompanied by the destruction of healthy shade-giving roadside trees, reduction in the width of pedestrian pavements, elimination of front margins of buildings and gobbling up of public spaces to make room for moving or parked auto vehicles. What is worse, when new roads and road-widening projects begin to symbolize a city's development, even priceless heritage structures of architectural, historic or cultural value can face the threat of destruction. The historical Mujumdar Wada, and the Aga Khan Palace, both Grade I listed heritage structures in Pune city, are threatened by proposed road-widening schemes, as are hills, river beds and other natural heritage assets of the city.

Invariably, the poorer sections of society pay a much higher price for such development, having to spend up to 30 per cent of their income on transport.

What then is the alternative? Are there ways to manage traffic and transport that can minimize these adverse impacts on the city and the citizens? Have such options been tried elsewhere and what is the result?

Cities that have successfully dealt with the growing need for mobility of people without damaging the city's environment and health have, without exception, succeeded in creating an efficient public transport system. Public transport can carry many more people in fewer vehicles, with less energy consumption, less air pollution and fewer road accidents (per person) than private transport—cars and two-wheelers.

Along with an adequate and efficient public transport system, urban traffic and transport planning also needs to include measures to optimize existing infrastructure, which is usually created at considerable expense to citizen taxpayers. This must not only include facilities

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that encourage walking, cycling and other non-motorized modes of travel, but also help to reduce or eliminate travel altogether—such as better land-use planning and communication technology (Internet shopping/banking etc). Providing safe and adequate cycle tracks should be a priority for most growing cities in our country because cyclists still make up a fair proportion of road users in most of our cities, and yet their needs get very low priority in the planning of transport. In contrast, cities like Amsterdam, Berlin and many others in Europe and South America now encourage cycling as an environment-friendly mode of travel which can play a significant role not only in reducing road congestion and air pollution but also in making the communities more humane. In Pune city, for instance, there are about 800,000 bicycles but no cycle tracks.

An ideal traffic and transport plan for urban areas will thus recognize the role played by all the different modes of transport—non-motorized (walking and cycling), intermediate public transport (autorickshaws, taxis and minibuses), public transport (buses, trams, suburban rail), and private transport (personal two- or four-wheelers) in meeting the needs of a whole range of citizens. This can only come about when the strength of each mode is properly understood and utilized to its full potential.

Several cities in the industrialized as well as the developing world have initiated steps in this direction and succeeded in improving the mobility options for all citizens, while at the same time improving the environment of these cities. Curitiba in Brazil is the most celebrated example of planning transport along environmentally sustainable lines. Curitiba has an excellent rapid-bus public transport system with modern buses, exclusive bus routes and disincentives on the use of private vehicles. The city has many parks, gardens and public spaces, and large areas reserved for pedestrians/cyclists. Inspired by Curitiba's pioneering work in transport planning, Bogota in Colombia has an even more impressive rapid-bus system called Transmillenio, which meets the travel needs of over 70 per cent of the city's commuters. In addition, it has over 300 km of exclusive cycling tracks and large public areas where auto-vehicle traffic is prohibited.

From February 2003, London has introduced a stiff congestion charge of £7 per car entering the central business district and benefited by a reduction of about 17 per cent in road traffic in this area. Singapore has Area-Licensing Schemes (ALS) for restricting the number of vehicles in the Central Business District, and offers excellent public transport by way of rapid buses, taxis and suburban trains. In addition to this, it has a vehicle permit system that controls the total number of new vehicles registered in the city. Paris has introduced heavy parking charges to discourage the use of private vehicles and to encourage the use of its public transport system, which has been improved and modernized.

We need to shift our policies to such environment-friendly and sustainable means and move away from the present auto-vehicle dominated policies if we are to save our cities and improve the mobility options of our citizens.

(*Contributed by Sujit Padwardhan and Sanskriti Menon*)

Consider and review the transportation scene in your own town/city. Is the public transport adequate? Is it efficient? How many roads in your city/town have footpaths or cycle tracks?

In planning a city, environmentally sensitive features such as natural drainage channels, waterbodies, wooded areas and hills must be identified and earmarked for protection and enhancement of their quality. The likely pattern of urban growth must be anticipated as well as influenced by the plan. Citizens, especially the poor, must have shelter which provides healthy living and working conditions. Residential areas should be as close as possible to places of work so that the least amount of energy, time and money is spent on transport. The commercial activities of the informal sector, typically represented by street and itinerant vendors, must be accommodated and provided for in the planning process. Efficient, reliable public transport facilities must be provided, which minimize the need for private vehicles and achieve a rational balance between the use of these two forms and of intermediary public transport (autorickshaws, taxis, etc.).

Public outdoor spaces are necessary within reasonable distance of homes, for children of different age groups to play in safety. The informal sector of housing and economic activity, indispensable well into the foreseeable future, must be proactively provided for in city plans. In reality, these desirables are difficult to achieve. But there are examples of innovative experiments such as the Slum Networking Project in Indore described in the following Box, which show that it is possible to achieve the desirables such as a significant improvement in the conditions in slums, and more.

### Initiating change: Slum networking in Indore

Indore is one of the largest cities in Madhya Pradesh. With a population approaching 1 million, the city's slums were proliferating. Their inhabitants were exposed to the hazards that go with poor living conditions. In response to this, the Indore Development Authority took up the Indore Habitat Project in 1990, to reduce the city's deficit in urban shelter and services. Over eight years, the project demonstrated, in 183 slums, the potential for improving rather than clearing slums.

The major components of the project were physical infrastructure improvement, health care, and community development. The provisions under physical infrastructure included water supply with individual or community taps, sanitation with individual or community toilets, paved streets, street lighting and solid-waste management. The health segment focused on preventive care, environmental awareness and primary services. Community development involved creating neighbourhood groups, vocational training for women, adult literacy, preschool and non-formal education, and community savings' mechanisms.

The unique feature of the project was the concept of Slum Networking (SN) as an approach to providing infrastructure. This concept provides a framework for integrated upgradation of the entire city, in which the slum areas are viewed not as individual settlements but as an urban network. The network links the city's low-lying areas along natural drainage channels and waterways where most of the slums are located, and which offer the potential for installing services and environmental and aesthetic improvement.

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SN also gave Indore trunk sewers and a treatment plant. Housing colonies and slums had been releasing untreated sewage directly into the watercourses and the river Khan flowing through the city. The sewers intercept the flow along affected banks and convey it to the treatment plant. This basic grid has converted the whole city from open drains into an underground sewage system following natural slopes that enable flow under gravity. It provides direct linkages from and through the slums, avoiding expensive and time-consuming land acquisitions and demolitions.

SN benefited not only 450,000 slum dwellers but the entire city. Sewage was diverted from river stretches flowing through the city centre, the banks were landscaped and pedestrian paths and gardens were laid along them. The project planned individual toilets connected to the sewers and individual water supply from a piped network. Cost-effective individual toilets, built for about 80,000 families, gave their users greater dignity and responsibility for maintenance than community toilets had.

Some innovative economy measures were adopted. For water connections, existing sources were integrated with the main supply lines. For drainage, contrary to normal engineering practice, roads were laid at a lower level than the built areas around them so that they drained most of the storm water, reducing flooding during heavy showers. This also reduced the cost of the storm-water drains. Their length and depth could be reduced as the roads partly took over their function. Soil from the excavation was used to fill up low-lying areas, giving them a slope towards the roads and storm-water drains, thus helping to prevent them from becoming waterlogged. Soft landscaping was adopted in a big way. Only some open spaces were paved and the rest left for landscaping by the community. Many of these areas were planted with grass, giving clean and firm surfaces at a fraction of the cost of hard paving, and helping to regulate peak flows into the drains.

The SN project is a partnership between the administration, community and private stakeholders. The direct beneficiaries have contributed significantly. All of them contribute part of the sewerage costs by paying for house connections from the main line. Beneficiaries do earthwork and landscaping through self-help groups. Community volunteers run the health, educational and social components. Cooperative groups operate revolving funds. Linkages have been formed by individual families and societies with established institutions such as the Self-Employed Women's Association (SEWA), among others, while the Housing and Urban Development Corporation (HUDCO) has financed housing and environmental improvement.

The project demonstrates the effectiveness of slum upgradation in keeping with the Draft National Slum Policy which states that 'Slums are an integral part of urban areas and contribute significantly to their economy, both through their labour-market contributions and informal production activities.' The policy thus endorses an upgrading and improvement approach in all slums. It does not advocate slum clearance except under strict guidelines.

## Management of Urban Areas

Local government bodies such as municipal corporations, municipalities, *nagar panchayats*, cantonment boards and special area development authorities, are responsible for the administration and upkeep of an urban area. Their functions may include some or all of the following:

1. Essential or core functions:

    - Regulation of land use and construction of buildings.
    - Construction of roads and bridges.
    - Provision of water supply for domestic, industrial and commercial purposes.
    - Public health, sanitation, conservancy and solid-waste management.
    - Provision of urban amenities and facilities such as parks, gardens, playgrounds.
    - Burials and burial grounds, cremations, cremation grounds, electric crematoriums.
    - Cattle pounds, prevention of cruelty to animals.
    - Vital statistics including registration of births and deaths.
    - Public amenities including street lighting, parking lots, bus stops.
    - Regulation of slaughterhouses and tanneries.

2. Environment management functions
3. Planning functions
4. Other functions

The rest, namely public transport, fire services, promotion of cultural, educational and aesthetic aspects, depending upon state policies and traditions, could be the responsibility of municipal agencies. They may be performed locally but their costs may be underwritten by the higher levels of government. Alternatively, they may be listed as municipal functions.

Urban Local Bodies (ULBs) traditionally generate their income through taxes and cesses for the services they provide. Their main sources of revenue are property tax and octroi (a levy on goods and commodities entering municipal limits). Both are unpopular for various reasons, and cannot entirely cover the costs of providing and managing municipal services. While they have the advantage of being totally under the control of the ULBs, they also have their disadvantages. Property tax, a politically tricky matter, cannot be hiked frequently to meet expenses. Octroi is unpopular because of the cumbersome method of collecting it, which involves stopping and checking vehicles, causing delays

and traffic jams and opening up opportunities for harassment and corruption. Almost all the states in India (excepting Gujarat and Maharashtra, two of the most industrially advanced) have abolished octroi, replacing it with an entry tax collected by the state government and passed on to the ULBs. In this, the fiscal autonomy of the latter is compromised. It becomes a sensitive issue when mutually opposed political parties are in power at the state and ULB levels.

Thus, the financial autonomy of the ULBs is apparently diluted. But on the other hand, a path-breaking legislative measure by Parliament seeks to vest them, through the states, with more powers and responsibilities, and also seeks to involve citizens more directly in the planning and management of urban services.

### The 74th Constitution Amendment Act

The Government of India took the initiative to strengthen local self-government in cities and towns in the form of the 74th Constitution Amendment Act of 1992. This 'empowers the State Legislature to endow the municipalities with requisite powers to enable them to function as an institution of local self-government.' Under this Act, 'the local elected bodies have been empowered to assume larger roles in planning, financing and management of urban services.'

This Act, through its provisions, attempts to ensure that citizens are involved in the planning and management of municipal services, and that the poor, women and minority groups are represented adequately in local bodies. It seeks to increase transparency in governance at all levels, and to ensure a voice for the people to communicate their needs to planners and urban managers.

The implications of these seemingly contradictory developments—the dilution of the financial autonomy of the ULBs on the one hand, and their empowerment for a larger role in planning, financing and management on the other—are still in the process of being resolved. What it may effectively mean is that citizens will be required to pay more for a better quality of urban life, but they will also have a greater say in deciding what constitutes that quality, and be able to demand it. However, this does not satisfactorily answer the question of how the urban poor fit into the scheme of things. Numerous studies around the world in recent years have concluded that the poor are willing to pay for minimum essential amenities such as water supply and drainage. These are unarguably the most basic constituents of quality of urban life, but they are by no means all. And whether the poor can really pay for all that is needed—minimum sound shelter, health services, education, nutritive food, transport and much more—is a moot question.

## ENVIRONMENT AND HEALTH

A healthy environment is a prerequisite for a healthy body. In many cases, poor environmental conditions are the reason for the health and related problems of the citizens. Poor sanitation, water-borne diseases and congested living conditions result in the rapid spread of contagious diseases, respiratory problems due to air pollution, etc. Most of the official time, effort and resources are spent on curative solutions for health and other problems. On the other hand, if we look at the causes of these problems and strike at their root through preventive measures, the resources could be used more rationally to deliver more and better services. If the water we drink and the air we breathe are clean, and the surroundings are hygienic, we would be able to lead a healthy life. With every person-day lost to illness, the economy of the city is affected.

A healthy city would also mean a healthy economy, not only by reducing loss of work output and productivity but also by reducing medical expenditure. That transforming a dirty city into one of the cleanest in the country is possible is borne out by the case of post-plague Surat.

### Participatory management of urban wastes: The story of Surat's transformation

Surat, on the banks of the Tapi, is Gujarat's second and India's twelfth most populous city, famous for its diamond polishing and power loom trade. As in all large cities, rapid urban growth resulted in slums, garbage and overflowing drains. In September 1994, there was an outbreak of plague in Surat, causing close to 200 deaths, widespread panic and a mass exodus. Besides the human tragedy, it dealt a severe blow to Surat's economy, which lost several crore rupees a day, and also to the country's economy and image, affecting industrial production, tourism, export and many other activities. International flights to India were temporarily suspended and the export of food grains from Surat was banned.

The pestilence was triggered by heavy rains which lashed the city for several days, causing flooding and waterlogging in low-lying areas and killing hundreds of animals. The primary reason for this was the faulty drainage system. The floods brought to a crisis point the risks inherent in inadequate urban-waste management. The Surat Municipal Corporation (SMC) swung into action to restore normalcy at the earliest, with an action plan involving the government, non-governmental agencies, civil society, and the private sector working together. Doctors in public and private hospitals joined hands with civic authorities. Top priority was given to clearing dirt and debris, disposing of carcasses, pumping stagnant water, spraying pesticides and rodent control.

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Environmental hygiene became the foremost concern. To sustain the initial momentum, a major programme to clean up the city was launched in May 1995. It gave top priority to monitoring, regulating and streamlining garbage collection and disposal, integrating it with sanitation, and public health. The city was divided into 52 sanitary wards under six administrative zones. Meticulous ward-level planning was undertaken, addressing the special needs of critical spots like vegetable markets, eateries, and congested areas. Environmental hygiene instructions were given to households, industries and eateries, with separate garbage-collection methods designed for each category.

Initially, the private sector volunteered trucks and excavators to clear 4,000 tonnes of garbage. Later, the hiring of vehicles for garbage collection, road cleaning, and transporting municipal waste was privatized. The contractors worked under municipal supervision and were charged penalties in the event of non-performance of their assigned tasks. Within a year these measures dramatically improved garbage collection from 50 per cent to almost 94 per cent of the 1,100 tonnes generated daily. This was a morale-booster for the civic employees, officials and citizens. The Suratis, who had earlier accepted filth and dirt as a part of life, were now proud of their city and concerned about its well-being.

The SMC's health department took up some initiatives with help from NGOs such as Sulabh International and *Paryavaran*, including 'public health mapping', strengthening the health services' infrastructure, reviving a work ethic among health workers, and an extensive sanitation drive. These measures dramatically improved the city's health indicators. The SMC began to regularly monitor these indicators, to act as an early warning system for possible future outbreaks of epidemics. Sanitation in slums was an important focus. Strategies for *in-situ* development and relocation were adopted. Emphasis was given to the provision of community facilities such as water taps, pay-and-use toilets, drains and paved roads.

Within 18 months Surat was transformed from a dirty, garbage-strewn city to one of the cleanest in the country. This change was led by SMC's swift and striking initiatives, strengthened by the positive, proactive participation of other stakeholders in the city. Death and infant mortality rates in Surat have declined dramatically. Community participation played a key role in the rapid change. There was a change in the attitudes of the citizens; they began to participate actively in improving living conditions.

## CONCLUSIONS

Historically, cities have been the engines of development and will continue to be so well into the foreseeable future. Therefore, with more people aspiring to a better life, urban populations will continue to grow. This has serious implications for the urban environment and the well-being of people living and working in it. With the possibilities offered by modern technologies of communication and transport, and the changing nature of

economic activities, it is possible that the physical form of the city may, in some aspects, change radically from what we are familiar with. At the same time, the challenges of survival and livelihood faced by large parts of the population will ensure that the essence of the city will retain its familiar character.

While economics and technology may suggest a new logic for the future shape of the urban environment, the social and cultural dimensions that make cities viable will not change as readily. As places of opportunity, socialization, learning life skills, intellectual stimulus, cultural enrichment, interaction and discourse, the advantages of density and the physical proximity of people in an urban environment far outweigh all its disadvantages. The positive values of these must not be lost; and planning and management efforts, as well as new technologies, must be addressed for the amelioration of the disadvantages.

In order to enjoy the benefits of urbanization, we have to be prepared to pay not only in monetary terms but also in terms of disciplining ourselves and foregoing some of the 'freedoms' of urban life that we seem to take for granted: littering; driving and parking our vehicles as we please; encroaching on public spaces and streets, whether to extend our shops and homes or for social and religious celebrations; wasting water (in the not-too-distant future we may have to use water recovered from drains and sewers for washing, bathing, cooking and drinking. The technologies for its extraction have already been developed for USA's space programmes; it is only a matter of time before they become affordable—or have to become affordable—for use in our cities); wasting energy; chopping down mature trees to make way for road widening.

At the same time, a serious effort is needed to reverse the negative consequences of urban growth and urbanization—alienation of people from the natural environment, unsustainable exploitation of natural resources, environmental degradation, social conflict and tensions. In the ultimate analysis, how the urban environment develops must be determined in partnership with citizens, and not by the visions of bureaucrats, technocrats and policy makers.

## I QUESTIONS

1. What is the difference between 'Urbanization' and 'Urban Growth'?
2. What are the main causes of urban air pollution?
3. What is the proportion of the slum population in your town or city? How does it compare with the national average of 26 per cent?
4. Can you list any heritage structures or any natural heritage features (like rivers, lakes, hills, urban forest, etc.) in your city that are likely to come under the threat of destruction because of urban development projects (such as road widening, construction of flyovers or buildings) in the near future?

5. What are the major elements of the 74th Constitution Amendment Act?
6. What were the factors responsible for the transformation of Surat from a dirty, garbage-strewn city to one of the cleanest in the country?
7. How many new vehicles are being added to your city each year? How much additional space would they need?

## II EXERCISES

1. From reference books or from the Internet, try to find answers to the following:

   a. Since when have regular censuses been conducted in India?
   b. Through the period covered by these censuses, what has been the growth of the total and the urban population of the country? Represent this on a graph.
   c. Plot on a graph the population growth of the four largest cities of India from the beginning to the end of the 20th century. For any one of them, trace the important developments that may have influenced the course of their growth during the century.
   d. Plot the population growth of your own town/city from 1951 to 2001. Try to find out the corresponding growth in its area. What significant infrastructure, institutions, businesses and industries were established during these 50 years, and when? What was the population when these events happened?

2. Research the history of your town by interviewing people who have lived there a long time: what was the town like when they arrived, or in their childhood and youth—if they were born there? What significant changes have they witnessed? What milestones are particularly memorable? What changes would they like to see? Write up this oral history project as a report.

## III DISCUSS

'The slum is the "solution" rather than the "problem" of urban living.'
Do you agree with the above statement? Discuss.

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# Chapter 9

# Industry

Meena Raghunathan

It is a significant achievement that India is one of the 10 most industrialized nations of the world. Industrial activity is essential to generate goods for the development of the nation, to meet the needs of the people, and to generate employment. At the same time, it must be accepted that industrial activities release pollutants that contaminate air, waterbodies and land, and adversely affect the quality of human and other life.

While industries are vital for development, it is equally important to be aware of the impacts of industries on environment. A proper understanding of this can help ensure that these impacts are minimized.

## How Industries Affect the Environment

The first and most obvious way in which industries affect the environment is the pollution caused by factories. The most visible are the water, solid-waste and air pollution that can be felt and seen. The nature and composition of industrial waste and pollutants vary widely from industry to industry and even within the same industry. The waste generated depends on the raw materials, processes, and operating factors. Different industries generate different types of pollutants. For example, food processing industries produce organic wastes that are readily decomposed but have high biological oxygen demand (BOD); pulp and paper mills produce toxic compounds and sludge; the electronic industry produces high levels of heavy metals such as copper, lead, manganese, etc. Apart from the pollution that they produce, industries affect the environment in other ways too. What are these other kinds of environmental impacts? Let us examine some of these factors.

*Raw materials:* A most basic need of any industry, be it the paper industry, the textile industry, the cement industry, etc., is raw material. A factory can turn out anything,

aeroplanes or cloth or paper. But it needs raw materials; for instance, aluminium to make an aeroplane, natural or synthetic fibre to make cloth, wood pulp to turn into paper.

The extraction and mining of raw materials, and the processing of the raw material, e.g., ores into metal, have major environmental impacts. For instance, if limestone is to be mined for cement production, large areas of land will get degraded. If cotton is to be grown for making cloth, hectares of agricultural land may have to be made productive with chemical fertilizers, and heavily sprayed with chemical pesticides to get a good crop. If wood is to be fed to a paper factory, hectares of trees or bamboo will have to be cut down.

*Transport of raw materials:* Getting the raw material from the site or field from where it is extracted and other inputs to the factory, involves transportation. This takes its own toll on the environment in terms of the fossil fuels consumed and the pollution caused by the transport.

*Other inputs:* In addition to the raw materials, most production processes need water and power. They may draw water either from surface water sources in the neighbourhood (e.g., river, lakes, etc.), or they may tap groundwater. In either case, there are serious environmental impacts to be considered, especially if the operation is large scale or water-intensive. For example, if a factory comes up in a semi-arid area, where groundwater levels are already low, it may draw so much water that the availability of drinking water for the local communities might reduce. After all, it is the same limited groundwater that both would be trying to draw out. The other essential input for any production process is power. Power, whether generated in a hydel plant, thermal plant, nuclear plant, or by any other means, has serious impacts on the environment. So every kW of power that the factory draws has environmental impacts. (See chapter on Energy for more information on impacts of power plants.)

Increased industrial activity since the Industrial Revolution is one of the main causes of air pollution. With growing populations and industries, the need for energy has increased multifold. To meet this increased power requirement, mega-power projects have come up. The use of coal in thermal power stations has led to the increase in air pollutants such as various oxides of carbon, sulphur and nitrogen. Apart from these, thermal power stations produce large quantities of fly ash as a by-product, which covers large areas of land with a fluffy, sooty layer.

The great leaps in industrial production have been achieved by the mushrooming of industrial establishments such as steel and chemical plants, paper plants, refineries, petrochemical plants, power plants and more. With this has come an increase in the pollutants discharged by industries. The emissions from these contain not only smoke and soot, but also other particulate as well as gaseous pollutants. Table 9.1 shows the contribution of different kinds of pollutants by some sectors of industry in India. These pollutants can have serious consequences not only on human health, but also on flora and fauna, soil, water and man-made structures.

Table 9.1
Industrial contribution of pollution by subsector in India

| Sector | Share of industrial output | Share of total industrial pollution (%) | | | | |
|---|---|---|---|---|---|---|
| | | *Toxic* | *BOD* | *Particulates* | *Sulphur* | *Nitrogen* |
| Iron and steel | 12.5 | 23 | 0 | 23 | 2 | 5 |
| Industrial chemicals | 7.5 | 44 | 29 | 8 | 11 | 15 |
| Non-ferrous metals | 2.1 | 6 | 10 | 3 | 1 | 0 |
| Other chemicals | 6.8 | 6 | 1 | 1 | 0 | 1 |
| Food products | 15.3 | 1 | 38 | 11 | 4 | 8 |
| Paper and pulp | 2.0 | 2 | 19 | 4 | 15 | 11 |
| Non-metallic mineral products | 3.4 | 1 | 0 | 32 | 3 | 10 |
| Petroleum refineries | 6.8 | 6 | 2 | 6 | 31 | 21 |
| Textiles | 11.1 | 3 | 1 | 6 | 30 | 23 |
| **Total** | 67.5 | 92 | 100 | 94 | 97 | 94 |

**Source:** *State of the Environment,* (2001) UNEP.

*Production processes:* Of course, the production process itself has impacts on the environment. It may generate pollutants and waste material in the form of liquids, solids, gases or even noise or heat. Some of this may be toxic or hazardous and long lasting. Some of it may pollute the immediate environment; some may travel hundreds of miles into another state or country. Industries also often contribute to noise pollution through the production process, e.g., from the running of motors. This also is a form of pollution.

*Packaging:* After the production process, the product has to be packaged and transported. This again impacts the environment. Packaging is getting more and more resource-intensive, e.g., biscuits are packed in a whirl of corrugated paper and then in a plastic sheet, which may then be put into a cardboard carton. Each of these packing materials has gone through its own processing cycle. After packing, the ready product has to be transported to the various, far-flung markets. Transportation also uses up resources and creates pollution.

*Environmental impact of use:* When a product is used, it affects the environment. For instance, when we buy a scooter, we will need a large amount of fossil fuels to run it. Similarly, a washing machine will need water, detergent and electricity to run it. This process will continue throughout the life of a product.

Thus, a manufacturing industry takes in raw material, processes it, and puts out both the product (which is the desired result of this production process), and the by-products (including pollution), which are a necessary but undesired outcome of the production process.

Hazardous waste

**Maharashtra:** The Thane–Belapur industrial area in Maharashtra, where about 1,200 industrial units are housed on a 20-km stretch close to New Mumbai, creates more than 100 tonnes of solid waste every day. About 85 per cent of this waste is either acidic or alkaline in nature. The area also produces 5 tonnes of waste every day which is difficult to treat because of its halogen content. The bulk of hazardous waste in this area is disposed along with municipal waste in dump sites. The waterbodies in the vicinity of this industrial area are polluted. Ulhas river empties into Thane Creek at its northern end. The sediment in the Ulhas river has registered high levels of mercury and arsenic. As a result, Thane Creek is one of the most polluted sea waters in the country.

**Gujarat:** The Ahmedabad–Vadodara–Surat industrial belt has over 2,000 industrial units in the organized sector and more than 63,000 small-scale units manufacturing chemicals like soda ash, dyes, yarns and fertilizers. Vapi in Valsad district has around 1,800 units of which 450 fall in the category of polluting industries. Industrial units in all these areas usually dump their wastes in low-lying areas within a 2-km radius. As a result, a major illegal dump yard has sprung up on the banks of river Daman Ganga. The Indian Petrochemical Corporation Limited (IPCL) at Vadodara, dumps 1,800 tonnes of hazardous wastes every month at a site near Nandesari. The IPCL dump site is on a hill. During the rainy season, the hazardous constituents of these wastes are washed down into the river. (*State of the Environment, India*, 2001. UNEP.)

## Reducing the Environmental Impact

Having seen that industries have major impacts, we need to see how to minimize them. There are guidelines and checks to be followed before setting up any industry and while running the industry.

*Location of the industry:* A polluting industry should not be located in an ecologically sensitive area or near human settlements. For example, Mumbai may have excellent infrastructure and markets, but a highly polluting industry cannot be located in such a densely populated place. The Government of India has issued guidelines for the setting up of certain industries. Under these guidelines, to set up industries mentioned in the guidelines, environmental clearance has to be obtained from the government. The guidelines include pointers on location, e.g., certain areas need to be avoided while setting up certain types of industries. These include ecologically sensitive areas, coastal areas, major settlements, flood plains, etc. The guidelines also specify certain conditions which must be followed in the siting of these industries; for example, no forest land or prime agricultural land can be cleared; enough land should be acquired so that there is space for treatment facilities, storage of solid waste, etc.

### The Bhopal tragedy

Apart from the environmental problems that occur during the normal course of the functioning of industries, there are grave consequences for environmental and human well-being in the event of accidents. One of the world's most serious industrial accidents took place in India at the Union Carbide factory in Bhopal. On 4 December 1984, when the city was asleep, a deadly chemical blanket spread over it. Something had gone wrong in one of the storage tanks at the Union Carbide factory, and close to 40 tonnes of a deadly chemical, methyl isocyanate (MIC), escaped into the air. At least 4,000 people died as a result of this, and the health impacts are still being felt in the area.

How could such a tragedy have happened? There were many contributing factors. One reason was that the safety measures put in place in this factory, which made and used such hazardous chemicals, were not adequate and did not work when they were most required. Another factor that contributed to the tragedy was that there were so many people living so close to the factory. Moreover, there was little information available about what the chemicals being processed in the factory were, what effects they could have, and how they should be treated. As a result, when the MIC leaked out, few people even knew what gas it was. Doctors did not know how to treat the patients. Helpless citizens did not know what precautions to take. City authorities did not know how to handle this midnight crisis.

The controversy about whether the victims were adequately compensated continues. But can money compensate for lost lives, lost health and sick babies? As a result of Bhopal, India and other countries have made stricter laws regarding such industries. But we have a long way to go before we can ensure that there are no more 'Bhopals'.

Clustering industries at one place—usually called an industrial estate—has several advantages. Several industries can avail themselves of the facilities of the common infrastructure developed there, either by institutions like the State Industrial Development Corporations, or by themselves. They can also share the cost of maintaining the common infrastructure. Transporting raw materials or finished goods also becomes easier if it is channelled from one place. The industries can themselves network for their production as well as marketing needs. An entrepreneur can have the advantage of being among fellow trade people and can be easily accessible to visiting clients. Waste products from the industries can also be treated together, which minimizes costs and leads to better treatment of the waste. In fact, in some cases, waste products from one industry can become raw material for another.

### Common effluent treatment plant

Industries carry out various processes that use water and other chemicals. The mixture of chemicals and water that is not utilized comes out as waste water from the industries. The waste water can prove very harmful to the environment if discharged without treatment to make it safe. At a Common Effluent Treatment Plant (CETP), the effluent (waste water) from a group of industries is treated to render it safe for disposal.

*Environmental Impact Assessment (EIA):* A planning tool, the objective of the EIA is to foresee and address potential environmental problems/concerns at an early stage of project planning and design. It is supposed to assist planners and government authorities in the decision-making process by identifying key impacts and issues and formulating mitigation measures. In India, the Ministry of Environment and Forests has issued sectoral guidelines for the EIA. The EIA process in India is as follows:

- Screening
- Consideration of alternatives
- Baseline data collection
- Impact prediction
- Assessment of alternatives, delineation of mitigation measures and environmental impact statement
- Public hearing
- Environment Management Plan
- Decision making
- Monitoring the clearance conditions

A key provision is the one regarding Public Hearing. The law requires that the public must be informed and consulted on a proposed development after the completion of the EIA report. Anyone likely to be affected by the proposed project is by law entitled to access the Executive Summary of the EIA. NGOs and alert citizen groups can play a key role in ensuring that this provision is properly used.

*Environment Management Plan (EMP):* Before a polluting industry becomes operational, an EMP needs to be prepared. This plan indicates what environmental protection measures have been or are proposed to be taken during and after the commissioning of the project. This management plan is based on considerations of resource conservation and pollution abatement, and looks at waste management methods, housekeeping systems, disaster planning, etc.

### Occupational health

Sometimes the place of work or the nature of work may lead to ill health. This phenomenon of the impact of the work environment on the physical, mental or social well-being of the worker is called **occupational health**. At workplaces, there are several factors that can be dangerous or can cause damage to the health of the worker. These are called **occupational hazards**. For example, a farmer is exposed to harmful chemicals present in pesticides as well as fertilizers; a teacher is exposed to chalk dust; workers in cotton mills are exposed to cotton dust which can cause a deadly respiratory disease called bysinnosis.

*Laws and rules:* Once an industry starts operating, there are rules and regulations to ensure that it does not harm the environment. These rules and regulations are enacted

under certain legal Acts. Some of the important Acts under which these rules and regulations are framed include: the Water Act for the Prevention and Control of Water Pollution; the Air Act for Prevention, Control and Abatement of Air Pollution; and the Environment Act for the Protection and Improvement of the Environment.

While corporate India is becoming increasingly environmentally responsible, the legal framework to prevent environmentally harmful industrial practices has also been particularly strengthened in the last two decades. While the Water Act (1974) and the Air Act (1981) were already in place for pollution abatement, the Environment Protection Act or EPA (1986), was promulgated as an umbrella legislation for environmental protection. Under this Act, the enforcement agency has the power to direct the closure, prohibition or restraining of any industrial operation or process for preventing, controlling or abating environmental pollution. The EPA lays down standards for the quality of the environment in its various aspects, as also emission standards with regard to various sources. It defines restricted areas where no industrial operation can be carried out, and gives powers of entry and inspection to the concerned authority for any industrial plant.

### Pollution control

The Central Pollution Control Board (CPCB) is an autonomous body of the Ministry of Environment and Forests, Government of India. The CPCB, along with the State Pollution Control Boards and Pollution Control Committee, is responsible for implementing the laws relating to the prevention and control of pollution. These bodies develop rules and regulations which describe the standards of emissions and effluents of air and water pollutants and noise levels.

Other rules like the Hazardous Wastes (Management and Handling) Rules, 1989, Environment (Siting of Industrial Projects) Rules, 1999, have also been enacted to further ensure pollution control and abatement.

It is not only the law that can control pollution. There are other approaches that can minimize the environmental impact of industries.

*Eco-efficiency:* This can be understood as the production of goods in ways that are less damaging to the environment and use fewer resources without increasing the cost of the goods. Eco-efficiency needs to be looked at as a whole. Thus, it could include reducing the amount of raw materials used; reducing the amount of energy used; reducing the pollution; trying to recycle materials and using renewable materials.

Think of a familiar example. At home, potatoes boiled in a pressure cooker take less time to cook, and, therefore, consume less fuel than if they were to be boiled in an ordinary vessel. So in a way, a pressure cooker is a fuel-saving and therefore an environment-friendly technology.

Similarly, there are also environment-friendly processes: if we were to soak *dal* before boiling it, it would take less time than if the *dal* were to be cooked without soaking. Similar changes can be made in industrial technologies and processes too. One example

is the use of agro-industrial waste, such as bagasse, for the cogeneration of electricity in sugar factories (see chapter on Energy).

### Enhancing environmental and economic performance

By collectively managing environmental and energy issues, eco-industrial park members can enhance their environmental and economic performance and, as a result, achieve a combined benefit that is greater than the benefits each company would realize from optimizing only its individual performance. (Eco-Efficiency Task Force Report, 1996. U.S. President's Council on Sustainable Development.)
http://www.greenroofs.ca/cein/whatsein.html

*Cleaner production practices:* The concept of cleaner production (CP) is to minimize or eliminate waste and emissions at their source, rather than treat them after they have been generated. CP conserves raw materials and energy, eliminates toxic raw materials and reduces the quality of toxicity of all emissions and wastes before they leave the production process. It reduces environmental impacts throughout the entire product life cycle—from raw material extraction to waste disposal.

An everyday example of cleaner technology would be the use of a solar water heater rather than a wood stove or LPG. A wood stove gives out smoke; LPG, in its extraction and processing, gives rise to pollution. A solar water heater uses renewable energy and gives off no pollution. If industries were to lay more stress on cleaner production, they would have to clean up less pollution and would put less a strain on the environment.

### Keeping up standards

The International Organization for Standardization (ISO) is made up of national standards institutes from various countries. The ISO develops voluntary technical standards which contribute to making the development, manufacture and supply of products and services more efficient, safer and cleaner. The ISO itself does not carry out certification. It develops guides and standards which carry out conformity assessment activities.

The ISO's environmental standards reflect global consensus on good environmental practice. There are more than 350 international standards for the monitoring of aspects such as the quality of air, water and soil, as well as noise and radiation.

ISO 14001 provided the tool for addressing the concern for environmental standards. ISO 14001 calls for creating standards in all systems of the industry, with special reference to environment management, and aims for economic benefits and reduced environment protection costs by working towards resource conservation and pollution prevention, thus benefiting both the industry and the environment.

When the Indian Aluminium Company Ltd started developing the environment management plan for a bauxite mine under the Environment Management System of ISO 14001, many 'self-imposed standards' were evolved for various mining and related activities. These

*(continued)*

*(continued)*

standards were close to the national/international standards. Once achieved, they were strictly adhered to, to ensure a performance better than the legal limits. All operational controls were modified to achieve these standards.

*Eco-industrial networking:* Eco-industrial networking is rapidly becoming an important new approach for industries, communities and businesses to improve their competitiveness, economic viability and human and ecosystem health. This approach uses the concept of industrial ecology, which looks at the potential for networking the material flows of a set of industries. The objective is to tap the potential to utilize the wastes of one unit as an input to another, with the final goal of integrating all industries as components of an industrial system.

Eco-industrial networking involves developing new local and regional business relationships between the private sector, government and educational institutions, in order to use new and existing energy, material, water, human and infrastructure resources to improve production efficiency, investment, competitiveness and community and ecosystem health.

Such networking is in the form of associations of industries which facilitate the implementation of cleaner production technologies and waste-minimization options in their member industries.

Polluter pays

The Polluter Pays Principle is simple: those who pollute must pay for any environmental damage created. The idea originated in the 1970s, when members of OECD countries introduced it as a payment method to ensure that pollution costs were financed by the polluters and not by the public in general.

While it sounds simple, in operation there are many complexities. For instance, when and how much should a polluter pay?

These initiatives by the government as well as by the industries themselves have contributed much towards curbing pollution and moving towards more sustainable technologies. These efforts reflect a growing sense of corporate responsibility towards a cleaner environment in the Indian industrial sector.

However, industry essentially is an economic activity guided by principles that are perceived to make economic sense. Manufacturers will, therefore, make investments in efficient technology and pollution prevention measures only if they lead to economic benefits by reducing quantifiable costs, or by increasing quantifiable benefits. For many industries, the introduction of innovative technologies that prevent or reduce pollution and lower the cost of complying with anti-pollution laws also tend to decrease energy consumption. In the present scenario, when the courts are coming down heavily on industries for non-compliance with pollution control laws, it makes economic sense to adopt

new technologies and improved practices aimed at pollution prevention and waste minimization that would reduce pollution remediation costs.

## WHAT CAN INDIVIDUALS DO?

Industries produce goods and services because people want them. If there was more demand for environment-friendly products, industries would have to produce them. But how would an individual consumer know if a product is environment friendly? In order to help in this, there is a worldwide movement to 'ecomark' products. Under such a scheme, an agency designated by the government, after satisfying itself that a product has been produced in an environment-friendly way, will certify it. Then the packaging of the goods will display a special sign so that consumers will know that it is environment friendly. As of now, in India, while there is a provision for the ecomark, there are few products that are marked with it.



Illustration 9.1 India's ecomark

Consumers may also choose not to consume, or to reduce their consumption of certain goods and services. For instance, the environmentally conscious may choose not to accept plastic bags at shops, preferring to carry their own cloth bags. They may choose to use only organic manure in their gardens rather than chemical fertilizer. Responsible consumers can make a difference to what is produced and how. As a consumer, ask before buying anything: Where does it come from? How is it disposed? How long will it last? Can it be repaired? Is it really needed?

### I QUESTIONS

1. What are the various kinds of impacts that industries can have on the environment?
2. What purpose does an environmental impact assessment serve?
3. What do you think would be the most powerful incentive to make industry take steps to reduce pollution?
4. If you were setting up an industrial unit, what are the steps you would take to ensure minimal environmental impact?
5. What does the concept of 'cleaner production' imply? Why is it not called 'clean production'?

6. What are the advantages and disadvantages of industrial society as opposed to an agricultural society?

## II EXERCISES

1. Quoted below is a report from a website. Read the paragraph carefully and answer the questions that follow.

   Stretching 400 km from the busy city of Ahmedabad to Vapi, in western India, a series of sprawling industrial estates make up the 'Golden Corridor'. For industrialists the Golden Corridor is a haven where all rules have been given the go-by by the government.

   Hundreds of small and medium factories manufacturing chemicals, dyes, paints, fertilizer, plastic, pulp and paper, spew untreated wastes into the air and water, poisoning farmland for miles all around. Industrial gases hang in the air, especially in the winter, making breathing difficult. Most of these industries have no safe disposal system for toxic wastes and discharge them into the river. This causes grave damage to the riverine ecology.

   In Nandesari village, 220 ha of fertile agricultural land has been turned into a chemical industrial estate. Abundant harvests of cotton, sugar cane, peanut and wheat grown in these region are being poisoned by factory wastes.

   Once-clear streams like the Amlakhadi are now noxious and foul-smelling channels of black sludge, and have killed livestock that drank from it. In the Golden Corridor, multicoloured hazardous waste lies in heaps on which children play. Discarded chemical drums are also part of their playground.

   The majority of the workers are poor migrants who are afraid they will lose their jobs if they raise issues of occupational health and safety. They complain of pollution, health problems, threat of accidents when containers explode and pipes burst.

   As if this was not enough, Gujarat's 1,600 km Arabian Sea coastline has been targeted for port-based industries. There is a lobby seeking denotification of India's only Marine National Park and its fragile mangroves, through which a proposed pipeline will carry crude oil from Oman to central and north India. A major portion of all future oil imports will arrive through Gujarat's ports. Already oil spills have affected vast stretches of mangrove forests in the Gulf of Kachchh.

   A High Court order on 21 October 2002 prohibited the dumping of effluents into the Amlakhadi unless they were treated. But the National Environmental Engineering Research Institute (NEERI) has recommended that

effluents be disposed in the deep sea. A 55-km pipeline is under construction at a cost of $3 million, although the National Institute of Oceanography is yet to complete its assessment of its impact on marine life. Regulatory boards, which are the watchdogs on industry, appear to be working at cross-purposes in Gujarat and there seems to be a lack of coordination among them.

Now answer the following questions.

a. Do you think this is a fair and unbiased report?
b. Who are the people you would interview if you had to prepare such a report, or if you were to check the veracity of the report?
c. What would happen if these industries are closed down? List the issues that could come up.
d. Find out more about the organizations/institutions named below, and write a brief note on each:
National Environmental Engineering Research Institute (NEERI), National Institute of Oceanography (NIO), Central Pollution Control Board (CPCB).
e. What do you think are the economic, social and environmental consequences for the local people of the industrialization in the region?
f. Give an appropriate title to the passage.

2. Given below are three 'half stories'. Read them carefully and complete them in the way you think is most suitable.

a. The Nimipur Sanctuary occupies 550 sq km of an economically backward state. The sanctuary is mostly covered by bushes. The rest of the area is flat and dry, except in the monsoon when grass covers it. An extremely rare species of deer, not found anywhere else in the country, lives in the sanctuary. The sanctuary is also home to the Pakari tribe who have been living in the area for generations. The Pakaris are nomadic, moving from place to place in the sanctuary with their grazing herds. A large industrial house has approached the government for permission to start mining in the sanctuary and to build a big industrial complex which will provide jobs to the Pakari and end their poverty. Many people in the state believe that the industrial complex will attract other industries and bring economic development to the state. But there are protests from wildlife enthusiasts that mining and industry will destroy the only habitat of the rare deer. Some people feel that the industrial complex may not provide jobs to the unskilled, illiterate Pakaris. They feel that the traditional way of life of the Pakaris will also be in danger as mining will destroy the land and grazing may no longer be possible.

b. Chetan Chemical Industries Limited (CCIL) is a large chemical factory that supplies chemicals to many industries in the state. More than 5,000 workers are employed in the industry. Waste water from CCIL finds its way into the nearby river. Villagers living downstream have been protesting that the waste water has ruined their agricultural lands, has been responsible for cattle deaths and has caused skin diseases. The pollution control authorities have recommended that the industry should be closed down as it has been causing severe pollution. The workers' union protests that if the industry is closed down, they will lose their livelihoods.
c. The government of Surya Pradesh wants to build a massive information technology complex outside their capital. They believe that the complex will attract many companies from all over the country and the world, and that this will provide jobs to the people of Surya Pradesh. The area selected for the complex has about 2,000 trees. Scientists say that this area acts as a 'green lung' for the heavily polluted city.

## III DISCUSS

1. When environment and industrial development concerns are merged, a better set of goals evolves. Do you agree? Discuss.
2. The industrial location policy is a crucial element in determining the impact of industry on the environment. How?

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# Chapter 10

# Climate Change and Ozone Depletion

Kiran B. Chhokar, Mamata Pandya and Meena Raghunathan

Change is a fundamental characteristic of the environment. From the ice ages of the past to the industrial age of the present, the climate of the earth has been changing. Scientists have studied and recorded the earth's climate over the millennia and found that the planet's average surface temperature has fluctuated over geologic time, with several ice ages in the past 800,000 years.

The ice ages of the past are examples of climatic changes due to natural factors. What is disturbing today is that human activities are leading to an unprecedented acceleration in such changes. The scientific evidence suggests that the earth's climate is changing. The atmosphere is warming, and this trend will continue. By the year 2050, scientists predict that the world will be warmer by an average of between 1.5°C and 4.5°C.

Earth's climate is a result of complex interactions between the sun, atmosphere, oceans, land and biosphere. Due to the complexity of atmospheric and ocean current interactions, this warming may increase the frequency and intensity of storms, droughts, floods and other, not-yet-predictable, weather events. Already several examples of atmospheric warming are available from around the globe. For example, nine of the hottest years recorded in more than a century have occurred since 1988. Worldwide, July 1998 was the hottest month ever. In 1998, India experienced its worst hot spell in 50 years, which took a toll of over 3,000 lives. Another worrying phenomenon is the retreat of the Himalayan glaciers—18 m per year in the case of Gangotri.

For the past two decades scientists have been collecting and debating evidence of long-term climate change. Are the observed warming trends simply natural variations in climate or are they a long-term trend? And if there is a trend, what is causing it—human activity or natural fluctuations? In 1988, the United Nations set up the Intergovernmental Panel on Climate Change (IPCC)—an official scientific body comprising of leading atmospheric scientists from around the world—to investigate climate change. The IPCC's Second Assessment Report published in 1995 states that climate change is a

long-term trend, and human activities are its major cause. At the root of this is the extensive use by humans of fossil fuels. When burned, these fuels release heat-absorbing gases, called **greenhouse gases (GHGs)**, into the atmosphere.

### Studying climate

The saying goes, 'Climate is what you expect; weather is what you get.' The word climate describes the general average pattern of the weather in a place over a period of years. Climatologists generally consider 30 years as the time needed to assess the climate of a place.

Scientists learn about the climate of the past by studying the ice cores, fossil remains of pollen, and fragments of plant species including the diameters in the rings of old tree stems. By analysing the air trapped in the ice, scientists can find out what the air temperature was at the time when the ice was formed. In ocean and lake sediments, oxygen isotopes of the shells of tiny organisms provide information about the temperature of the water in which the shells were formed.

To study likely future changes in the earth's climate, scientists develop complex mathematical models of the systems and components that affect climate (such as atmospheric and ocean circulation), and run them on supercomputers.

## The Greenhouse Effect

The release of key GHGs—carbon dioxide, methane, and nitrous oxide—is, however, not only due to the burning of fossil fuels. It is also a part of nature's normal processes. Like the panes of a greenhouse, GHGs allow sunlight to pass through the troposphere (lower atmosphere), but trap the heat. As the heat rises from the earth's surface into the troposphere, some of it escapes into space, some is reflected back to the surface by the molecules of GHGs, warming the air. This natural trapping of heat, or the **greenhouse effect**, has made the earth habitable. Without it, the earth would have been a cold, lifeless planet.

Thus, in the normal scheme of things, GHGs, which make up less than 1 per cent of the atmosphere, are benign and useful. Their levels in the atmosphere are determined by a balance between 'sources' (processes which release these gases) and 'sinks' (processes such as photosynthesis which absorb, sequester or remove them. Since $CO_2$ dissolves in water, oceans are a gigantic sink as well). But a lot of modern human activity tends to disrupt this optimal balance. Such disruption may happen by way of the introduction of new or additional sources of natural GHGs, man-made GHGs, such as CFCs (chlorofluorocarbons) and their substitutes, or of interference with natural sinks (such as by deforestation).

One hectare of tropical forest, for example, is estimated to store 445 t of carbon in its biomass and soil. When a forest is cleared away and replaced by agriculture or human settlements, much of the stored carbon is released into the atmosphere as carbon dioxide.

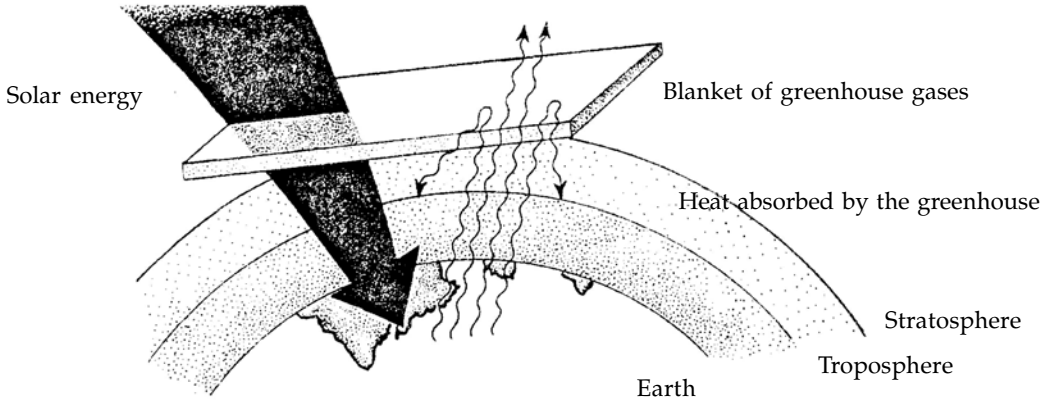



Illustration 10.1 The greenhouse effect

With the forest gone, fewer plants are left to remove carbon dioxide from the atmosphere through photosynthesis. The enhanced levels of GHG accumulation in the atmosphere resulting from this disruption are causing an increase in the temperature of the earth, referred to as 'Global Warming', which in turn leads to 'Climate Change'.

## Potent Warmers of the Globe

GHGs added to the atmosphere by human activity can significantly affect the amount of heat trapped in the atmosphere over time. Most of these gases have fairly long lifespans, ranging from 10 years to thousands of years. What we put into the atmosphere today will, therefore, continue to warm the planet for a long time to come.

**Carbon dioxide** ($CO_2$) is responsible for more than 55 per cent of the current global warming from GHGs produced by human activities. Its concentration has increased by more than 30 per cent since pre-industrial times (around 1750), and currently increases by 1 per cent every year. The main sources (75 per cent) are the burning of fossil fuels, particularly coal, and, increasingly, motor vehicle exhaust. Deforestation and biomass burning contribute 25 per cent. $CO_2$ remains in the atmosphere for around 200 years.

**Methane** ($CH_4$) accounts for 16 per cent of the increase in GHGs. It can trap 20 to 25 times more heat than $CO_2$ on a molecule for molecule basis. It stays in the atmosphere for only 10 to 12 years, but is removed when it reacts with the hydroxyl (OH) radical to form $CO_2$. Methane is produced by the decomposition of organic matter in rice paddies, natural wetlands, landfills, the intestines of cattle, sheep and termites. Methane is also produced in natural gas leaks. Its concentration has doubled since pre-industrial times.

A typical domestic cow may produce 73,000 l of methane per year. About one-third of humans have methane-producing bacteria in their guts as well. The increasing amount of methane is linked to the world's population growth—more people need more food and cattle.

The largest agricultural source of methane production is associated with rice cultivation. Paddy fields are estimated to emit anywhere between 25 and 170 million tonnes of methane per year. However, these estimates are subject to huge uncertainties. There have been very few field measurements. Existing field studies have shown variations in results because of the differences in measurement methods, crop patterns and crop varieties. Additional factors that affect the rate of emissions from paddy fields include soil properties, temperature, fertilizer use and agricultural practices.

### Methane and rice fields

Methane is generated biologically by methanogenic bacteria. The warm, waterlogged soil of rice/paddy fields provides ideal conditions for methanogenesis. Methanogenesis is the production of methane and carbon dioxide by biological processes that are carried out by methanogens. Methanogens are single-celled micro-organisms that produce methane by the fermentation of simple organic carbon compounds or oxidation of $H_2$ under anaerobic (without oxygen) conditions with the production of carbon.

The possible sources of methane emission from paddy fields are organic matter applied to the fields, such as rice straw, soil, organic matter, and carbon supplied by decaying rice plants.

**Nitrous oxide** ($NO_2$) accounts for 6 per cent of the human input of greenhouse gases. It is released during nylon production, from burning biomass and fossil fuels like coal, from the breakdown of nitrogen fertilizers in the soil, livestock wastes, and nitrate-contaminated groundwater. Its lifespan in the troposphere is 120 to 190 years and it traps about 200 times as much heat per molecule as $CO_2$. Its concentration is growing by 0.25 per cent per year.

Both natural and chemical fertilizers contribute towards the release of nitrous oxide through denitrification—the reduction of nitrate in soils. Nitrification, a process of converting ammonia into nitrate, can also produce nitrous oxide. In recent years, the use of fertilizers has increased due to the increasing demand for agricultural produce. The excess nitrate in the soil that is not taken up by plants is drained out and pollutes surface water and groundwater. The nitrate remaining in the soil is also available for denitrification, thereby releasing nitrous oxide into the atmosphere.

**Chlorofluorocarbons** (CFCs) are believed to be responsible for 24 per cent of the human contribution of greenhouse gases. CFCs are entirely man-made greenhouse gases. They can trap 1,500 to 1,700 times more heat than $CO_2$ on a molecule for molecule basis and remain in the atmosphere for several thousand years. The main sources are leaking refrigerants, industrial solvents, aerosol propellants and the production of plastic foams.

The concentration of CFCs increased by 4 per cent per year in the 1990s, but their use is now being phased out because of their ozone-depleting properties. The substitutes developed for CFCs do not directly destroy the ozone in the earth's atmosphere, but they do contribute to global warming. Although at present, the CFC substitutes listed below contribute little to global climate change, the projected growth in their use could contribute to it significantly in the 21st century.

**Hydrofluorocarbon** gases (HFCs) are a man-made alternative for CFCs in refrigeration, as agents used to blow foams or insulation, and as solvents or cleaning agents, especially in the manufacture of semiconductors. However, their global warming potential is 4,000 to 10,000 times that of $CO_2$.

**Perfluorocarbons** (PFCs) are replacement gases for CFCs, but they are also a by-product of aluminium smelting. Small amounts are also produced during the uranium-enrichment process. They can trap 6,000 to10,000 times more heat than $CO_2$ as GHGs.

**Sulphur hexafluoride** ($SF_6$) is a man-made gas used as insulating material for high-voltage equipment such as circuit-breakers. It is also used for detecting water leaks in cable-cooling systems. It can trap 25,000 times more heat than $CO_2$.

## Other Greenhouse Gases

**Ozone** ($O_3$) is a greenhouse gas that has 2,000 times the heat-retention property of $CO_2$. At ground level, ozone is found in small quantities in the air and is formed when other pollutants react in sunlight. It is also harmful to human health and animal and plant life.

**Carbon monoxide** (CO) is generally not thought of as a greenhouse gas as it does not trap heat directly. However, it is indirectly responsible for increasing greenhouse warming because it raises the levels of methane and ozone. CO participates in the formation of ozone. Motor vehicles are the major source of CO.

Human sources of greenhouse gases

| Greenhouse gases | Sources |
|---|---|
| Carbon dioxide | Fossil-fuel burning<br>Industrial processes<br>Deforestation |
| Methane | Livestock<br>Paddy fields<br>Biomass burning<br>Transport and handling of natural gas<br>Coal mining<br>Sewage/landfills |

*(continued)*

*(continued)*

| | |
|---|---|
| CFCs | Refrigeration<br>Foams<br>Aerosols<br>Solvents |
| Nitrous oxide | Fossil-fuel burning<br>Fertilizers<br>Biomass burning<br>Deforestation<br>Manure management |

**Source:** IPCC, 2001.

HOW MUCH HAVE GREENHOUSE GASES INCREASED? The concentration of greenhouse gases in the atmosphere has continued to increase. Atmospheric concentrations of $CO_2$, $CH_4$ and $N_2O$ have increased by 30 per cent, 145 per cent and 15 per cent, respectively, since pre-industrial times. $CO_2$ concentration, for example, increased from 280 ppmv (parts per million by volume) in the 1750s to almost 360 ppmv in 2000.

EFFECTS OF A WARMER WORLD: Most scientists agree that the earth's mean temperature has risen by at least 0.6°C over the last 120 years. But what will happen if the earth's temperature rises by a small amount? Is it something to worry about?

*Weather extremes:* Scientists predict that earth's mean surface temperature will rise by between 1.5°C and 4.5°C by 2050 if inputs of greenhouse gases continue to rise at the present rate. As a result, most places will become hotter. Some will become drier and others wetter. Climate-change processes may cause ocean currents to shift and change. This would result in some places becoming colder—such as Japan and northern Europe—where warm ocean currents have so far kept the temperatures mild.

The energy imbalance in the climate system caused by global warming will result in more violent weather events, increasing the threat of heatwaves, drought, floods (because of heavier rainfall in some regions) and intense storms.

*Rise in sea level:* According to the Intergovernmental Panel on Climate Change (IPCC), the global sea level has risen by 10 to 15 cm over the last century, but it is not certain if this can be entirely attributed to the greenhouse effect. Current estimates suggest a further rise of 10 to 30 cm by 2030, and by about 50 cm by 2100. This rise will be due to higher temperatures leading to the expansion of sea water and to the melting of glaciers and polar ice caps, which at present store 70 per cent of the total fresh water on earth.

About one-third of the world's population and more than a third of the world's economic infrastructure are concentrated in coastal regions. So a rise in sea levels would displace populations on the coasts and islands, and submerge small island states. The Republic of Maldives is an example of a nation exceptionally vulnerable to a further rise in the sea level. Its problems of living space, availability of fresh water and coastal protection will be exacerbated by accelerated sea-level rise.

Delta regions are also high-risk areas. Many of these regions are already prone to flooding. Thousands of people dependent on these fertile agricultural areas would suffer. A 1 m sea-level rise would flood several coastal cities and the thickly populated deltas in Egypt, Bangladesh, India and China, where much of the world's rice is grown.

*Impacts on water resources:* The demand for water is generally increasing due to population growth and economic development; but it is falling in some countries where it is being used more efficiently. Climate change is expected to substantially reduce available water (as reflected by projected run-off) in many of the water-scarce areas of the world, but to increase it in some other areas. Freshwater quality generally would be degraded by higher water temperatures, but this may be offset in some regions by increased flows.

*Agricultural production:* Changes in weather patterns would have far-reaching effects on agriculture. Due to the changes in the global distribution of heat, food production could vary considerably. Areas that are currently productive would become less productive, but climate change may make the colder areas of the world, such as Siberia, more conducive to agriculture. Increased evaporation and drier soils in some regions would result in prolonged droughts. In the drier areas the need for irrigation would increase. Agriculture in warmer areas would also suffer from increased pest infestations, crop diseases and weeds.

The flooding of coastal areas as a result of sea-level rise would lead to the loss of agricultural land. It would also lead to the intrusion of salt water into coastal aquifers which would in turn affect agricultural production.

*Loss of ecosystems and biodiversity:* Rapid climate change would have severe impacts on natural ecosystems. Plant and animal species would be forced to migrate to keep up with climate shifts. Species that have adapted to cool climates could become extinct as their habitats disappear. Some species would migrate but others would not be able to. There may be heavy damage to sensitive ecological systems, which may not recover for centuries. Marine ecosystems, especially tropical corals, which grow at a slow rate, would be affected by climate change. Fish would die as temperatures increased in streams and lakes.

Large areas of forests would disappear. Shifts in regional climate would threaten many national parks, wildlife reserves and coral reefs. Ecosystems will be in peril as more

areas experience extreme heatwaves and more forest fires. Drier climates would cause wildfires, further destroying forests and adding more $CO_2$ to the atmosphere.

### Species and climate change

Climate change, along with other human factors, is likely to cause a net decrease in global biodiversity. Individual species of animals and plants are likely to respond in different ways to changes in temperature and rainfall; however, we can only speculate on the trends. For example, a change in the range of habitats of species as a result of climate change will break up communities of associated species that depend on each other for vital functions such as pollination.

Some species will benefit from climate change while others will not. Species that will do well may, in the long run, outcompete the presently abundant ones. A list of some 'winners' and 'losers' is given below.

***Species likely to benefit from climate change***

**Adaptable and generalist species:** Species that are capable of adjusting to changing conditions and are also widely distributed.

**Species able to establish themselves in disturbed habitats:** Species that are capable of establishing themselves in disturbed areas or where others have died.

**Species commensal with humans:** Species adapted to living with humans, such as rats, mice, sparrows, pigeons, crows and cockroaches.

**Species that can reproduce quickly when the opportunity presents itself:** Species known as 'r-selected species' or 'r-strategists', which can take advantage of climate change and increase their reproduction rate. For example, parasites.

**Species able to disperse quickly:** Species that can disperse quickly without relying on too many extraneous factors. This would enable them to rapidly colonize new areas as old areas become uninhabitable.

**Species likely to benefit from increased $CO_2$ levels:** Although plants are likely to benefit to begin with, the effects in the long run are debatable.

***Species likely to be harmed by climate change***

**Relic species:** Species that have been left from past ages in some specific places and still survive. These may not find suitable habitats or climatic conditions to survive.

**Isolated species:** Species that are found in inaccessible places and will not be able to migrate to other suitable places.

**Genetically impoverished species:** Species with low genetic diversity and extremely small population sizes.

**Species with highly specialized ecological niche:** Species dependent on a narrow range of habitat conditions.

*(continued)*

*(continued)*

**Species dependent on more than one habitat:** Migratory species that require a range of different habitats over a period of time.

**Slow-growing and poorly-dispersing species:** Species such as these will find it difficult to adapt quickly to changing conditions.
(Condensed from: A. Markham et al. 1993. *Some Like it Hot*.)

*Adverse effects on human health:* The rise in global temperatures could directly and indirectly affect human health. The availability of food and fresh water will get disrupted if the earth gets even slightly warmed. Death due to heatwaves and other extremes of climatic conditions is one of the direct consequences.

Indirect effects are more complicated as they involve the interplay of complex ecological relationships and habitats. Factors such as drought, rising sea levels and new storm patterns would give rise to water-borne diseases. Sea-level rise could spread infectious diseases by flooding sewage and sanitation systems in coastal cities. Tropical diseases such as malaria could spread to formerly temperate zones, affecting 60 per cent of humanity. Other insect-borne tropical diseases such as encephalitis, yellow fever and dengue fever could also spread to the temperate zone.

*Conflicts and refugees:* The impact of climate change will influence the social and economic structures of nations around the world. Terrorism, civil wars and economic crises may be some of the consequences. Environmental problems will give rise to conflicts between nations, for example, war for resources like water. Sea-level rise and changing weather patterns could trigger large-scale migration from more seriously affected areas. By 2050, global warming could produce as many as 150 million environmental refugees, most of whom would migrate to other countries, causing social tensions and political instability.

All these consequences of global warming will translate into huge financial costs.

## Combating Climate Change

The consequences of global warming are a real threat to India. India is a developing country with a population of over one billion, whose population and economy will continue to grow in the coming decades. In India, nearly two-thirds of the population is rural, whose dependence on climate-sensitive natural resources is very high. Rural populations depend largely on agriculture, followed by forests and fisheries for their livelihood. Indian agriculture is monsoon-dependent with over 60 per cent of the crop area under rain-fed agriculture, which is highly vulnerable to climate variability and change. India therefore needs to take action to combat climate change. So also do all other countries.

## Climate Change and Indian Concerns

Climate change is an international concern. Gases responsible for global warming recognize no political boundaries. GHG emissions anywhere in the world would contribute to global warming, and to climatic changes. Growing scientific evidence in the 1980s linking global climate change with greenhouse gas (GHG) emissions from human activities prompted several governments to collectively address the emerging concerns about the impacts of global warming.

## Climate Change Convention

In 1990, the UN General Assembly established the Intergovernmental Negotiating Committee (INC) for a Framework Convention on Climate Change (FCCC). The convention was signed in June 1992, at the UN Conference on Environment and Development, or the Earth Summit, in Rio de Janeiro by 154 states and the European Union (EU). By November 1999, 181 states and the EU had ratified the convention, which committed the signatories to making voluntary efforts to curtail their GHG emissions (see Appendix 2).

The objective of the convention is to achieve the 'stabilization of greenhouse gas concentration in the atmosphere at a level that will prevent dangerous anthropogenic interference with the climate system' (FCCC, Article 2). The convention further states that 'such a level should be achieved within a time frame sufficient to allow ecosystems to adjust naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner'.

The convention notes that the largest share of historical and current global emissions of greenhouse gases has been contributed by the industrialized countries. It also notes that the per capita emissions in developing countries are still relatively low, but will increase in the process of economic development. Considering the global nature of climate change, the convention calls for an appropriate international response, and assigns the lead in combating climate change to the industrialized countries.

Under the convention, industrialized countries (collectively called Annex I countries), made voluntary commitments to limit their emissions of greenhouse gases so that by 2000 they were emitting no more than they were in 1990. No commitments were required of the developing countries (referred to as the non-Annex 1 parties) in recognition of their need for development. The industrialized countries were also expected to help finance greenhouse gas reduction projects as well as promote and finance the transfer of environmentally sound technologies to non-Annex 1 countries.

The negotiations among the countries have centred around how emissions quotas should be determined for the countries. Should every country try to stabilize where it is now? Or should the industrialized countries reduce emissions, while the emissions continue to grow in developing countries? Should emissions be determined on a historical or a per capita basis? Several mechanisms have been negotiated into the convention

which allow developed countries to pay for and get credit for emissions abatement in developing countries.

### Kyoto Protocol

At a meeting of member countries held at Kyoto in December 1997, delegates approved the Kyoto Protocol, which set terms for legally binding commitments for the industrialized countries. It also proposed mechanisms to enable countries to move towards cleaner technology (see Appendix 2).

The Kyoto Protocol lists six greenhouse gases whose emissions should be reduced and controlled. They are carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride ($SF_6$). It does not list GHGs already included in the ozone depletion abatement under the Montreal Protocol.

The protocol calls for emissions reduction by industrialized countries. The overall reduction commits them to jointly reduce GHG emissions to 5 per cent below their 1990 levels. These targets are to be achieved in the period 2008–12, termed the first commitment period.

The Kyoto Protocol will come into force when 55 countries, together responsible for 55 per cent of the world's GHG emissions, ratify (agree to abide by) the protocol. Despite continuing negotiations, this has not been possible till now, primarily because the USA, which contributes the largest share of the total GHG emissions, decided to withdraw from this collective effort. The reason given is that such reductions would harm the nation's economy, a view promoted by the strong lobbies of the oil, coal, automobile and other industries likely to be affected by the treaty. The international community now has its hopes pinned on the ratification of the protocol by Russia so that it can come into force.

## Global Warming Controversies

The issue of global warming is a controversial one. One of the reasons is the scientific uncertainty about the phenomenon; another relates to the contributions of the industrialized and developing countries to the problem and its solutions.

### Scientific Uncertainty

Earth's climate system is a very complex web of interconnected physical, chemical and biological processes. Therefore, to understand the potential causes of global climate change is a very complex exercise. Scientists try to do so by creating computer models of

the earth's climate system. These models are called general circulation models, or GCMs, and they attempt to include the relevant physical principles governing the behaviour of the atmosphere and the oceans. The attempt is to create realistic models, but some processes such as cloud formation are extremely complex and difficult to understand and incorporate into models. Due to the complexity, different simulations can give different results. While a consensus has gradually emerged that human activities can affect climate, and are indeed doing so, some scientists disagree.

Prevention is better than cure

In order to protect the environment, governments, institutions and individuals need to adopt the **precautionary principle** according to their capabilities. Essentially, this means that when we are unsure, it is better to be on the side of caution, especially where there are threats of serious or irreversible damage to the environment. Scientific uncertainty should not be taken as an excuse for avoiding or postponing measures to prevent environmental degradation.

## DIFFERING CONTRIBUTIONS

Historically, industrialized countries have contributed significantly to global warming as they have used and are still using large quantities of fossil-fuel energy which results in the discharge of large quantities of greenhouse gases into the atmosphere. A study shows that the total carbon released into the atmosphere as carbon dioxide by an average US resident is about 260 tonnes, whereas it is about 6 tonnes for the average resident of India. The total amount placed into the atmosphere by a US citizen since 1900 is more than 40 times that by an average Indian. In 1999, whereas the USA was responsible for 25 per cent of the world's carbon emissions from the burning of fossil fuels, India with its much larger population contributed 4.5 per cent (see Table 10.1).

Table 10.1
Carbon emissions per year from burning fossil fuels

| *Country* | *% Share of world emissions 1999* |
|---|---|
| USA | 25.5 |
| Russia | 4.6 |
| Japan | 6.0 |
| EU | 14.5 |
| China | 13.5 |
| India | 4.5 |
| Indonesia | 0.9 |
| Brazil | 1.5 |

**Source:** *State of the World, 2001.*

As most of the greenhouse gases accumulated in the atmosphere are the result of activities of industrialized countries, the developing countries argue that corrective action should be taken by developed countries first. They have argued that no emissions limits should impede their economic development. Moreover, developing countries contend that their very livelihood depends on activities like cattle rearing or growing paddy, which contribute to the production of greenhouse gases; in addition, their economic development would necessarily involve some increase in greenhouse gas production. They argue that cutting down drastically on greenhouse gas emissions at this stage in their development would impede their economic growth.

On the other hand, industrialized countries feel that developing countries, especially rapidly growing economies like India and China, will add significantly to GHG emissions. While accepting some responsibility to set and meet emissions reduction targets in industrialized countries first, they argue that many cost-effective opportunities exist for developing countries to become more energy efficient. They feel developing countries should also immediately commit themselves to moving towards lower GHG emissions.

The sentiment of many developing countries in this debate is expressed in the following statement by an eminent Indian environmentalist, the late Anil Agarwal, who said, 'Solutions to the greenhouse effect are getting more and more ridiculous. The latest is to plant trees in the Third World in order to deal with the dirty carbon emitted into the air by western countries, so that the West can go on expanding its fleet of cars, power stations and industries while the Third World grows trees.'

## Towards Solutions

In order to stabilize the concentration of GHGs at their present level, their emissions would need to be immediately reduced by 60 per cent. When countries are bickering about the much smaller reduction recommended by the Kyoto Protocol, such a change seems very unlikely for political and economic reasons. The need is, thus, not only to take steps to *mitigate* the effects of climate change, but also to prepare ourselves to *adapt* to the effects of global warming and climate change. These steps would include:

- reduction in the use of fossil fuels;
- shifting to renewable energy resources that do not emit GHGs;
- increasing the use of energy-efficient and cleaner production technologies and practices;
- reducing deforestation, adopting better forest management practices, and undertaking afforestation to sequester carbon;

- exploring other options to sequester carbon (such as by storing in deep aquifers and beneath the oceans);
- adopting practices and technologies to make agriculture sustainable;
- limiting population growth;
- developing disaster management plans and strategies to cope with the expected increase in the frequency of natural disasters like floods and drought; and
- creating widespread awareness about the need to undertake all these steps.

## India and the Climate Change Issue

India is vulnerable to a range of impacts of climate change—from more frequent and severe floods and droughts, violent storms, the submergence of parts of its coastal lands and islands due to sea-level rise, change in rainfall patterns, etc., to their consequences such as the disruption of food and water supplies, displacement of large numbers of people, increase in diseases and death.

Being a largely agricultural economy, India is particularly vulnerable to the impacts of climate change in that sector. Changes in temperature, precipitation and $CO_2$ levels as well as changes in soil moisture and in the distribution and frequency of infestation by pests, insects, diseases or weeds, are expected to adversely affect plant growth, and hence the productivity of staple crops. The increasing frequency and intensity of extreme weather events will also have a direct bearing on agriculture. Besides, the IPCC predicts that a 1 m rise in sea level would inundate about 1,700 sq km of agricultural land in Orissa and West Bengal. The most vulnerable section of society will be the poor, the marginal farmers and the landless agricultural labourers.

India's commitment to addressing climate change issues is reflected in the various steps it has taken over the years—in policy initiatives, development plans, support to research and to a variety of initiatives and activities for promoting energy conservation, energy efficiency and renewable energy, and in its persistent pursuance of large-scale afforestation programmes. Environmental protection and sustainable development are India's key national priorities. Therefore, even though the Climate Change Convention does not require India to reduce its greenhouse gas emissions, several ongoing activities and programmes as well as new initiatives contribute to achieving this end either directly or indirectly.

At the policy level, India's commitment is reflected in the principal aim of the National Forest Policy of 1988, which is 'to ensure environmental stability and ecological balance *including atmospheric equilibrium*, which are vital for sustenance of all life forms, human, animal and plant.' The National Agriculture Policy of 2001 states, 'In order to reduce risk in agriculture and impart greater resistance to Indian agriculture against droughts and

floods, efforts will be made to achieve greater flood proofing of flood prone agriculture and drought proofing of rain fed agriculture for protecting the farmers from the vagaries of nature.'

In addition to government efforts, several NGOs are helping communities to upgrade and conserve their natural resources through activities such as afforestation and reforestation, water harvesting, soil and moisture conservation, organic farming, advocating alternative technologies in agriculture and energy, installing biogas plants, promoting improved agricultural and animal husbandry practices, etc. Though not promoted as such, these sustainable development activities would enhance the ability of the communities to adapt to climate change.

As a commitment towards the UNFCCC, to which India is a party, India has prepared its first national communication to be submitted shortly. It contains information on the greenhouse gases emitted by sources from various human activities, their sinks, an assessment of the vulnerabilities that India is likely to face due to climate change, and the policies of the government that take into account the climate change concerns.

### Global warming and ozone depletion

Though many people confuse ozone depletion with the greenhouse effect, the two are quite different, independent phenomena caused by entirely different gases. Ozone is chemically destroyed by chlorine from CFCs, while the largely non-reactive greenhouse gases that cause global warming have a negligible chemical effect on ozone. Increased carbon dioxide in the atmosphere may warm the planet, but it does not eat ozone. Nor does the ozone hole cause global warming. Because ozone is a greenhouse gas, ozone depletion actually leads to global cooling (Drew Shindell, 1999).

## Ozone and its Depletion

Another global environmental problem causing grave concern is the depletion of ozone in the stratosphere.

Ozone is a naturally occurring gas found in very small traces in the earth's atmosphere. The earth's ozone is found in two areas. Ozone molecules make up a very sparse layer in the upper atmosphere (stratosphere), which is about 17 to 48 km above the earth's surface. This is called the **ozone layer**. The stratosphere contains about 90 per cent of all the ozone in the atmosphere. Some ozone is also found in the lower atmosphere (troposphere).

The presence of ozone can be a good or a bad thing depending on where it is present. In the stratosphere, ozone acts as a protective layer shielding the earth from harmful ultraviolet radiation. In the troposphere, ozone acts as a harmful pollutant and sometimes

causes photochemical smog. More than a trace of this gas in the troposphere can damage human lungs and tissues, and also harm plants. Ozone is also a greenhouse gas and contributes to the greenhouse effect.

The total amount of ozone in a 'column' of air from the earth's surface up to an altitude of 50 km is the total column ozone. Total column ozone 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. In other words, 100 DU = 1 mm of pure ozone gas at normal temperature and pressure at sea level. The average amount of ozone at mid-latitudes is 3 mm or 300 DU. The mean total ozone amount in the atmosphere varies geographically and seasonally. It is slightly less than 260 DU at equitorial latitudes. It increases towards the poles in both hemispheres, going up to a maximum of about 400 DU.

The level of ozone in the atmosphere is naturally fluctuating by small amounts all the time. It is affected by the seasons, changing wind patterns and other natural factors. For billions of years, a delicate balance has been maintained by nature. However, today, many human activities are harming the ozone layer and are leading to a decrease in the ozone levels in the upper atmosphere. The decrease in the amount of ozone in the upper atmosphere is known as ozone depletion. The chemicals causing this are called Ozone Depleting Substances (ODS).

Depletion of the ozone layer allows potentially dangerous ultraviolet (UV) rays into the lower atmosphere. Most life forms on earth would suffer from the excess UV radiation.

### How the ozone hole was discovered

British scientists based in Antarctica, while measuring the atmospheric ozone over the Antarctic in the late 1980s, made an unpleasant discovery—there was significant depletion in the ozone layer over Antarctica each spring (September–October). It has been found that during every southern spring since then, 50 to 95 per cent of stratospheric ozone is destroyed at a height of 15 to 24 km above Antarctica, creating pockets which have been described as the Antarctic 'Ozone Hole'.

The Antarctic is the site of major ozone depletion because of its unique weather conditions. During the cold, dark southern winter, a powerful swirling vortex of westerly winds is formed. In these conditions, temperatures drop below –85°C and clouds of ice particles, called Polar Stratospheric Clouds, are formed. These clouds trap and concentrate the highly reactive chlorine on their surface.

Chlorine atoms get frozen and locked within ice particles. At the end of the polar winter, with the first rays of the spring sun, the chlorine atoms are released. These begin reacting with the ozone. Thus, the hole is observed every spring. However, ozone-rich air from the tropics gradually fills up these holes. The phenomenon of the 'hole' is thus a temporary one.

Latest scientific research has proved that ozone depletion occurs over the Arctic as well. But the Arctic stratosphere is less vulnerable to chlorine attack because it is warmer and fewer clouds form. Also it is not isolated by the vortex as is the case in Antarctica.

## Should We Worry about Ozone Depletion?

The ozone layer absorbs harmful ultraviolet radiation before it reaches the ground. Ozone depletion in the stratosphere results in more UV radiation reaching the earth's surface. High levels of UV radiation have a direct effect on human life, animal life, plants, materials, etc.

The effects of ozone depletion will be felt globally, though some parts of the earth may be more severely affected than others. Countries like Australia, New Zealand, South Africa and parts of South America, where the ozone layer is depleted, are at greater risk than the rest of the world.

Some of the effects of ozone depletion on various life forms and materials are:

**Humans and animals:** Ozone depletion may increase the rate of skin cancer and cause the skin to freckle and age faster. It will increase the frequency of cataracts and other eye diseases in humans and animals. The ability of the human system to fight diseases (immune system) will also be weakened.

**Plants:** Increased UV radiation affects plants by reducing leaf size and increasing germination time. This could decrease crop yield of corn, rice, soybeans, peas, sorghum and wheat.

**Food chains:** There may be a reduction in the growth of microscopic phytoplankton when UV radiation penetrates deep below the surface of oceans. These tiny floating producers form the base of ocean food chains and food webs, and help remove $CO_2$ from the atmosphere. The food chain of the terrestrial ecosystems will also be affected as over half the land plants are adversely affected by high levels of UV.

**Materials:** Increased UV radiation damages paints and fabrics, causing them to fade faster. Plastic furniture, pipes, etc., exposed to the sun, also deteriorate faster.

## Ozone Depleting Substances

Ozone depleting substances (ODS) are those that destroy ozone molecules. These are all man-made.

**CFCs:** Chlorofluorocarbons (CFCs) are gases or liquids made of chlorine, fluorine and carbon. They are used as coolants in the compressors of refrigerators and air conditioners. They are also used to clean electronic circuit boards used in computers, phones, etc. They are used in the manufacture of foams for mattresses and cushions, disposable styrofoam cups, packaging material, insulation, cold storage, etc.

CFCs are powerful ozone destroyers. They rise slowly from the earth's surface into the stratosphere. Here, under the influence of high-energy ultraviolet (UV) radiation, they break down and release chlorine atoms, which speed up the breakdown of an ozone molecule ($O_3$) into an oxygen molecule ($O_2$) and oxygen atom (O). One CFC molecule can break down 100,000 ozone molecules through a catalytic chain reaction.

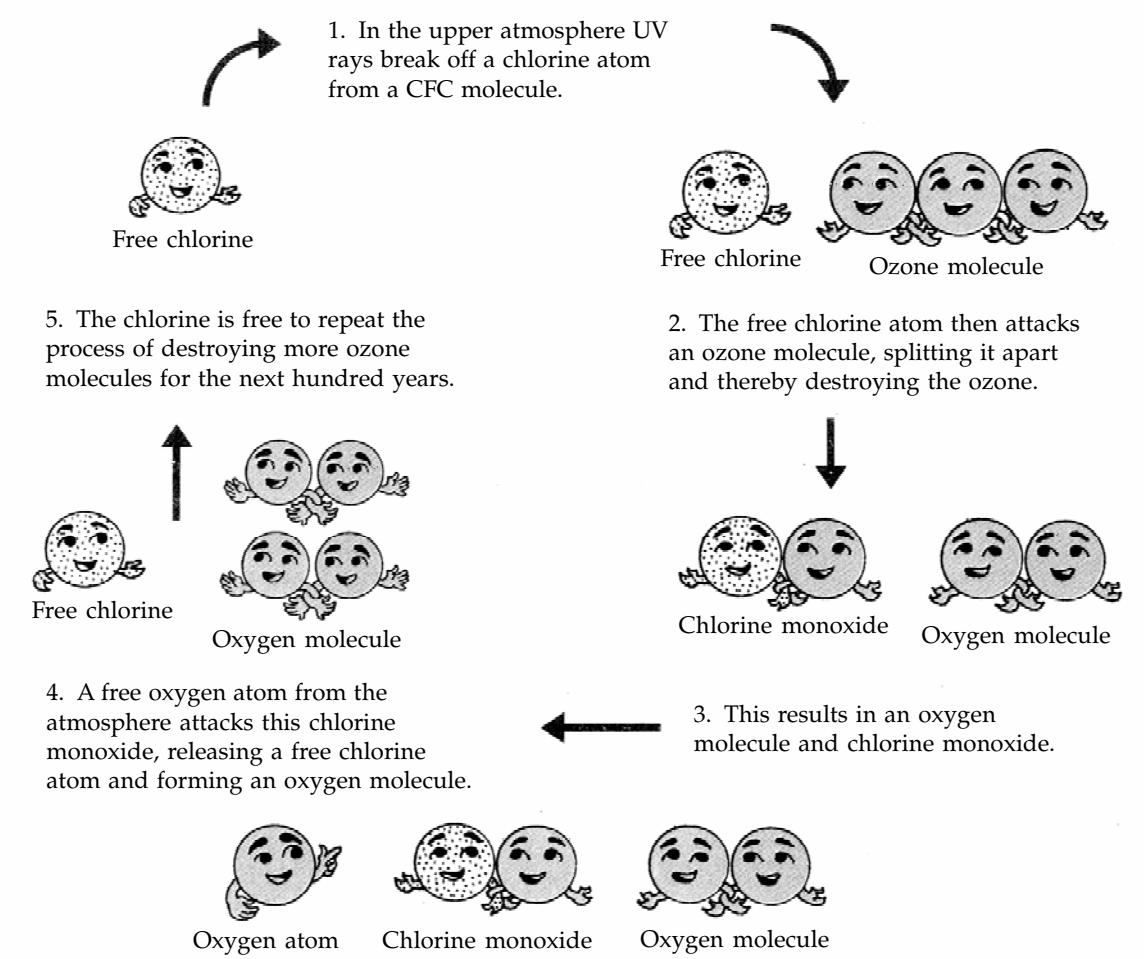



Illustration 10.2 How ozone is destroyed

Each time a polystyrene cup is thrown away, it eventually adds over 1 billion CFC molecules to the stratosphere—this can destroy up to 100 trillion molecules of ozone. CFCs do not destroy the ozone layer directly, but they act as carriers for the chlorine to the upper atmosphere.

**Halons:** Halons are similar to CFCs in structure but contain bromine atoms instead of chlorine. They are more dangerous to ozone than CFCs. Halons are used as fire-extinguishing agents. Each bromine atom destroys hundreds of times more ozone molecules than a chlorine atom does.

**$CCl_4$:** Carbon tetrachloride, used as cleaning solvent for clothes and metals and also in products such as correction fluid, dry-cleaning sprays, spray adhesives, fire extinguishers, etc., is another ozone depleting substance.

Phasing out ozone depleting substances as soon as possible is essential for the health of the ozone layer. That means putting a stop to the production, consumption and release of CFCs and other ozone depleting substances worldwide.

To phase out ODS, ozone-friendly replacements or substitutes for CFCs have to be found. HFC, PFC, $SF_6$ and HC (hydrocarbons) are the emerging substitutes for CFCs today. Changing over to processes and technologies which do not use these chemicals is another way of reducing CFC emissions.

## International Efforts

All over the world, efforts are on to save the ozone layer. The United Nations formed a committee which drafted an agreement that calls for a stepwise reduction of CFCs. This agreement, called The Montreal Protocol, came into effect in 1987 (see Appendix 2). Under this legally binding agreement, the consumption and production of CFCs and halons is to be stopped within a stipulated time. The committee keeps a regular check on the amount of ozone depleting substances in the world. It also provides technical and financial assistance to developing countries to reduce CFC consumption.

Under the Montreal Protocol, all the signatory countries have to assess their consumption and production of ODS every year. All signatories were to phase out their consumption and production of ODS by the year 2000. Only those developing countries whose per capita consumption of ODS was less than 0.3 kg were given a grace period of 10 years for phasing out ODS. To make the phase-out fair for developing countries, which cannot afford the higher priced substitutes and the replacement of machineries, the agreement establishes an environmental fund paid for by the industrialized countries. The fund will help developing countries switch over to more ozone-friendly chemicals .

Large-scale research studies are underway all over the world to come up with new and better substitutes for all the ODS and also to assess the environmental impacts of substitutes.

The United Nations General Assembly has proclaimed 16 September as the International Day for the Preservation of the Ozone Layer. It was on this day in 1987 that the Montreal Protocol to control the production and consumption of ozone depleting substances was signed by various countries at Montreal, Canada.

## India and the Ozone Issue

India is concerned about the ozone problem and signed the Montreal Protocol in 1992. Strict measures have been taken in the country to phase out ozone depleting substances.

These measures include a ban on trade in ODS, licensing the import and export of ODS, and a ban on the creation of new ODS-production facilities. The Ozone Cell at the Ministry of Environment and Forests, Government of India, is the Indian national lead agency coordinating all matters relating to the Montreal Protocol.

Industrialized countries are the major producers and consumers of CFCs. Developing countries like India consume very little. For instance, the per capita consumption of CFCs in India is 0.01 kg per year, while in the US it is about 50 times more. We are, therefore, not contributing very much to ODS pollution. In a hot country like India, however, refrigeration and air conditioning are often a necessity for the preservation of foods, medicines, vaccines, etc.

In spite of all this, India signed the Montreal Protocol recognizing that ozone depletion is a global problem and that it needs to be solved through cooperation. India has always maintained that such agreements must be fair and equitable to all parties.

### Eco-fridge

A major initiative towards reducing the use of ozone depleting substances was taken by Godrej Industries Limited, a leading manufacturer of refrigerators in India. Godrej is now manufacturing Eco-fridges, or environment-friendly fridges. The eco-fridge, launched under the brand name Pentacool, is the result of the combined effort of Godrej and the National Chemical Laboratory (NCL), Pune. The technology change is based on the use of safe pentane technology rather than choosing other harmful gases. The green refrigerator concept is being used to create awareness among consumers about the adverse effects of harmful technology on the environment and on the necessity of adopting and using environment-friendly technology.

## Making a Difference

Scientists all over the world are monitoring the changes taking place in the climate. Efforts are underway, nationally and internationally, to reduce global warming and ozone depletion. We need to recognize that even if countries do undertake immediate and rapid action to reduce their emissions, some degree of climate change and ozone depletion is inevitable. We also need to recognize that many of our decisions and actions, as individuals, contribute to these problems. Each one of us can take steps to prevent further damage to the ozone layer and the earth's climate—by not wasting energy, ensuring that we do not buy products that contain CFCs, by not using styrofoam cups, to name just a few. Collectively, as consumers, we can influence the demand, and hence the market, for environment-friendly products and services.

## I Questions

1. List five things you, as an individual, can do to help prevent further damage to the ozone layer?
2. List five things you, as an individual, can do to help prevent further concentration of GHGs in the atmosphere?
3. How can improving energy efficiency help in dealing with climate change? Explain.
4. What steps can governments take to ensure a reduction in the use of fossil fuels?
5. What are some of the steps that would help in adapting to climate change? If we are already taking steps to reduce GHG emissions, is there any need to worry about adapting? If yes, why? If no, why not?
6. Against each of the gases listed below, write its chemical symbol, and G if it is a greenhouse gas and O if it is an ozone depleting substance.

| Gas | Chemical Symbol | G/O |
|---|---|---|
| Methane | | |
| Ozone | | |
| Perflurocarbons | | |
| Nitrous oxide | | |
| Halon | | |
| Carbon dioxide | | |
| Pentane | | |
| Carbon monoxide | | |
| Sulphur hexafluoride | | |

## II Exercises

1. Global warming would lead to greater evaporation. What would be the consequences of an increase in water vapour in the atmosphere? Would it cause further warming or would it cause cooling? Do some library or Internet research to find out whether your thinking was on the right track.
2 Imagine yourself in 2020 AD. Imagine what the situation of the earth would be if CFCs and other ODS have not been phased out. Describe the environment around you, the climate and weather conditions, the general health of the people, etc., in that period.

## III DISCUSS

1. *Current preoccupation is with terrorism, but in the long term climate change will outweigh terrorism as an issue for the international community. Terrorism will come and go; it has in the past ... and it's very important. But climate change is going to make some very fundamental changes to human existence on the planet.*

   David Anderson
   Canadian Environment Minister
   6 February 2004

   Comment on the above statement.

2. Do you agree with the argument of the developing countries that the primary responsibility of reducing $CO_2$ emissions should be of the industrialized nations because they have produced much more of these emissions in the past and continue to do so. If yes, why? If no, why not?

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# Chapter 11

# Population, Consumption and Environment

Kalyani Kandula

- In 2001, with a population of 1,027 million persons, India ranked as the second most populous country in the world. The USA's population was 281 million.
- The consumption of food grains per person in India is less than 200 kg per year. Diets in India are generally dominated by a single starchy staple, for instance, rice or wheat. An average American, on the other hand, consumes 800 kg of grain each day, directly or indirectly, in the form of beef, poultry, pork, eggs, milk, cheese, ice cream, and yogurt.
- Only about 28 per cent of the people in India have access to sanitation facilities. In the USA, 100 per cent of the population is reported to be served by municipal services.
- In 2000, electricity consumption per capita in India was equivalent to 335 kilowatt-hours. USA's per capita electricity consumption during the same period was 12,331 kilowatt-hours.
- The USA uses about 25 per cent of the world's processed mineral resources and non-renewable energy compared to India's 3 per cent.
- The USA produces at least 25 per cent of the world's pollution and waste, including 18 per cent of the global emissions of greenhouse gases and 22 per cent of ozone-destroying CFCs. India produces about 3 per cent of the world's pollution and waste, including about 4 per cent of the global emissions of greenhouse gases and 0.7 per cent of ozone destroying CFCs.

Which country has a larger population?
Which country consumes more resources?
Which country generates more waste?
Which country's population has access to basic facilities such as sanitation required for, and resulting in, a healthier and safer living environment?
These are some of the questions this chapter addresses.

India has more people consuming fewer resources and contributing less pollution. But because they are many in number, the total impact is significant. Another significant aspect is the quality of life of the people. The majority of Indians live in undesirable conditions, with poor access to basic facilities such as sanitation, education, health facilities, etc. This leads to a more direct adverse effect on the environment and also limits opportunities for a better quality of life.

On the other hand, the USA has fewer people with affluent lifestyles. Though they are not many in number, because of their lifestyle, they consume considerable resources and produce considerable pollution and waste.

What does this have to do with the environment? Does the number of people influence the well-being of the environment? Does the way people live and what they consume—their lifestyle—also determine their impact upon the environment?

## Population, Consumption, Environment: The Links

The following equation can be used to discuss how population growth and consumption affect the environment:

Number of people × Unit of resources consumed per capita = Environmental impact of population

As we have seen, the USA, which has only a third of India's population, has a far greater impact on the environment. The environmental impact of 28.1 crore (281 million) Americans is equivalent to that of 1,400 crore (14 billion) Indians at their current levels of consumption. Therefore, while India suffers from 'people overpopulation', the USA suffers from 'consumption overpopulation'.

So it becomes obvious that when we think of environmental degradation, we have to simultaneously think of population and consumption.

Let us begin by looking at the aspects of population and then of consumption.

### World's consumption expenditure

Since 1950, the world's consumption expenditure has increased sixfold, to $24 trillion in 1998. Of this, 86 per cent is accounted for by the richest fifth of the world's population, while the poorest fifth's share is only 1.3 per cent.

The world's three richest people together own assets that exceed the combined gross domestic product of the 48 least developed countries. Meanwhile, almost 3 billion people live on less than $2 a day, totally excluded from the 20th century's boom in the consumption of goods and services. Too many people thus live in utter deprivation.
(http://www.un.org/ecosocdev/geninfo/afrec/subjindx/122undp.htm.)

## Understanding Population Patterns

Three main factors make populations grow or decline: births, deaths and migration.

**Birth rate** is defined as the number of births in a year per thousand people in a geographical area. Similarly, **death rate** is the number of deaths in a year per thousand people. According to the Census conducted in 1921, the birth rate in India was 48 per thousand while the death rate was 47 per thousand. As the birth and death rates were nearly in balance, population growth was slow. In 2001, the birth rate had come down to 24 per thousand and the death rate to 9 per thousand. **Migration** is the rate of population change for a specific area which is also affected by the movement of people into and out of that area.

When the birth rate in an area is greater than the death rate, its population grows. When the death rate is the same as the birth rate, the population size remains stable. This condition is called zero population growth. When the death rate exceeds the birth rate, the population size decreases.

In 1921, the average lifespan of a person born in India was 20 years. The average life expectancy of an Indian is now 63 years. Improvements in medical science and in health-care facilities have resulted in the drop in the death rate. We have been able to control a number of dangerous diseases such as small pox. It is now possible to treat diseases such as tuberculosis which, not too long ago, were considered fatal.

India has also achieved some success in reducing its birth rate, but it has not declined as much as the death rate. India's birth rate of 24 per thousand people still high when compared with 14 in developed countries. In order to reduce the population growth, it is therefore necessary to reduce the birth rate.

### Demography

The study of human population trends is called demography. Demographers analyse the factors that influence human population growth, such as total fertility rates, rates of natural increase, migration patterns, population age structures, demographic transitions, and environmental factors. These data are used to project future population trends and to analyse alternative scenarios aimed at solving population-related environmental problems.

## Factors Responsible for High Birth Rate

The high birth rate in our country is due to several factors. Some of these are discussed here.

**High infant mortality:** People tend to have more children when they are not sure how many will survive. In India many children die before their first birthday. The number of deaths of babies up to one year old per thousand babies born in a year is called the

infant mortality rate. In developing countries such as India, a large number of infant deaths are due to inadequate nutrition, unsafe drinking water and lack of medical care. The countries that have successfully reduced their population growth are generally those that have also reduced their infant mortality rate.

In recent years, the number of infant deaths in India has come down to 63 per thousand. However, this rate is still high when compared with other countries. For instance, the infant mortality rate in China is 29, and in Japan only 5.

**Poverty:** For the poor, more children mean additional hands to work—to help in the fields, to work for wages or to beg in the streets, to fetch water and fuelwood, to look after younger siblings while the parents work, and to look after the parents in their old age. But the poor are unable to adequately feed their children. Nor can they educate them, so most of these children remain illiterate, unskilled and hence poor throughout their lives and, in turn, have several children themselves when they grow up.

**Preference for sons:** In most parts of our country, there is a strong preference for sons. This attitude is found not only among the poor and illiterate but among all classes of society. In most communities, traditionally, sons inherit and transmit the family's name, land and other property. As daughters marry and move away, it is the sons who are expected to look after their parents in their old age. Also, among most communities in India, the dowry system is a widely prevalent custom. Dowry can be an enormous financial burden on a family, not just among the poor but also among those who are not poor. Although demanding and giving a dowry has been banned by law, the custom continues and is one of the reasons why people prefer sons. In many families, this desire for a son, and often more than one son, results in having several children.

**Custom of early marriages:** Another reason for the high birth rate is the custom of early marriage, particularly in rural areas. Persons who are married at an early age have more children because they start having children early. Laws have been made from time to time to stop the practice of child marriage, but these laws are often flouted. According to the current law in India, it is illegal for a girl to marry before she turns 18, and for a boy to marry before he attains the age of 21.

**Illiteracy:** Illiteracy is another factor responsible for the high birth rate. Literate people can find out information relevant to them much more easily than those who cannot read. In this context, the education of women is very important. It has been found that literate women have fewer children than illiterate women, and are able to give them better nutrition and health care.

This is what has happened in Kerala. By 1991 a major literacy campaign in the state had raised the female literacy rate to 86 per cent, the highest in the country. The average for India at that time was only 39 per cent. In 1991, the state also recorded the lowest birth rate at 17 per thousand population compared to 28.5 as the average for India, and also the lowest infant mortality rate at 13 per thousand live births as against 74 for India.

**Some other factors that influence birth rates are:**

- People tend to have fewer children where the cost of raising a child is more, for instance in developed countries.

- People have fewer children in societies where women have access to education and paid employment outside the home.
- When people have access to social security and pensions, it eliminates the need for them to have many children to support them in their old age.

**To bring down the birth rate** it is, no doubt, necessary to have a good family planning programme which offers safe, effective and inexpensive contraceptive devices and other methods of birth control. But it is equally important to provide education and adequate health care to all, especially to women. It is also important to ensure that girls have access to all opportunities that boys do, so that they grow up to be as capable as boys in every sphere of economic and social activity.

### National population policy

India started the world's first national family planning programme in 1952, when its population was nearly 400 million. In 1993, after 51 years of population-control efforts, we are the second most populous country in the world, with a population of 1,065.5 million. In 1952, India was adding 5 million people to its population each year. In 2003, it added 15.5 million!

With India's population crossing 1 billion in the year 2000, the National Population Policy announced in that year has special significance. Its change in focus from merely setting target-population figures to achieving population control through greater attention to socio-economic issues such as child health and survival, illiteracy, empowerment of women, and increased participation by men in planned parenthood, gives it greater breadth and depth, and, therefore, holds better promise of achieving its long-term objective of a stable population by mid-century.

The official realization that population is not merely about numbers but also about the health and quality of life of people in general and women in particular, must be reinforced and sustained by an informed debate to bring key population issues into ever-sharpening perspective at various levels of policy making, from the national and state legislatures to local government institutions.

There is a need for a better and more widespread understanding of the fact that the number of children desired by any couple depends on a large and complex interrelated number of socio-economic and cultural factors, and that any policy action seeking to control population must seriously take all these variables into account.

An important part of empowering women in matters pertaining to population is to explicitly recognize and respect their rights over their own bodies and their reproductive behaviour. This recognition must permeate society in general, and religious, judicial and law-enforcement institutions in particular, through continual campaigning and dialogue.

The pursuit of population control must not be allowed to compromise human rights and basic democratic principles. Such compromises are often implicit in the disincentives aimed at controlling family size; in comments on the fertility of particular social groupings; and in the occasional demands to control in-migration to metropolitan areas. It is essential to place these matters in a balanced and rational perspective through informed public discourse supported by the wide dissemination of authentic data.

## Does Population Growth Follow a Pattern?

Examining the birth and death rates of western European countries that industrialized during the 19th century, demographers (people who study population) developed a hypothesis of population change called the **Demographic Transition**. This transition occurs in four phases:

1. In the pre-industrial stage, living conditions are harsh and the birth rate is high (people have more children to replace children who die from infectious diseases, malnutrition, etc.), but the death rate is also high. Thus, there is little population growth.
2. In the transitional stage, when industrialization begins, food production rises and health improves. Death rates drop, but birth rates remain high, so the population grows rapidly.
3. In the industrial stage, industrialization is widespread. The birth rate drops and eventually approaches the death rate. This is because people in cities realize that children are expensive to raise. Having too many children also hinders them from taking advantage of job opportunities. Population growth continues, but at a slower and fluctuating rate, depending on the economic conditions.
4. In the post-industrial stage, the birth rate declines even further to equal the death rate, thus reaching zero population growth. Subsequently, the birth rate falls below the death rate, and the total population size slowly decreases.

**Do you think this hypothesis applies to India's population too?**

Table 11.1
India's population

| *Year* | *Population* | *Annual growth rate (%)* | *Density per sq km* |
|---|---|---|---|
| 1901 | 238,396,327 | | 77 |
| 1911 | 252,093,390 | 0.56 | 82 |
| 1921 | 251,321,213 | 0.03 | 81 |
| 1931 | 278,977,238 | 1.04 | 90 |
| 1941 | 318,660,580 | 1.33 | 103 |
| 1951 | 361,088,090 | 1.25 | 117 |
| 1961 | 439,234,771 | 1.96 | 142 |
| 1971 | 548,159,652 | 2.20 | 177 |
| 1981 | 683,329,097 | 2.22 | 216 |
| 1991 | 843,930,861 | 2.11 | 267 |
| 2001 | 1,027,015,247 | 1.62 | 324 |

**Source:** Ashish Bose (1991). *Population of India 1991: Census results and methodology*, Delhi: B.R. Publishing Corporation.

## LIMITS TO POPULATION GROWTH

One of the earliest and most popular theories on the limits to population growth is the one proposed by Malthus in 1798. Thomas Malthus, a British clergyman and intellectual, warned in his famous piece, 'An Essay on the Principle of Population', of the tendency for population to grow exponentially while food supply grows only arithmetically. He saw a world where food supplies would not be able to keep pace with the population growth.

Today, there are differing viewpoints about the number of people the earth can support. One viewpoint is called the **Limits Thesis**. According to this, there are definite limits to population and economic growth. These limits are due to the fact that air, water, minerals, space, and all usable energy sources have fixed stocks that would ultimately be exhausted. For example, land availability is likely to constrain world agriculture as widespread degradation is occurring on a major portion of the world's farmlands. Groundwater in many areas is being removed faster than it can be recharged.

According to the **Cornucopian Thesis**, on the other hand, there are limits to growth only if science and technology stop advancing, but there is no reason why these advances should stop. So long as they continue, the earth is not really finite, because technology creates resources. There are people who believe that resource shortages resulting from population or income growth usually leave us better off than if the shortages had never risen, because such shortages force the development of technology. For example, if firewood had not become scarce in 17th-century England, coal would not have been developed. If coal and whale oil had not become scarce, oil wells would not have been dug.

### World population day

World Population Day was first celebrated in 1987 when the earth's population reached 5 billion. In 1988, the Governing Council of the United Nations Population Fund (UNFPA) designated the day for annual observance on 11 July, and the United Nations authorized it as a vehicle for building awareness of population issues and their role in development and the environment.

Governments, United Nations' agencies and organizations, non-governmental organizations, universities, population institutions and citizens take part in its observances and help raise awareness on population issues. The events organized include rallies and speeches by national and local leaders, lectures, print and electronic media programmes and supplements, exhibitions and sports events.

## Overpopulation

Overpopulation must not be confused with mere numbers. An area is over-populated when its population cannot be maintained without rapidly depleting the natural resources and without degrading the capacity of the environment to support the population. As we know, the earth's resources are finite. It is because of these finite resources that every place on earth has a **carrying capacity**, which is the maximum number of people the area can support. The carrying capacity can, to some extent, be increased with the help of technology—for example, more food can be produced from the same piece of land using modern seeds, chemical fertilizers, pesticides and machines—but not indefinitely.

Almost all the rich nations are rapidly drawing resources from around the world and creating waste that affects the global environment. Can these countries be considered overpopulated? In many poor and developing nations, natural resources are being depleted to meet the needs of growing numbers of people. Can these countries be called overpopulated?

It is obvious that 'overpopulation' is a relative term. It is not possible to give an absolute value and say, 'Anything above this is overpopulation'!

Overpopulation undoubtedly is an important concern. An equally significant but often overlooked concern is over-consumption.

## Over-consumption

Almost all human consumption activities affect the environment. Let us see the ways in which consumption of a product affects the environment:

- It depletes non-renewable resources (like metals and minerals).
- It depletes and degrades renewable resources by activities such as overfishing, over-exploitation of forests, groundwater, etc.
- It creates pollution and waste that go beyond the capacity of the environment to absorb them.

Let us take a simple example to understand this.

Think of any product (or service) that we consume; for example, a packet of *sooji/rava*. Environmental resources are used in the production of the packet of *sooji/rava*—raw materials (such as wheat grain), energy, water, packaging materials, etc. Environmental resources are also used in the consumption of the product. In this case, spices, salt, water

and cooking fuel are needed to cook the *sooji* to make *upma*. The waste created by the consumption of the pack of *sooji*, the packaging material, also affects the environment. (See also the chapter on Industry).

## NEEDS, WANTS AND LUXURIES

Needs are absolute necessities which we cannot do without. Basic needs—food, water, shelter, clothing, social interaction—are common to people across the world. Wants, unlike needs, depend on the social and economic background of the person. A city executive's wants may include a personal computer. A farmer's wants may include a better plough. The quality and quantity of our consumption defines if we are catering to our needs, wants or luxuries.

All humans need to consume in order to survive. The most basic essentials for our survival—food, water, clothing and shelter—come from natural resources. When does this consumption become over-consumption? This again is a very difficult question to answer.

Consider food. A simple meal of *dal* and rice is food. On the other hand, a lavish spread of *pulao*, sweets, ice cream, etc., is also food. The amount and kind of food we consume determines whether we are meeting our basic needs or enjoying luxuries.

The perceptions of needs and luxuries vary from person to person, community to community and country to country. What some people might consider necessities for basic survival, others might consider luxuries.

Yesterday, today ...

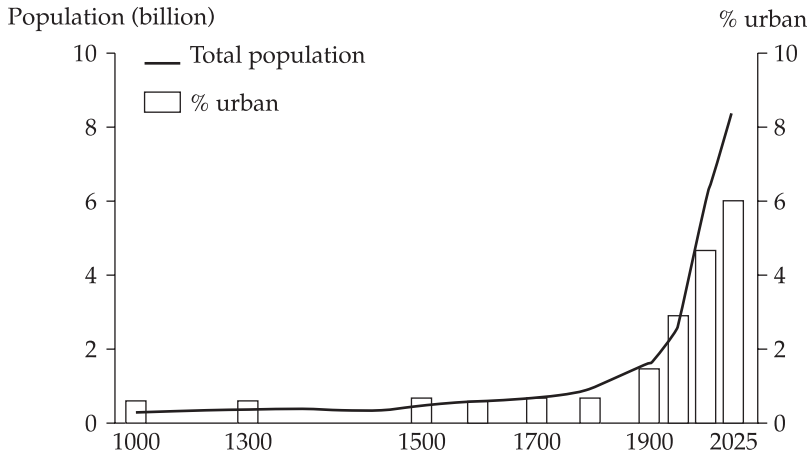
In the good old days, there was the cloth shopping bag. We took it to the shops hundreds of times till it was torn. We did not have plastic bags to throw away. We drank tea in china cups or steel tumblers; no paper cups to litter the place. We did not have soft drink fountains with their disposable cups; we used bottles instead. An empty milk powder tin remained on the kitchen shelf for years to store sugar or *dals*. Milk was bought in glass bottles which were returned the next day; no plastic pouch to be thrown into the waste bin. We had handkerchiefs, washed and rewashed till they were torn; no paper napkins to throw away. Babies wore clean cloth diapers (usually made from grandmother's old soft sarees), washed and rewashed: no throwaways. Those days we did not waste.

In the new age of convenience consumerism, we may waste as much as we consume. We may pay more for the packaging than for the product. Nearly a quarter of India's precious energy is used for producing what ultimately turns out to be waste. According to the All India Food Preservers' Association, the cost of packaging is about 55 per cent of the price of a product (*The Week*, 2 October 1994).

Over-consumption is when a section of people uses a large share of resources and causes pollution and environmental degradation. Over-consumption is apparent both in developed countries and in the affluent sections of less developed countries.

What we need to bear in mind is that both overpopulation and over-consumption matter, and both issues have to be explored and solutions sought with the same conviction. Our concern is not with mere numbers of people. It is with the quality of life of people, the consumption patterns of people, the technology used by people and the influence of all these factors on people and on the environment.

This recognition of the significance of overpopulation and over-consumption is relatively new. The graph shows that centuries of slow population growth were followed by a rapid explosion of numbers in the past half century.




The trend of human population growth over the past 1000 years

It took 2 million years for the human population to reach a billion. To add up to a second billion, it took only 130 years, 30 years to add a third billion, 15 years for a fourth, and only 12 years for a fifth. The J-shaped curve shows that at first the population growth rate is slow, then it increases rapidly.

The past few centuries have seen rapid advances in agriculture, health, etc. Better food availability and better health have brought down death rates. Better health facilities also means that more children are surviving today than before. This has contributed to an increase in the population growth rate.

The last two centuries have also seen the emergence of a new type of society—the urban industrial society. The urban industrial society is marked by higher production and consumption of goods, increased use of fossil fuels and other non-renewable resources, a shift from using natural materials to synthetic materials, and increased energy consumption per person. Both overpopulation and over-consumption are recent phenomena. They also coincide with a period of increasing environmental impact.

## HOW DO POPULATION AND CONSUMPTION IMPACT THE ENVIRONMENT?

The capacity of an area to support human population depends not only on the number of people but also on the needs and lifestyles of the people living there. If the needs of the people are few and their lifestyles simple, an area can support a larger number of people than if the needs and *desires* of the people are many.

Overpopulation occurs when the population of an area exceeds its carrying capacity. When that happens, the environmental resources that support life and economies get depleted, and more wastes than the earth's natural processes can handle are added to the environment. This can happen when there are too many people trying to meet their basic needs. But it can also happen when there are few people in an area but they indulge in over-consumption.

To understand the impacts of population and consumption on the environment, let us look at a few specific examples.

## DEFORESTATION

Forests provide timber, fuelwood, pulp for paper, and other major and minor forest products, and thus have great economic value. They also have great ecological value. They conserve soil, are storehouses of biodiversity and act as giant sponges, by slowing down the run-off of rainwater and absorbing and holding water that recharges springs, streams and groundwater. They also act as sinks for greenhouse gases.

**The deforestation-consumption link:** Over-consumption is significantly responsible for deforestation across the world. Often, less developed countries sell their forest lands for lumbering to foreign companies at prices far below the real worth of the timber. They do so to stimulate economic growth, pay interest on foreign debt, etc. The environmental costs of deforestation are not included in the prices charged for lumbering rights, and so it is not possible to take up reforestation programmes at a scale which compensates for the deforestation.

One example of the effects of consumption on forests is the demand for cheap beef in fast-food outlets in rich countries. In much of Central America and Amazonia, forests have been cut down to provide temporary pasture for cattle raising. These pastures are used for a few years, after which they are abandoned and other pieces of forest are cut down for pasture. If we were to factor in the environmental costs, the true cost of a hamburger made from cattle grazing on land which was once tropical forest is the cost of 5 sq m of forest. Considering the value of forests (both economic and ecological), this cost would be tremendously higher than the price at which a hamburger is usually sold.

Another example is Japan which imports 60 per cent of all tropical timber, resulting in deforestation in many countries including Papau New Guinea, Thailand, Malaysia, Colombia and Cameroon. Much of this wood is used for making throwaway items such as moulds for concrete, packing crates, chopsticks, etc. Similar examples can be found in India as well, where tracts of forests are cut down to meet the need for furniture and construction wood for urban areas.

**The deforestation-population link:** According to one estimate (Harrison 1992), population growth in developing countries has accounted for 79 per cent of the tropical deforestation suffered during 1973–88.

As long as the population of firewood gatherers in a local community does not exceed the capacity of the local tree stock to replenish itself through tree growth, the community can exploit the resource indefinitely. But as the population increases, so does the number of fuelwood gatherers. When firewood collection exceeds the self-renewing capacity of the trees, there comes a stage when the tree stock starts depleting, and the tree cover starts disappearing.

It was estimated that in 2000, about 2.4 billion people met their wood requirements by cutting fuelwood faster than it could regenerate through natural growth. Of these, nearly 350 million people cannot meet even minimum needs without over-harvesting stocks.

Another school of thought holds that economic and political factors exert more harmful impacts on deforestation than population growth per se. For example, according to the United Nations, the pressure from expanding populations leads to the destruction of only small patches of rainforests by peasants who expand cultivation along the edge of the forest in small amounts (United Nations 1990). This population growth is not responsible for the deforestation of large tracts of rainforest. Large blocks of rainforests are difficult for peasants to exploit as there are barriers in the form of rivers, dense forests, etc. When large-scale infrastructure projects (such as highways) open up a forest area for exploitation, the land is made accessible to landless farmers and new migrants who clear it in the absence of any enforced property rights.

## Soil Erosion

Land is being degraded at an alarming rate due to soil erosion and other causes. This degradation is of great concern as soil re-formation is an extremely slow natural process. Flowing water and wind are natural eroders. Agriculture, deforestation, overgrazing, and other human activities increase the chances of soil being eroded. Today, all around the world, soil is being eroded at a rate much faster than the rate at which it forms.

**The soil erosion-consumption link:** According to one estimate, about one-third of the USA's original prime topsoil has found its way into streams, lakes and oceans, mostly as a result of over-cultivation, overgrazing and deforestation. About 86 per cent of the

soil eroded in the USA comes from land used to graze cattle or to raise crops to feed cattle. Each half kilogram of beef from the cattle causes about 16 kg of soil to be eroded! Another 14 per cent of eroded soil in the USA comes from land used to raise crops for human consumption.

**The soil erosion-population link:** Two-thirds of seriously degraded soils are in Asia and Africa. Increasing populations put pressure on land for housing, agricultural fields, etc., which in turn puts pressure on forest cover.

Another example of how population leads to soil erosion is 'shifting' cultivation. This is a form of cultivation traditionally practised by people in tropical forests. It involves clearing small patches of the forest by cutting down trees and other vegetation, and then burning the remains. The ashes fertilize the soil. After this preparation, the cleared land is cultivated for a certain period, after which it is left fallow (uncultivated) for about 10 to 30 years to allow the soil to become fertile enough to grow crops again.

This system of agriculture was sustainable in early societies as the food demands of their small populations required only small patches of the forest to be cleared and the land could be left fallow for long periods to enable it to regenerate. With growing populations, the number of patches in forests that are put under such cultivation has increased, with the result that greater numbers of farmers compete for less. This limitation of forest area also forces farmers to return to abandoned patches after shorter fallow periods, sometimes after as little as two years. The result of this has been vanishing topsoil and soil nutrients.

## Climate Change

The global climate is under threat from increasing pollution of the atmosphere by gases that heat up the earth, such as carbon dioxide, methane, chloroflurocarbons, nitrous oxide and nitrogen oxides.

**The climate change-consumption link:** It is widely recognized that affluent countries, which account for less than a quarter of the world's population, are responsible for roughly three-fourths of the carbon dioxide released by burning fuels—in automobiles, power plants, and other industrial plants—to satisfy consumption needs. In the USA, since 1970, while the population has increased by 25 per cent, the number of passenger cars sold has increased by 50 per cent. These increased numbers naturally increase the USA's contribution to the greenhouse gases emitted.

**The climate change-population link:** An increase in population is associated with a growth in the demand for food supplies. As humans try to expand food production to meet the needs of growing populations, the resulting increase in land cleared for food and pasture, in livestock, and in fossil-fuel use would release more greenhouse gases (including methane). Population growth will also mean more organic wastes. The

putrefaction of these wastes also releases methane. Methane is a greenhouse gas which contributes to global warming. A molecule of methane traps roughly 25 times as much of the sun's heat as a molecule of carbon dioxide.

Deforestation, soil erosion and climate change are just three environmental issues discussed here to illustrate the impact of overpopulation and over-consumption on the environment. People and their lifestyles obviously have a role in almost every environmental threat known today—biodiversity loss, ozone-layer depletion, desertification, etc. It is, therefore, important to examine and address the roles of both population and consumption while attempting to solve environment and development problems. This requires a better understanding of population and consumption patterns.

## The Indian Story

Currently, India produces enough food for all its people to get an adequate survival diet. But mere production of sufficient quantities of food does not ensure the access of all sections of people to the food. Widespread poverty means that people do not have enough land to grow food or enough money to buy food.

Poverty is a very complex problem which is related both to overpopulation and to over-consumption. The simple meaning of poverty is the inability to meet minimum human needs in respect of food, clothing, housing, education and health.

Economists and planners in India have been using the term **poverty line**. Those who cannot afford two square meals a day are said to be below the poverty line. According to this definition, nearly one-third of India's population lives 'below the poverty line'. This proportion is less than it was in the early 1950s, when nearly half of India's population lived in poverty. However, because of the huge increase in population, the number of poor people rose from 164 million in 1951 to 320 million in 1993–94. Nearly 77 per cent of India's poor live in rural areas.

### Poverty line diet

The poverty line is defined as a monthly expenditure per person which is able to buy food that provides a person with a daily intake of 2,400 calories in rural areas and 2,100 calories in urban areas.

Based on average prices, the daily diet of a person living on the poverty line would be the following:

| | |
|---|---|
| Food grains | 400 g |
| *Dal* | 1 cup cooked |

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| | |
|---|---|
| Milk | 1/3rd cup |
| Edible oil | 2 teaspoonfuls |
| Vegetables | 1 potato, 1 small brinjal, 1 onion, 1/2 tomato |
| Dried chillies | 1 teaspoon |
| Tea leaves | 1 teaspoon, enough for two cups of tea |
| Eggs | 1 every 5 days |
| Fresh fruit | 1 piece per week |

After buying these food items, the person would have only about Rs 2 per day left over for all other expenses. One in every three Indians cannot afford even this frugal diet.

Poverty is usually measured in terms of cash income because it indicates whether people are able to buy what they need to meet their food and other basic requirements. But many of the rural poor depend directly on what they grow in their fields and yards, and what they can get from their environment—grasslands, forests and waterbodies—to meet their daily needs. Income alone, therefore, does not adequately reflect the kind of poverty they face.

## To be Poor

Life for the poor is a daily struggle for survival. However, despite their poverty, the poor tend to have large families because children come not just with a mouth to feed but also a pair of hands to work with. But when many poor families have several children, the result is often far more people than locally available resources can support. This leaves the poor little choice but to deplete and degrade local forests, soils, grasslands and water supplies in a desperate attempt to survive. The net result of their struggle for short-term survival is often a vicious cycle: a larger population leads to more poverty and to more pressure on the environment, which can make future chances of survival more difficult.

It is because of the rapidly increasing population that farmers have too little land to grow enough food for their families. The land available per family also becomes less because of the system of inheritance prevalent in India. Each generation has smaller plots of farmland than the one before. Many of these plots are too small to support a family. With no other means of supporting their families, the rural poor move to towns and cities in the hope of finding work.

In towns and cities, the poor live in squalid conditions in slums or on pavements, where they have access neither to toilets nor to safe drinking water. Their flimsy shelters provide little protection from heat, cold or rain. They often live close to polluting factories, and work (if they can find a job) in unhealthy and unsafe conditions for very low wages.

Their living and working conditions and undernourishment make the poor vulnerable to disease, ill health and early death. At least 125,000 people are reported to die every year in India from malnutrition and water-borne diseases. Another 267,000 die from respiratory diseases caused by air pollution. The death toll from these preventable diseases is about 1,100 persons per day, which is equivalent to four plane loads of 275 passengers each crashing every day with no survivors!

Beyond the suffering that illness causes, the inability to work adds to their problems of daily sustenance. Due to their poor standard of health, they can neither work much nor earn much. Thus, they continue to be hungry, sick, and not very productive. They are caught in a 'poverty trap' from which it is not easy to escape.

In India where such a large number of people are poor, their low productivity in turn affects the country's economic development. In the absence of adequate economic development, the people continue to live in poverty.

## The Rich and the Poor

India's economic development may not be widespread enough, but it has created pockets of affluence. An increasing number of people have more money to spend and more things to spend it on. More products mean more production, which means more resources from the environment. It also means more pollution and more damage to the environment. Since the poor depend directly on the environment for their basic needs, they suffer most from environmental damage.

The demand for wood for furniture and in house building and industry depletes the forests on which the poor depend for fuel and food. They also depend on fruit, berries and roots gathered from the forest to supplement their food, and on herbs and other forest products for medicines. As forests disappear so do these forest products which are so essential for the poor.

As more and more good soil is used for cash crops to meet the demands of the rich, at home or abroad, the poor are pushed on to less productive lands. For example, land around cities such as Bangalore and Delhi is being taken over for floriculture to meet the growing demand for flowers, both in India and abroad, to decorate the homes and offices of the rich and to gift to each other on various occasions.

Lacunae in the food procurement, pricing and distribution systems have prevented programmes such as the public distribution system from effectively reaching all the poor. Some analysts fear that the problems of hunger and malnutrition may worsen as India's population grows. About 40 per cent of our cropland is degraded due to soil erosion, waterlogging, salinization, overgrazing and deforestation; and about 80 per cent of our land is prone to droughts.

There is a strong need for alternative approaches to address the population issue.

## UNDERSTANDING SUSTAINABLE CONSUMPTION

Population often is at the forefront of discussions on environment and development issues. Consumption, an equally significant and related concern, does not often get the consideration it merits. Understanding consumption and the alternatives to unsustainable consumption patterns is as important for a better environment as is controlling population growth.

What is an appropriate level of consumption? Here are a few statements which can help us to understand what is sustainable (or appropriate) consumption:

- Sustainable production and consumption [are] the use of goods and services that respond to basic needs and bring a better quality of life, while minimizing the use of natural resources, toxic materials and emissions of waste and pollutants over the life cycle, so as not to jeopardize the needs of future generations. (Symposium on Sustainable Consumption, Oslo, Norway; 19–20 January 1994.)
- Sustainable production and consumption involves business, government, communities and households contributing to environmental quality through the efficient production and use of natural resources, the minimization of wastes, and the optimization of products and services. (Edwin G. Falkman, *Waste Management International. Sustainable Production and Consumption: A Business Perspective*. WBCSD, n.d.)

## ECOLOGICAL FOOTPRINTS

How do we measure over-consumption? A number of new techniques and tools have been developed to weigh the ecological impact of consumption. One recent emerging technique is the **Ecological Footprint**.

Everybody (from a single individual to a whole city or country) has an impact on the earth, because they consume the products and services of nature. Their ecological impact corresponds to the 'amount of nature' they 'occupy' to keep them going. Ecological footprints are a way of putting a quantifiable value on the biologically productive areas necessary to continuously provide the resource supplies and to absorb the wastes, using prevailing technology. Thus ecological footprints show us how much nature we use. A country's ecological footprint is the total land and water area in various ecosystem categories that is required by that country to produce all the resources it consumes, and to absorb all the waste it generates.

The earth has a surface area of 51 bn ha, of which 36.3 bn ha is sea and 14.7 bn ha is land. Of this, only 8.3 bn ha is biologically productive. The remaining is covered by ice, or has unsuitable soils, or lacks water.

In 2001, India supported 16.7 per cent of the estimated world population of 6.055 billion, but the country's land mass is a mere 2.4 per cent of the world's surface area.

Taking into account the biologically productive land and sea area, the earth has about 2 ha of land per person. Leaving a portion of this land for other plant and animal species, we have about 1.7 ha per person. This is the benchmark against which we measure our ecological footprints. (Table 11.2).

Table 11.2
Ecological footprints

| | *Population 1997* | *Ecological footprint (ha per capita)* | *Ecological capacity (ha per capita)* | *Ecological deficit (ha per capita)* |
|---|---|---|---|---|
| | | *(all expressed in world average productivity 1993 data)* | | |
| World | 5,892,480,000 | 2.8 | 2.1 | 0.7 |
| India | 970,230,000 | 0.8 | 0.5 | 0.3 |
| USA | 268,189,000 | 10.3 | 6.7 | 3.6 |
| Singapore | 2,899,000 | 7.2 | 0.1 | 7.1 |
| Ireland | 3,577,000 | 5.9 | 6.5 | 0.6 |
| Australia | 18,550,000 | 9.0 | 14.0 | 5.0 |

**Source:** www.ecouncil.ac.cr/rio/focus/report/English/ranking.htm.

Some countries use more ecological capacity than there are resources within their boundaries. This means they run into ecological deficits (represented by negative numbers), which represent the extent of over-consumption by these countries. They depend on imports to make up for the lack of their ecological capacities to support their lifestyles. Countries with footprints that are smaller than their ecological capacity are living within their nation's ecological means (represented by positive numbers). But often, the remaining capacity is used for producing goods for export to other countries (such as the ecological deficit countries), rather than keeping it as a reserve.

Measures such as the ecological footprint need to be developed so that we can understand the extent of over-consumption and its impact on the earth's resources.

## Strategies for Change: Affecting Consumption Patterns

Changing consumption patterns is not an easy task. A combination of different efforts at different levels is required to change unsustainable lifestyles and keep people's consumption at sustainable levels.

Some key actions required are:

1. Information access and raising awareness about sustainable consumption so that people can make informed choices is an important step.
2. Taking actions to ensure minimum consumption for all would make it possible for all people to have access to basic facilities and opportunities.
3. Promoting technological innovations and resource efficiencies would help to reduce both environmental damage and poverty.
4. Correct pricing of raw materials would help towards improving the efficiency of materials' use and reducing waste. Natural materials (e.g., mineral ores, water, etc.) are now kept artificially cheap because of governmental subsidies. That is, the environmental costs of extracting and using a particular material are not reflected in its cost. The mining and logging industries, for example, are heavily subsidized by governments, in spite of the extensive environmental damage these industries usually cause. Correctly pricing these raw materials will motivate people to reduce wastage.
5. Correctly pricing products whose use contributes to environmental degradation is another crucial step. For example, the cost of aerosol sprays, which contribute to ozone-layer depletion, needs to reflect their environmental impact.
6. Establishing and enforcing adequate laws and regulations can help in making polluters pay for the environmental damage they cause. Regulations can also help in ensuring that the waste discharged meets certain minimum set standards so that pollution is minimized. Governmental regulations can be in the form of minimum quality standards, fines for violations, etc.
7. Strengthening the mechanisms for international cooperation and action can help in addressing consumption issues that have a global environmental impact. For example, parts of many species of animals and plants are used for human consumption in the form of medicines, clothing, fashion accessories, etc. Animal furs, ivory, etc., are examples.

   The Convention on International Trade in Endang-ered Species of Wild Fauna and Flora was adopted in 1973, and was ratified by 135 nations around the world. This convention seeks to regulate the trade in wildlife and plants. Under this convention, trade in more than 600 species of endangered plants and animals is prohibited.

Efforts by governments and businesses alone will not be able to effectively change consumption patterns. What may be the crucial action is questioning our own lifestyles.

## Making a Difference

Individual action is a way to begin to make a difference. One way of understanding individual initiatives to reduce over-consumption is by adopting the 5 'Rs' of consumption.

**Refuse:** Refuse unnecessary goods and services. A common example of this is the ubiquitous plastic carry bag that is used to package groceries. Plastic is non-biodegradable and very few of the plastic carry bags have recyclable value. It is best to refuse plastic carry bags and instead use your own cloth bag. Less demand for plastic bags would mean less production and finally less non-biodegradable waste.

**Reduce:** Reduce your consumption of goods and services as much as you can. Electricity use is an example. By using electricity, we will be saving precious coal resources which are used for generating electricity in thermal power plants. Saving electricity also means that fewer dams may need to be built for hydroelectricity generation. This will mean a reduction in the area of land being submerged and the number of people being displaced.

**Reuse:** Reusing goods will reduce the demand for new goods. This would imply that the demand on natural resources for the production of new goods will also reduce. For example, reusing 'disposable' plastic jars for storing spices, etc., in the kitchen prevents the jars from becoming non-biodegradable waste.

**Repair:** Repairing goods reduces the need for new goods and saves the natural resources used in the production of new goods. For example, repairing old furniture and putting it to use is a cost-effective and eco-friendly option to buying new furniture.

**Recycle:** Recycling goods ensures that they are used again in another form. For example, used paper can be recycled and made into paperboard, handmade paper, etc. This reduces the demand on wood pulp and saves trees.

### Population, consumption and the global divide

Why should the North limit its fossil fuel consumption if the resources and atmospheric absorptive capacity saved thereby will simply be gobbled up by the Southern overpopulation, resulting in a larger number of people living at the same level of deprivation? Why should the South limit its population if the resources saved thereby will be gobbled up by Northern over-consumption, resulting in still more extravagance by the already profligate? At every global environmental conference these questions are raised. The North refuses to talk about over-consumption while the South refuses to talk about overpopulation. The result of this is that the two causes most responsible for environmental degradation and poverty cannot be addressed directly. It should be clear by now that as long as we focus on these problems one at a time we will get nowhere. The bargaining needed to get Southern attention to overpopulation is Northern willingness to face up to over-consumption—and vice versa. These two parts have to be put together.

(Herman Daly, 1998. *World Watch*, 11[1] January–February.)

## I QUESTIONS

1. Match the following

| | |
|---|---|
| A. The average number of children that women in a given city, region or country give birth to during their childbearing years | a. Rate of natural increase |
| B. The annual rate at which a human population increases (not including immigration or emigration). A country or region's birth rate minus its death rate | b. Population age structure |
| C. The rate of natural increase in a given year, plus the number of people immigrating into the country, minus the number of people emigrating out of the country | c. Growth rate |
| D. The current relative proportion of a country's population in different age groups | d. Total fertility rate |

2. Do you know of any communities or states in India where traditionally women, and not men, inherit their parents' property? Find out the literacy levels of women, birth rates and infant mortality rates in those states. Do you find any correlation?
3. Find out the female literacy rate, birth rate and infant mortality rate for your state. How do these compare with the rates for India and Kerala? What do the rates prevalent in your state signify? If you live in Kerala, try to find out the rates for as many census years in the past as possible and compare them with the rates for India for the same years. What conclusions can you draw from the data?
4. Your friend says that population growth can be controlled by making contraceptives and sterilization procedures easily accessible? Do you agree? If yes, why? If not, why not?
5. Imagine you are on a committee making recommendations to help India's National Population Policy be a success. What will be your recommendations?
6. Standard of living refers to consumption of goods and services. Quality of life refers to a combination of attributes that provide a sustained human

experience of physical, mental, spiritual and social well-being. These would include access to basic goods and services, security, justice, healthy human relations, opportunities, peace of mind, a healthy environment, etc. It is not possible to put on economic value to many of these.

If you were given a magic lamp and allowed five wishes for a better quality of life for yourself, what would you wish for? (You are not allowed to ask for money.)

Now put together a similar '5 wish list' imagining that you are the following persons:

- A poor farmer in a drought-prone area.
- A slum-dwelling woman in a large city.
- A housewife in a middle income housing colony.
- The CEO of a multinational corporation.

What are the common items in the lists? Which ones are different, and why?

## II EXERCISES

1. Imagine that the earth has become so overpopulated that people are being settled on Mars. On the spaceship to Mars, each family is allowed to carry just 20 things from their homes. Make a list of the 20 things your family would choose to take. You are not allowed to take any money.

   Now imagine that the spaceship is already overloaded, and so you have to drop any 5 of the 20 things you have with you. Which five will you choose to drop? Strike these from your list. After lift-off, the space ship develops a problem because of excess cargo. The Commander of the ship orders every family to get rid of five more things. Which five things will you discard now? Strike out five more items from the list. After ejecting the items, the problem of excess weight is still not solved. You must part with five more items out of the ten you are carrying. Which five items will you give up? Strike out these five items from the list.

   Finally you will have a list of five items. Review your original list and your final list. What does this tell you about needs, wants and luxuries? Make a list of the things you own which you can easily do without. Think about the environmental impacts of each such thing.
2. Using the data from Table 11.3 showing the distribution of population, make a graph to show the distribution of population amongst the states in India. Is the population distributed evenly or unevenly? Find out which states

and union territories (UTs) have the highest and lowest populations. Which five states or union territories have the highest population density?

What do you understand by sex ratio? Which states or UTs have the highest sex ratio? Which have the lowest? What do you think are the reasons for these high as well the extremely low sex ratios?

Table 11.3
Population share of Indian states/union territories, 2001

| States | Total population in millions | | | Percentage of decadal growth 1991–2001 | Sex ratio (number of females per 1,000 males) | Density (per sq km) |
|---|---|---|---|---|---|---|
| | Persons | Males | Females | | | |
| India | 1,027,015,247 | 531,227,078 | 495,738,169 | 21.34 | 933 | 324 |
| Jammu & Kashmir | 10,069,917 | 5,300,574 | 4,769,343 | 29.04 | 900 | 99 |
| Himachal Pradesh | 6,077,248 | 3,085,256 | 2,991,992 | 17.53 | 970 | 109 |
| Punjab | 24,289,296 | 12,963,362 | 11,325,934 | 19.76 | 844 | 482 |
| Chandigarh | 900,914 | 508,224 | 392,690 | 40.33 | 773 | 7,902 |
| Uttaranchal | 8,479,562 | 4,316,401 | 4,163,161 | 19.20 | 964 | 159 |
| Haryana | 21,082,989 | 11,327,658 | 9,755,331 | 28.06 | 861 | 477 |
| Delhi | 13,782,976 | 7,570,890 | 6,212,086 | 46.31 | 821 | 9,294 |
| Rajasthan | 56,473,122 | 29,381,657 | 27,091,65 | 28.33 | 922 | 165 |
| Uttar Pradesh | 166,052,859 | 87,466,301 | 78,586,558 | 25.80 | 898 | 689 |
| Bihar | 82,878,796 | 43,153,964 | 39,724,832 | 28.43 | 921 | 880 |
| Sikkim | 540,493 | 288,217 | 252,276 | 32.98 | 875 | 76 |
| Arunachal Pradesh | 1,091,117 | 573,951 | 517,166 | 26.21 | 901 | 13 |
| Nagaland | 1,988,636 | 1,041,686 | 946,950 | 64.41 | 909 | 120 |
| Manipur | 2,388,634 | 1,207,338 | 1,181,296 | 30.02 | 978 | 107 |
| Mizoram | 891,058 | 459,783 | 431,275 | 29.18 | 938 | 42 |
| Tripura | 3,191,168 | 1,636,138 | 1,555,030 | 15.74 | 950 | 304 |
| Meghalaya | 2,306,069 | 1,167,840 | 1,138,229 | 29.94 | 975 | 103 |
| Assam | 26,638,407 | 13,787,799 | 12,850,608 | 18.85 | 932 | 340 |
| West Bengal | 80,221,171 | 41,487,694 | 38,733,477 | 17.84 | 934 | 904 |
| Jharkhand | 26,909,428 | 13,861,277 | 13,048,151 | 23.19 | 941 | 338 |
| Orissa | 36,706,920 | 18,612,340 | 18,094,580 | 15.94 | 972 | 236 |
| Chhattisgarh | 20,795,956 | 10,452,426 | 10,343,530 | 18.06 | 990 | 154 |
| Madhya Pradesh | 60,385,118 | 31,456,873 | 28,928,245 | 24.34 | 920 | 196 |
| Gujarat | 50,596,992 | 26,344,053 | 24,252,939 | 22.48 | 921 | 258 |
| Daman & Diu | 158,059 | 92,478 | 65,581 | 55.59 | 709 | 1,411 |
| Dadra & Nagar Haveli | 220,451 | 121,731 | 98,720 | 59.20 | 811 | 449 |

*(continued)*

*(continued)*

| States | Total population in millions | | | Percentage of decadal growth 1991–2001 | Sex ratio (number of females per 1,000 males) | Density (per sq km) |
|---|---|---|---|---|---|---|
| | Persons | Males | Females | | | |
| Maharashtra | 96,752,247 | 50,334,270 | 46,417,997 | 22.57 | 922 | 314 |
| Andhra Pradesh | 75,727,541 | 38,286,811 | 37,440,730 | 13.86 | 978 | 275 |
| Karnataka | 52,733,958 | 26,856,343 | 25,877,615 | 17.25 | 964 | 275 |
| Goa | 1,343,998 | 685,617 | 658,381 | 14.89 | 960 | 363 |
| Lakshadweep | 60,595 | 31,118 | 29,477 | 17.19 | 947 | 1,894 |
| Kerala | 31,838,619 | 15,468,664 | 16,369,955 | 9.42 | 1,058 | 819 |
| Tamil Nadu | 62,110,839 | 31,268,654 | 30,842,185 | 11.19 | 986 | 478 |
| Pondicherry | 973,829 | 486,705 | 487,124 | 20.56 | 1,001 | 2,029 |
| Andaman & Nicobar Island | 356,265 | 192,985 | 163,280 | 26.94 | 846 | 43 |

**Source:** Census of India 2001.

## III DISCUSS

1. An estimated six billion human beings are living on earth today. At an average growth rate of about 1.3 per cent, close to 78 million people are being added each year. The population in some countries is doubling in less than one person's lifespan. If the current rate of growth continues, the number of human beings on earth will double by 2053, to a total of 12 billion.
   World population growth is creating environmental economic, social and political problems never before encountered. Discuss.
2. The challenge of poverty and the challenge of environment are not two different challenges but two facets of the same challenge. Discuss.
3. 'The North refuses to talk about overconsumption while the South refuses to talk about overpopulation.' Discuss.

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# Chapter 12

# Environment and Development: The Links

Kalyani Kandula

Why are massive development projects, once considered the temples of modern India, facing opposition? Are the groups that oppose these projects against the development of the country?

It is worthwhile to examine the linkages between the environment and development in the context of large development projects, because these projects clearly bring to the forefront environment and development conflicts. For example, we may say that a polluting industry needs to be closed down to safeguard the environment. But this may deprive its workers of their livelihoods. Similarly, forest areas may be leased out for logging to promote the export of timber and timber products. But logging results in the loss of forests and their biodiversity.

People who question the relevance of development projects like big dams say they are not against development per se. They say they are raising questions on the following fundamental issues—development for whom, and at what cost?

## What is Development?

What do we mean by development? Some of the elements of development include:

- Increase in real income per capita.
- Opportunity to have a satisfying livelihood.
- Improvement in health and nutritional status.
- Improvement in educational status.
- Access to resources.
- A 'fairer' distribution of income.

- Assurance of basic human rights.
- Conservation of nature and natural resources.

As we can see, development is concerned both with humans and with the environment. The crucial point is: does a particular development project address or achieve all or many of these? This brings us to the next question: **How do we make development possible**?

Can we 'develop' by building huge factories, large dams, tall buildings, massive bridges, and by manufacturing fast cars and computers? All of these may be required for economic growth, which is one component of development. But focusing all our efforts on these activities at the cost of ignoring other equally important dimensions of development may be counterproductive. We will examine the different dimensions of development later in this chapter. But first, let us understand the problems with the approach to development only through economic growth.

Economic growth has generally been accepted as the approach to development. Richer countries are often called 'developed' countries while poorer countries are referred to as developing countries. Economic growth is usually measured by tools such as the gross domestic product (GDP). It was believed that by looking at the GDP of a nation, we could get an idea of its economic growth and thus its level of development. But this seemingly simple approach has problems. To understand what the problems are we need to understand what GDP is.

The **gross domestic product** is the total output of goods and services for final use produced by an economy by both residents and non-residents, regardless of the allocation to domestic and foreign claims. It does not include deductions for the depreciation of physical capital or the depletion and degradation of natural resources. GDP is usually divided by the total population, and this gives the per capita GDP. The per capita GDP provides a yardstick of relative levels of economic growth. Table 12.1 illustrates this clearly.

Table 12.1
Per capita GDP of selected countries (2001)

| *Country* | *Per capita GDP in US$* |
|---|---|
| Nepal | 1,310 |
| India | 2,840 |
| China | 4,020 |
| South Africa | 11,290 |
| Saudi Arabia | 13,330 |
| Japan | 25,130 |
| Australia | 25,370 |
| USA | 34,320 |

**Source**: Human Development Report, 2003.

The **gross national product**, or GNP, is another measure of economic growth. It comprises GDP plus net income from abroad, which is the income residents receive from

abroad for services (labour and capital), less similar payments made to non-residents who contribute to domestic economy.

The GDP, like any measure, has its strengths and weaknesses. Some of the areas of concern regarding the GDP, from an environmental point of view, are described here.

As we can see from the definition, the GDP includes only marketable goods and services. It excludes goods and services that are not marketable. There are a number of such unmarketable, unmarketed and non-marketable goods and services that contribute to human well-being. For example, medicinal plants that are maintained and used by village communities for use in traditional medicine may not be marketed. Similarly, fuelwood and fodder collected by villagers for their own use may not be marketed. Apart from such material goods and services, other things such as peace, freedom, low crime rates, etc., have a tremendous influence on human well-being. It is not possible yet to put an economic value to these, and thus they are not in the purview of the GDP.

Another feature of the GDP is that it does not take into account the nature of the goods or services produced. Consider this example. If water is polluted, a huge amount of money must be invested to clean it because people cannot live without clean water. The investment made in cleaning the water is accounted for, and the GDP shows an increase. Fresh, clean water straight from nature is not included in the GDP because it is a free gift of nature. But cleaning polluted water costs something and thus increases the GDP!

Also, the GDP does not account for many of the traditional approaches to conserving natural resources because these do not involve economic transactions. For example, the GDP does not account for conservation efforts through sacred groves. These are tracts of forest set aside by people with the belief that a particular pocket of the forest has a resident god who must be protected. As a result of this protection, the sacred groves harbour a great diversity of plant and animal life. They contain some important species of flora and fauna that have been lost in the surrounding area. Efforts such as these, which have immense conservation value, do not feature in the GDP, whereas some ecologically destructive activities may contribute to increasing the GDP!

Thus, while it does not account for the natural resources that a country has, the GDP may actually account for the exploitation of these resources if the process of exploitation yields money; that is, having 50 per cent of its land under forests may not feature in the GDP of a country, but cutting down these forests for marketing their timber will show up as an increase in the GDP. The eminent environmentalist, Anil Agarwal, proposed another GNP—the Gross Nature Product—as a more relevant measure of human and environmental well-being.

In the traditional economic thinking, the goal was always to increase the GDP, in the belief that an increase in the GDP necessarily implied an increase in human well-being. But we now understand that while the GDP may be a useful measure to estimate economic growth, it is inadequate to give an idea of development as a whole.

The GDP and the economic growth it represents give only a partial understanding of development. Development in its true sense is more than just economic growth. In its

holistic sense, development is concerned with economic growth, the quality of life of the people and the health of the environment.

Let us now try to understand what quality of life implies.

## Quality of Life

Quality of life refers to our health and happiness. There is a difference between quality of life and standard of living. Standard of living refers to our consumption of goods and services, which may or may not make us happier or healthier.

The GDP and GNP do not give us an idea of the quality of life of people. Recognizing this, the United Nations Development Programme (UNDP) has established another measure, the Human Development Index. This index is a combined measure of a country's scores on three basic components of development:

- physical well-being, as measured by life expectancy,
- education as measured by a combination of adult literacy rates and mean years of schooling, and
- standard of living, as measured by GDP per capita, adjusted to Purchasing Power Parity.

Purchasing power parity

**Purchasing Power Parity (PPP)** measures how much of a common 'basket' of goods and services each currency can purchase locally, including goods and services that are not traded internationally. Using PPP-based currency values to compare levels of economic prosperity usually produces lower GDP figures in wealthy countries and higher GDP figures in poorer nations, compared with market-based exchange rates.

While holistic development strives for a better quality of life for all people, it also accords priority to the wise management of the environment.

## What Does the Environment Have to Do with Development?

All the basic resources required for living come from the environment. It is the environment that provides raw materials to our industries, food for our people, fuel for our transport, etc. The environment also absorbs the waste that our developmental activity

creates. That is, the environment is both a **source** and a **sink** for developmental activity. For example, inland waterbodies are a source of fish, water for irrigation, etc., for village economies. They also act as a sink for excess fertilizer and pesticides that may run off from agricultural fields. This is the reason why we cannot look at development in isolation from the environment which supports it.

Attempting development only by increasing economic profits and in isolation from concerns of human and environmental well-being can have undesirable consequences. This is illustrated by the example in the following box.

### Breaking much more than ships

The ship-breaking industry has earned notoriety for flouting environmental norms as well as for its dreadful working conditions.

Alang, a small place on the western coast of Gujarat, has come to symbolize this industry, which is a virtual death trap for its workers. The other face of Alang is that it occupies a prominent place on the business map of India—most of the ship-breaking business in India is done here and it has an annual turnover of $2 billion. However, there are 11 more places in India where ship-breaking is done.

India has now established itself as a major player among the countries involved in the business of breaking old discarded ships; the charm being huge quantities of re-rollable steel scrap which comes out of ship-breaking. Alang alone gives 2.5 mn t of scrap yearly, which is directly used by re-rolling industries for production of rolled steel products used in the construction industry. The ship-breaking industry is considered to be a major source for providing rollable steel at a low price.

However, life in Alang reveals the real cost of procuring cheap steel. For the workers, the process of ship-breaking is akin to walking through a minefield. The method of ship-breaking is such that a worker is constantly under the threat of death or physical mutilation.

A worker has to climb atop the ship and start cutting it from the top with crude hacksaws and oxygen LPG torches. The ships brought in for breaking are generally not stripped of toxic elements, inflammable fluids and gas; a worker's torch often accidentally sets off an explosion in a pipe carrying inflammable fluid, leading to severe burns and deaths.

In the process of dismantling a ship, big steel plates, giant boilers, generators and other heavy parts fall from great heights on the workers below, often resulting in mutilated bodies, fractured bones, and broken heads. There are numerous other ways in which workers get hurt while breaking a rusted, dilapidated giant ship.

What happens in the shipyards of Alang is barely known to the outside world: deaths and injuries are neither properly recorded nor are they revealed. The law of land—as far as labour is concerned—literally does not touch the shores of Alang. Around 40,000 workers—mostly migrants from Orissa, Bihar and Uttar Pradesh—employed in the various shipyards of Alang remain at the absolute mercy of the owners of these units. Labour laws have been simply banished from here.

The ships that are brought in for breaking contain a wide range of toxic substances capable of inflicting great harm to the environment. Toxic substances like paints, lead, heavy metals,

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polychlorinated biphenyls (PCB), tin, asbestos, etc., are the most common waste materials that come out of broken ships. The Central Pollution Control Board (CPCB) agrees that the release of these substances into water during ship-breaking results in changes in water quality and in the marine ecosystem, especially in the intertidal zone.

The toxic release of one or two ships may not have made any difference to the sea and the marine life, but hundreds of ships releasing their toxic wastes every year certainly damages the environment in a big way. The number of ships scrapped between April 1998 and March 1999 alone was 361. There are hardly any restrictions imposed on the ship-breaking industry in terms of regulating its polluting activities.

There are prospects of boom for this industry as a large number of ships are lined up for scrapping in the next few years, including an entire fleet of 6,700 oil tankers, on account of a new law which has stipulated that oil tankers must be double-hulled ships.

This means more cheap steel scrap for India, more profit for ship-breakers of Alang and elsewhere. This also means more smashed skulls, more mutilated bodies of workers, and irreversible damage to the marine life in coastal areas.

When developmental activity focuses only on economic growth and ignores social and environmental well-being, it cannot be sustained. The example, aquaculture, will illustrate this point.

### Aquaculture: The blue revolution

Aquaculture is the farming of a wide variety of aquatic organisms, including fish, molluscs, crustaceans and aquatic plants. It can be undertaken in a wide variety of aquatic areas such as rivers, lakes, reservoirs, ponds, estuaries and coastal waters.

Shrimp aquaculture has been traditionally practiced in low-lying coastal areas of Kerala and Bengal, which are inundated with brackish water during the monsoon. The wild shrimp and other fish seed are brought in with the high tide. Farmers impound these waters by simple means and allow the shrimp seed to grow naturally without devoting any special attention. Four to six months later, during low tide, the earthen bunds are broken, the water drained through a net and the shrimp harvested.

Modern shrimp aquaculture started in a small way in the 1980s to meet the growing export demand for shrimp. After 1991, many large industrial houses set up export-oriented shrimp farms. In Andhra Pradesh, the area under shrimp aquaculture grew from about 5,000 ha in 1990 to more than 84,000 ha in 1999.

Modern shrimp aquaculture farms were entirely different from the traditional farms. The modern farms were based on constructing ponds and pumping in brackish water from the sea. The ponds are stocked with shrimp seed (harvested from the wild or produced in hatcheries). The shrimps were fed oil cake, fish waste, or industrially produced feed and harvested when they had grown.

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Shrimp aquaculture can be extensive or intensive, depending on the number of shrimp seed per hectare. The density of shrimp varies from 20,000 shrimp seed per ha to 350,000 per ha across the range.
Increase in intensity of shrimp seed per hectare also means:

- Increase in the frequency of releasing pond water contaminated with left-over feed and other organic wastes into the environment.
- Increase in pumping of brackish and fresh water into the ponds.
- Increase in risk of disease (due to rapid spread of disease from one infected farm to another, as the infected farms' waste water flows into the input source of the other farm) which leads to an increase in the use of drugs and chemicals.
- Increase in the number of shrimp harvested per hectare and in profits.

The tremendous increase in both extensive and intensive aquaculture, with passage of time, revealed that the 'boom' has not been without problems.

**Socio-economic problems:** The lands occupied by corporate aquaculture ponds were once freely accessible to local communities who used them for fish drying, net drying, grazing, subsistence cultivation, etc. The increase in demand for land for conversion into shrimp ponds lured many local farmers to sell their land to corporate giants. The conversion of paddy lands into shrimp ponds resulted in loss of employment and loss of local-level food security. Local fishermen in some places also found their access to the sea made difficult because of shrimp farms along the shore.

**Environmental problems:** Shrimp farming requires brackish water, which is salty. Conversion of large areas of land into ponds that store brackish water led to salinization of nearby agricultural lands. It has been estimated that at least 9,000 ha of paddy lands have become useless due to shrimp aquaculture in coastal Andhra Pradesh. The water in nearby wells has also been affected by salinity. Organic wastes from the shrimp pond find their way into the local surface waters each time the pond water is thrown out. In 1994–95, a viral attack wiped out most of the shrimp produce. The rapid spread of the virus from one farm to the other is believed to be the result of the unplanned growth of the farms, which made one farm's waste water flow into the input source of the other farm.

**Sustainability:** The environmental and socio-economic impacts of the aquaculture industry were brought to the notice of the Supreme Court and resulted in judicial action. The Court gave a judgement in December 1996, which served as a severe setback to the shrimp aquaculture industry. It ordered the closure of shrimp farms in areas where they are not permissible under the Coastal Regulation Zone (CRZ). But even before the Court action, the industry nearly collapsed on its own.
Excerpted from V. Vivekanandan and John Kurien, 1998. Aquaculture—Where Greed Overrides Need, *The Hindu, Survey of the Environment 1998*.

Thus, the aquaculture boom contributed to short-term economic growth but raised concerns regarding the well-being of the local communities and of the local environment. For these reasons it was not sustainable.

This case serves to highlight the fact that, for development to be sustainable, the challenge is to make economic growth, human well-being and environmental well-being compatible. This idea has captured the imagination of many people across the world and has led to the emergence of the concept of sustainable development.

## What is Sustainable Development?

There have been many different definitions of sustainable development. Some of them are:

1. Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs. (*Our Common Future*, 1987.)
2. Sustainable development is using, conserving and enhancing the community's resources so that ecological processes, on which life depends, are maintained and the total quality of life, now and in the future, can be increased. For development to be sustainable, it must take account of social and ecological factors, as well as economic ones; of the living and non-living resource base; and of the long- and short-term advantages and disadvantages of alternative actions. (*World Conservation Strategy*, 1980.)

The main features either explicitly stated or implicit in many definitions of sustainable development are: **a desirable human condition**—a society that people want to sustain because it meets their needs; **a durable ecosystem condition**—an ecosystem that maintains its capacity to support human and other life; and **equity** between present and future generations; and within the present generation.

One way of understanding this coexistence is the 'egg of sustainability' model developed by IUCN—the World Conservation Union. 'The egg of sustainability' is a model that comprises people (human communities, economies, etc.) within the ecosystem (ecological communities, processes and resources), together with their interactions. Interactions consist of flows from the ecosystem to people; both benefits (life support, economic resources, etc.) and stresses (natural disasters, etc.) and, conversely, from people to the ecosystem, both stresses (resource depletion, pollution, etc.) and benefits (conservation). Human societies are a subsystem, or a dependent part, of the ecosystem.

People depend on the ecosystem, which surrounds and supports them just as the white of an egg surrounds and supports the yolk. At the same time, a healthy ecosystem is no compensation if people are victims of poverty, misery, violence or oppression. Just as an egg can be good only if both the yolk and the white are good, so a society can be well and sustainable only if both the people and the ecosystem are well.

Human well-being is a requirement of sustainability because no rational person would want to perpetuate a poor quality of life. Ecosystem well-being is a requirement because

it is the ecosystem that supports life and makes possible any standard of living. The well-being of humans and the well-being of the ecosystem are equally important, and a sustainable society needs to achieve both together.

## Is Sustainable Development Possible?

While it may be relatively easy to conceptualize sustainability, the more difficult task is finding out how it can be put into practice. There are some examples which illustrate how societies have moved towards sustainable development. The case of Ralegan Siddhi is one such example.

### Ralegan Siddhi: An oasis of prosperity

When Kisan Baburao Hazare, an army jeep-driver, retired and returned to his village Ralegan Siddhi in 1976, it was barren, drought stricken, and little different from the hundreds of other villages in Ahmednagar district of Maharashtra. The wells were dry. To survive, several villagers had found an alternative occupation—brewing illicit liquor. Alcoholism was rampant. Every summer, people either walked miles to work on Maharashtra government's drought relief projects, or left the village in search of work.

The first thing Hazare did was to rebuild a dilapidated temple using his own meager provident fund. He found people coming forward voluntarily to help either with money or with labour. A youth club was formed. And Hazare learnt his first lesson: 'If people are convinced that you are not selfish, they rally behind you.' The temple became a place where people gathered. Hazare used these gatherings to discuss village issues and plan collective action.

In a stagnant economy, Hazare set to work. He realized that a permanent solution could only be found if agriculture could be made more productive. As lack of water was a major constraint, Hazare tapped government schemes such as the Comprehensive Watershed Development Programme to initiate soil and water conservation measures. To reduce soil erosion and retain the meager rainwater, a mix of methods was used. **Contour** and ***nala* bunds** were built. Trees were planted with the help of government social forestry schemes. The district administration's funds were tapped to repair the percolation tank.

When government funds ran out, Hazare suggested *shramdan* (voluntary work). The villagers responded. They cooperated to build 42 bunds and dig 20 new wells. Cooperatives of about seven farmers each were formed, among whom the water was distributed equitably according to their needs.

Hazare, now called 'Annasaheb' (elder brother) by the villagers, wanted to close down the liquor distilleries and outlets. He used his army contacts to find alternative work for those who earned their living from distilleries. Many were taught vocational skills.

Meanwhile, more and more land was brought under irrigation. Water was lifted from the Kudki canal, three kilometres away. A simple drip irrigation scheme was also adopted. Water was supplied to plant roots by means of perforated pipes embedded in the soil. The area

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under irrigation increased from 45 hectares to 350 hectares. Crop yields increased dramatically. By 1991, the cropped area had increased from 630 to 950 hectares.

After the water table rose from 8 metres to 14 metres, three bore wells were also constructed. These were managed and operated by the youth of the village. Piped water from the bore wells was supplied to clusters of houses. The rotation and timings for different outlets were fixed so that no one had to walk more than 150 metres to fetch drinking water. A small water fee was charged every month.

Anna Hazare made sure that each villager had a stake in the prosperity of the village. Issues were discussed and debated, and decisions were taken collectively. To protect the saplings being planted as part of the afforestation programme, villagers agreed not to allow their animals to graze freely. Cattle were, henceforth, to be fed in stalls. Of the two lakh trees planted, 90 per cent survived. Villagers jointly decided not to grow sugarcane because it required a lot of water. Food crops were given priority. The only cash crops grown were chillies and onions. Thirty biogas plants were set up. These were fed with human excreta as well as cow dung. Smokeless *chulhas* were installed. The village has solar-powered street lights and water pumps.

In a few years Ralegan Siddhi became a green oasis in a barren area. Blazing sunflower patches grew alongside flourishing fields. The bunding scheme ensured year-round irrigation. In the drought years of 1987–88, there was no shortage of drinking water. No villager worked on a drought relief scheme as enough work was available in the village itself. The per capita income increased from Rs 250 to Rs 2,200. And moneylenders found themselves out of work.

Socially, too, change was evident. Getting drunk became taboo. So did dowry and lavish weddings. Every child in the village began to go to school, and 99 per cent of the children, including girls, could study up to the tenth standard in the local high school.

The system of decision-making was organized so that both men and women could participate. Fourteen committees in the village looked after separate subjects like cooperatives, water supply, rations, etc., in which members had an active say.

A study done in 2002 found that a quarter of the households in Ralegan Siddhi earn more than Rs 5 lakhs per year! A major bank has a branch located in the village, with the savings of the villagers totaling Rs 3 crore!! All this is a result of the community's sustained efforts at ecological regeneration.

Hazare sees his challenge in working for success stories similar to Ralegan Siddhi's in nearby villages. 'Because,' he says, 'if Ralegan Siddhi is a lone lamp, it can be blown out in a storm. So, many more lamps must be lit'.

(*Excerpted from* CEE. 1998. *Citizen Action*).

## INTERNATIONAL INITIATIVES

There are several initiatives at different levels to understand what sustainability means in practical terms and to identify the actions needed for progress towards sustainable

development. A major initiative at the international level was the **United Nations Conference on Environment and Development** (UNCED, or the Earth Summit) held in Rio de Janeiro in 1992, which brought together governments from across the world. The principal outcome of the Rio conference was *Agenda 21*. This *Agenda* describes the actions necessary for progressing towards a sustainable society.

The 40 chapters of *Agenda 21* focus on a range of environment and development concerns that include:

- International cooperation
- Combating poverty
- Changing consumption patterns
- Population and sustainability
- Protecting and promoting human health
- Sustainable human settlements
- Protecting the atmosphere
- Managing land sustainably
- Combating deforestation
- Combating desertification and drought
- Sustainable mountain development
- Sustainable agriculture and rural development
- Conservation of biological diversity
- Protecting and managing the oceans
- Protecting and managing fresh water
- Safer use of toxic chemicals
- Managing hazardous waste
- Managing solid wastes and sewage
- Managing radioactive wastes

*Agenda 21* also stresses the initiatives required for strengthening the participation of major groups, such as women, children and youth, indigenous people, non-governmental organizations, local authorities, workers and trade unions, business and industry, science and technology, and farmers, in the action for sustainable development. It also spells out the means of implementation that include financial resources, transfer of technology, science, education, legal instruments, etc.

Five years after the Rio conference, the countries of the world met again in 1997 to review the progress that had been made towards implementing *Agenda 21*. While it was recognized that several nations had initiated efforts, it was also noted that much greater concerted efforts were required to put the *Agenda* into practice and to make real progress towards sustainable development.

A decade after the Rio conference, the World Summit on Sustainable Development (WSSD) was held in Johannesburg in 2002. The concept of sustainable development and its value have gained recognition and currency in the decade since the Rio conference.

This is reflected in the name of the latest conference to review the progess in the past decade and plan for the 21st century.

The significant outcomes of WSSD were the Plan of Implementation and the Johannesburg Declaration on Sustainable Development. The declaration outlines the path taken from 1972 when the first UN Conference on the Human Environment was held in Stockholm, to UNCED, to WSSD. It highlights present challenges, expresses a commitment to sustainable development, underscores the importance of multilateral cooperation, and emphasizes the need for implementation. The Plan of Implementation is a framework for action to implement the commitments originally agreed at UNCED, and the action plans for sustainable development in the 21st century. It has sections relating to Poverty Eradication, Consumption and Production, Natural Resource Base, Globalization, Health, Small Island Developing States (SIDS), Africa, Other Regional Initiatives, Means of Implementation and Institutional Framework.

## TOWARDS SUSTAINABILITY

Despite the currency of the term sustainable development, different groups of people all around the world are still struggling to understand what it means for them and how they can make it possible. When all peoples and governments share sustainability as a common concern and work towards it, the vision of sustainable development may in fact be realized.

### I QUESTIONS

1. What is the difference between quality of life and standard of living? An improvement in which of these would you like for yourself? Why?
2. What is the difference between growth and development?
3. How is development different from sustainable development?
4. The development path we have followed so far has created wealth and prosperity for a few, but it has not been able to banish poverty, illiteracy, disease, unemployment, and gender inequality. Development should mean not just economic prosperity for some; it must mean a better life for all. Name five steps that must be taken to ensure this.
5. Ralegan Siddhi is considered a model of success in ecological restoration and rural development. Do you think this model can be replicated in other villages? If yes, why? If no, why not?

6. Name the two most significant environmental problems that affect the development of your state.

## II EXERCISES

1. If you were a planner and had 100 units to spend on the development of your country, how would you allocate the money among the projects listed below. Give your reasons for the various allocations.

| *Projects* | *Units allocated* | *Reason for allocation* |
|---|---|---|
| Raising income | | |
| Building schools | | |
| Providing basic health care | | |
| Education for girls | | |
| Building a dam | | |
| Establishing modern industry | | |
| Giving loans for village industry | | |
| Increasing food production | | |
| Improving roads | | |
| Introducing renewable energy | | |
| Building a fertilizer plant | | |
| Building an air-conditioned resort | | |
| Building a Disneyland | | |

If you could add one project of your choice to those listed above, what would it be and why? How many units of money would you allocate to it?

2. Read the following story and then answer the questions that follow:

**Paradise Squandered!**
Long, long ago on a little island, a happy people lived. Their island, Karu [name changed], had everything they needed: coconut trees for food and

drink, magnificent spreading tomano trees for shade, abundant bird life and an ocean full of fish. Two centuries ago an English sailor discovered Karu and called it Pleasant Island.

Another century passed before an expedition was carried out to Karu. It was then discovered that the island had one of the richest piles of phosphate rock on the globe. For most of this century, millions of tonnes of phosphate were shipped to other countries, where they fertilized fields and farms.

Today the 20 sq km island has a population of 7,000 native Karuans and another 3,000 imported workers.

Karu has only one road around the island, but the average Karuan family has at least two vehicles. They also have microwave ovens, stereo equipment and multiple televisions per family. Nine out of every 10 Karuans are obese, and young men can weigh more than 135 kilos. Why? This is because their native food was replaced by imported foods which are subsidized by the government. Meat brought from another country more than 3,200 km away is cheaper in Karu than it is in that country. Today Karuans even import fish! The changed diet habits are showing their ugly effect on Karuans. A person on the island can be expected to live only for about 55 years. Diseases like hypertension, heart disease and diabetes are common on the island.

Karuans receive their housing, power supply, water, telephones, education and medical services free or for a nominal charge. The tiny island has two hospitals, and Karuans needing special treatment are flown at government expense to other countries.

Where does all this wealth come from? The phosphate. What then is the problem? The phosphate could run out before the next century. The government is now desperately searching for more phosphate even as the interior of the island lies ravaged by mining. They even plan to demolish the President's residence in their search. Karuans continue to tear their island apart, and live and spend as if there is no tomorrow. At this rate there may not be one.

(Based on: Paradise Squandered. *Reader's Digest*, August 1997.)

**Questions**

a. Karu is an example of economic growth without sustainability. Do you agree? If yes, why? If no, why not?
b. How would you plan Karu's development to make it sustainable?

## III Discuss

Read the following letter, and then discuss the questions that follow:

Excerpt from a letter from Bava Mahalia of Jalsindhi village in Jhabua district, to Madhya Pradesh Chief Minister, in 1994.

'We are people of the river bank. We live on the banks of the great Narmada. You, and all those who live in cities, think that we who live in the hills are poor and backward, like apes.

We have lived in the forest for generations. The forest is our moneylender and banker. In hard times we go to the forest. We build our houses from its wood. From the forests we make baskets and cots, ploughs and hoes, and many other useful things .... We get various kinds of grasses; and when the grasses become dry in summer, we still get leaves .... If there is a famine, we survive by eating roots and tubers. When we fall sick, our medicine men bring us back to health by giving us leaves, roots, bark from the forest. We collect and sell gum, tendu leaves, bahera, chironji and mahua.

The forest is like our mother; we have grown up in its lap. We know the name of each and every tree, shrub and herb; we know their uses. If we were made to live in a land without forests, then all this knowledge that we have cherished for generations will be useless.

The river, too, is our sustenance. The Narmada has many kinds of fish in her belly. Fish is our standby when we have unexpected guests. The river brings us silt from upstream which is deposited on the banks so that we can grow maize and jowar in the winter, as well as many kinds of melons. Our children play on the river's banks, swim and bathe there. Our cattle drink there throughout the year, for the river never dries up. In the belly of the river we live contented lives.

You city people live in separate houses. You ignore each other's joys and sadness. We live with our clan, our relatives, our kind. All of us pool together our labour and build a house in a single day, weed our fields, and do any small task as it comes along.

You tell us to take land in Gujarat. You tell us to take compensation. For losing our lands, our fields, for the trees along our fields .... But how are you going to compensate us for the forests? ... How will you compensate us for our river—for

her fish, her water, for the vegetables that grow along her banks, for the joy of living beside her? What is the price of this? Our gods, and the support of our kin—what price do you put on that? Our adivasi life—what price do you put on that?' (**Source:** 'We will drown but we will not move.' *Frontline*, 4 June 1999.)

1. How would the damming of the Narmada affect the people of the village?
2. What does a better quality of life imply for the people of Jalsindhi village?

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# Chapter 13

# Citizen Action

Kiran B. Chhokar, Mamata Pandya and Avanish Kumar

## Introduction

It is happening all over the world. From remote Indian villages, the slums of Mexico City, the rainforests of Malaysia, to the back door of the White House in the USA, ordinary people are working for change through citizen action. By organizing into groups, they cajole, demand, and persuade governments to save natural resources, build housing for the poor, and halt the indiscriminate cutting down of forests. They force industries to reduce pollution levels and persuade financiers to make environmentally sound investments.

Such groups could be made up of just a few people or several thousand. They could be informal groups or registered societies. The more formal and structured of such groups are known as non-governmental organizations (NGOs). During the past two decades, NGOs have collectively played an increasingly important role around the world. They have initiated, catalyzed, mobilized, organized and supported citizen action for the protection of the environment. In a growing number of environmental NGOs, students play important roles.

Although these citizen action groups are as varied as the people who join them, many share common visions. They labour to reduce poverty, advance human development and manage natural resources for the long- and short-term good of the community. Many begin by tackling a local problem. After succeeding at the micro-level, they may form coalitions with other groups to tackle larger problems.

Groups also share methods. They win victories through community action campaigns by using similar components of management and strategy. NGOs have also strengthened democracy throughout the world by giving voice to the poor and the powerless—people whose interests and priorities may often be overlooked by public policy.

## WHAT IS CITIZEN ACTION?

People, in informal or formal groups or as individuals, work out ways of tackling their problems, improving their lives and fighting injustice. People's concern for the environment has found expression as protests against policies, decisions or actions, and as positive moves in exploring, suggesting or demonstrating alternatives.

Citizen action is a powerful medium of change. Groups have protested against the building of dams and irrigation works which displace large numbers of people who may benefit little from such development. People have opposed the setting up, or existence, of nuclear power plants and highly polluting industrial units near human habitation. Recognizing the dangers posed by an environment over-exploited for its resources and overburdened with wastes, people have come up with innovative methods to regenerate the natural resource base and use it in sustainable ways.

Other strategies adopted by concerned individuals and groups to protect the environment have been to use the media to create awareness and pressure, and to seek legal intervention. Groups have also set up and run non-formal education centres and organized awareness campaigns.

Some of these attempts have succeeded; some have not. But failure does not always break the people's spirit; they review and revise their strategy, and fight on. Irrespective of whether the immediate objectives have been achieved or not, such initiatives by citizens have helped heighten environmental awareness.

But what sparks off such actions? What motivates people to take charge of their lives and do something to help themselves? This chapter takes a look at some stories of people who, in different ways, decided to take action to achieve what they wanted.

## FIELD ACTION: INSPIRING MODELS

There are several examples of local leadership which have found innovative methods of socio-economic development for improved livelihood, equity and the sustainable management of environmental resources.

One of the outstanding examples of natural resource management systems developed with people's participation and control is the *Pani Panchayat* programme, which has tried to build a participatory and equitable system of water management in a drought-prone area of Maharashtra.

Another inspiring example is from Mendha Lekha, a tribal village in Maharashtra. It is the story of the struggle and transformation of a helpless, uninformed and fear-ridden community into one that is informed, self-improving and empowered.

### From parched lands to green fields

In the drought-prone Mahur village of the Pune district of Maharashtra, the residents could not get enough food from their land. Drinking water was a problem. In the 1970s, Shri Vilasrao Salunke decided to undertake an experiment on 16 ha of barren land leased from a temple to find a long-term solution to the recurring drought. With his colleagues, Salunke built a percolation tank on the land, **contour-bunded** and levelled the fields to trap water and check soil erosion, removed stones and dug an open well downstream of the tank. A 7.5 h.p. pump was installed to lift the water from the well for irrigation. They planted fruit trees on fertile land, and grass and shrubs on uncultivated land. They also carried out experiments in soil and water conservation.

Gradually, every villager began seeing the change. Whereas 10 ha of Salunke's land produced 200 quintals of food grains, 17 ha of their own land produced barely 10 quintals. Salunke learnt from the experience that with irrigation, small farms intensively cultivated can achieve higher levels of productivity than larger farms less intensively cultivated. He realized that the overall agricultural production in the village economy would therefore increase further if irrigation water was allocated to a large number of small farmers rather than to a small number of large farmers.

Based on these considerations, a *Pani Panchayat* (water council) was formed. The key policy of the water council therefore was water allocation, not in proportion to the landholding but in proportion to the number of people in the family. A scheme aimed at better operation and maintenance of irrigation was formulated. Inspired by the success of the model, other villagers started joining the *Pani Panchayat*. Landless villagers were given land on lease.

The five basic principles of the *Pani Panchayat* were:

- Irrigation schemes would be given to a group of farmers. A family of five would have water rights that would help irrigate 1 ha.
- Crops that require large amounts of water would not be allowed to be grown.
- Water rights would not be attached to land rights.
- All members of the community, including the landless, would have right to water.
- The beneficiaries of the *Pani Panchayat* would have to bear 20 per cent of the cost of the scheme. They would have to plan, administer and manage schemes and distribute water in an equitable manner.

Motivated by the desire to achieve the productivity of the demonstration model on their own lands, the villagers worked together to ensure equitable distribution and management of water. Spurred by promising results, they continued their efforts. Inspired by their success, others joined in. Farms in Mahur began yielding three times the crop they had earlier yielded. Because the *Pani Panchayat* model worked, it has sustained itself for a quarter of a century, which is a remarkable achievement indeed!

Community-based conservation: Mendha Lekha shows the way

Mendha Lekha is a village of about 70 households located in the Gadchiroli district of Maharashtra. It is inhabited exclusively by Gond tribals, who have lived and used the surrounding forests since time immemorial. They depend on subsistence agriculture, daily wage employment and forest produce. The area is rich in biological and cultural diversity.

In the late 1970s, the government proposed setting up two dams in this region. For the economically backward tribals, these projects meant not only displacement from their traditional homes and the social disruption that would ensue, but also the destruction of large stretches of forest on which their livelihood and culture depended.

This realization led to stiff opposition from the local tribal community. A movement called 'Save the Forests, Save Humanity' became the spearhead of the opposition to the dam. In the face of the strong opposition from the tribals, the government decided to shelve the project. But this incident was instrumental in sowing the seeds of a strong movement towards tribal self-rule in the region.

The demand for self-rule was validated by the initiative of the people to take on responsibility. After the movement against the dam, the villagers decided to take de facto charge of the forests, which had traditionally been under their management until the government declared them as Protected Forests in the 1950s. Subsequently, the village organized itself into a strong unit. There were discussions on alcoholism, equal status for women in their society, the need to protect and regulate the use of the surrounding forests, etc. As a result of these long and transparent discussions, prohibition became a rule, a forest protection and management system was developed, and an active village-level women's body was created.

In order to sustain such positive changes and for continued development, the village united itself into a body called the *Gram Sabha* (village assembly). The *Gram Sabha*, the main decision-making body in the village, has representation from each family (at least two people—one male and one female) in the village. Decisions are taken unanimously and implemented through unwritten but strong social rules.

Subsequently, the village formed various other working groups to handle different responsibilities. These were also forums for frank, in-depth discussions on various issues ranging from immediate village problems and their solutions, to wildlife conservation.

In order to protect and conserve the forests, the villagers undertook water and soil conservation to arrest excessive run-off and soil erosion. They decided that the forest would not be deliberately set on fire and that they would help to extinguish forest fires to whatever extent possible. The villagers put in place rules about the extraction of natural resources from the forest area. They are vigilant against illegal activities in the forest, and manage to control encroachments in the surrounding areas. Forests are protected from commercial activities, such as the extraction of bamboo by paper mills. The village has managed to get into a Joint Forest Management (JFM) arrangement, convincing the Forest Department to include, for the first time, standing natural forests in this scheme.

The achievements of the village include the protection and regulated use of its 1,800 ha of forest, the creation of study circles and savings schemes, non-violent honey collection and, increasingly, a move towards tribal self-rule, self-employment, gender equality and capacity building. The people of Mendha Lekha are now looking forward to consolidating and sustaining these gains through legal, political as well as social support mechanisms.

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The spirit of the movement and its sustained outcome are best summed up in the words of Devaji Topa, a participant as well as a leader of the 'Save the Forests, Save Humanity' movement. He says, 'Self-rule does not mean freedom to do what one wants; it actually means being able to act responsibly, as an individual and as a society. It also does not mean cutting ourselves off from the larger society. It means being able to assert one's rights while recognizing one's role and responsibility in the society.'

## Campaigns

Peoples' organizations and NGOs have protested through campaigns against policies and actions harmful to the environment. These have sometimes snowballed into mass movements that have left an enduring effect.

Perhaps the most widely known campaign is the Chipko movement, which was an organized to protest against reckless deforestation in the Garhwal Himalayas. Another notable campaign was the Silent Valley campaign against a proposed hydroelectric project in Kerala. These two movements are described here.

### The Chipko Andolan

The Chipko Andolan—the movement to hug trees—was born one morning in March 1973 in the remote hill town of Gopeshwar in Chamoli District. On that day a forest contractor and his men representing a sports goods factory situated in Allahabad reached Gopeshwar to cut 10 ash trees near village Mandal. The villagers courteously told them not to do so but when the contractor persisted, they hit upon the idea of hugging the earmarked trees. The contractor had to return empty-handed.

Some weeks later the same contractor surfaced at Rampur Phata, another village some 80 km away from Gopeshwar, with a fresh allotment from the forest department. As soon as the villagers of Gopeshwar learned of this, they marched to Rampur Phata with drums and songs, gathering more people on the way. A confrontation ensued and the agitators hugged the earmarked trees to foil the contractor once again.

The Chipko movement reached its climax in 1974 when the women of village Reni, some 65 km from Joshimath, got involved in a dramatic way. One day when their men were away in Joshimath protesting against the auction of a forest neighbouring Reni, the contractor arrived at the village to begin felling, taking this as an opportune moment. Undaunted by the number of men or their axes, the women of Reni led by Gaura Devi, a 50-year-old illiterate woman, barred the path to the forest which went through the village. As the women stood there, they sang: 'This forest is our mother's home; we will protect it with all our might.'

The genesis of the Chipko movement has both an ecological and an economic background. The area was the scene of an unprecedented flood in 1970. The tragic aftermath of this flood left a deep impression on the hillfolk and, with it, soon followed the appreciation of the vital ecological role that forests play in their lives. The villagers here had also seen, and resented,

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the manner in which successive governments—beginning with the British—had taken away their forest wealth and turned it into a resource bank for faraway urban markets. Even for minor forest produce and daily necessities like firewood, the local people had been forced to become thieves in their own homeland. Slowly, the entire ecology of the region had changed.

The non-violent, action-oriented Chipko movement greatly helped to unite the people and focus attention on the mismanagement of forest resources. Its Gandhian character brought it considerable sympathy. The expert committee set up by the state government to enquire into whether the Reni forest should be felled found that the Reni women were more correct from a scientific point of view than the forest department. This gave the movement considerable respectability. The committee concluded that because of the highly sensitive nature of the watershed situated deep in the Himalayas, all felling should be banned to allow regeneration. These developments did not make the forest department change its forest policy, but at least in the Chamoli district it was no longer in a position to implement its policy of selling forests to private contractors.

(*Excerpted from*: The Chipko Andolan. 1982. *The State of India's Environment 1982: A Citizens' Report: 42–43.*)

The Silent Valley movement is cited as an outstanding example of people's action at many of the major developmental debates in the country. The campaign raised questions which added a new dimension to the environmental movement in the country. The debate on environmental issues began to criticize more sharply, the economic and industrial growth-oriented model that developing countries had adopted from the industrialized world. During the Silent Valley movement, a new paradigm was articulated: 'Development without destruction', that is, development that can be sustained without compromising the interests of either the environment or the people who depend on it.

### Storm over Silent Valley

Tucked away in the Western Ghats, not far from Ooty, is a small and secluded forest in Kerala known as Silent Valley. The 90 sq km area of the Valley is surrounded by high ridges. It is one of the few places in India with no human habitation. Because Silent Valley has always been difficult to reach, even on foot, it had remained a well preserved forest.

The forest is a storehouse of rare and valuable plants and animals. Cardamom grows wild as do black gram, rice and bean. Several plants have medicinal value, such as the evergreen forest tree—*Hydnocarpus*, whose seeds contain the oil used to treat leprosy. Rare fauna include the Lion-tailed Macaque, Great Indian Hornbill, and Nilgiri Tahr.

This remote valley triggered off one of the fiercest environmental disputes the country has known. It all began with an innocent enough proposal put forward by the Kerala State Electricity Board (KSEB) to build a 130-metres-high dam across the Kuntipuzha river to create a reservoir in Silent Valley, and use the impounded water to generate electricity.

Almost by accident the proposal came to the attention of an official in the central government. Concerned about the protection of India's environment, he asked for the project to be reconsidered. KSEB had started work on it in 1973, but the shortage of funds had delayed

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activity until 1976, when the Board wanted to resume building of the dam. By then a large number of big trees had already been cut.

The issue came up before the then Prime Minister, Indira Gandhi, who had shown more interest in environmental matters than other political leaders before her. She appointed a committee in 1980 to look into whether the Western Ghats as a whole were in danger of damage. The committee pointed out that Silent Valley was the last remaining example of flora and fauna that had evolved to the fullest possible extent in a tropical rainforest, and was an ecosystem undisturbed by human interference. Were the dam to be built, the unique ecosystem might be irretrievably lost.

The committee argued that the 120 MW of power which the dam would help generate were [*sic*] not so important for Kerala. The state had an even bigger hydroelectric project in Idukki, capable of producing more power than the state required. The committee suggested that the dam either be dropped altogether, or if it had to be constructed, it be completed keeping in view certain safeguards. The KSEB, which was anxious to build the dam, readily agreed to the committee's conditions.

Around this time, a group of schoolteachers and others who constituted the Kerala Sastra Sahithya Parishat (KSSP), became involved in the Silent Valley campaign. For many years, this NGO had been writing and publishing science texts in the local language, Malayalam, so that they could be read by a wider group of people, and science could become a tool for social revolution.

Many of KSSP's members were teachers of physics, chemistry and biology. They initially thought it would be a good idea to dam the Silent Valley because it would help produce electricity which would help the state to develop. However, some members such as Professor M.K. Prasad, a botany teacher in a Calicut college, realized that many of Kerala's environmental problems were being caused by the cutting down of trees in the Western Ghats.

KSSP's arguments, based on academic knowledge and reasoning, did not appeal to everybody. The idea of conserving a virgin forest for its flora and fauna seemed irrelevant to the people living near the proposed dam site, and to the inhabitants of the northern districts of Kerala who were suffering due to an acute shortage of electricity and unemployment. The Silent Valley struggle needed to consider not only the ecological and aesthetic value of the Valley but also the socio-economic implications of the project. Keeping these in view, KSSP conducted its own studies which showed why the Valley should not be destroyed and how the same benefits could be obtained in other ways.

KSSP's studies showed that the benefits of producing electricity would go only to a small number of people as two-thirds of Kerala's electricity was consumed by industries which employed only a few thousand people. Another argument was that the submergence of vast areas of forest would destroy the source of energy of a large number of people who depended on firewood to cook.

Scientific bodies of botanists, zoologists and geologists, set up by the Central Government, lent support to KSSP's findings. They backed KSSP's contention that rather than an overall decline in rainfall, deforestation in evergreen forests such as Silent Valley results in an increase in the number of dry days in the monsoon season. This means fewer rainy days but heavier rainfall. In the absence of tree cover, the run-off of soil increases, thereby degrading the land in the area.

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Besides many NGOs in Kerala, the Bombay Natural History Society (BNHS) and other environmental groups in Mumbai and other parts of the country supported KSSP. The support of Dr Salim Ali, eminent ornithologist and personal acquaintance of Mrs Indira Gandhi, was particularly valuable.

KSSP was able to rouse public opinion on the need to save Silent Valley. It had science groups in many villages and its journals and newsletters reached out to a large number of people. KSSP collected signatures of around 600 teachers, prominent citizens and students, and sent a memorandum to the Kerala government. It organized street plays, exhibitions, public debates, and a unique *jatha*—a marathon march—covering nearly 400 villages along a 6,000 km route. Leading intellectuals of Kerala, who were members of KSSP, wrote letters and articles in the press and participated in the public debates.

Because of KSSP's involvement with students, across Kerala students proclaimed their opposition to the project. This was the first time in India that teenagers came out on the streets to protest against the destruction of the environment.

In protest against the Save Silent Valley committees that had mushroomed in the state and in cities such as Chennai and Mumbai, a local committee was formed in Mannarkad to save the project. Their argument focused on the high unemployment rate and the absence of industries in the state, leading to the high rates of outmigration. Industrialization, for which electric power was a must, was seen as the only solution.

The KSEB, on its part, tried to convince people about its stand. In this it was supported by the local people near the dam who were convinced that they would find jobs either directly during construction, or in industries which would subsequently come up in the area. KSSP worked hard to convince the people that the promised benefits were only illusory and were not going to be sustainable.

At this stage, another actor made a dramatic appearance on the stage—the Lion-tailed Macaque, one of the most threatened species of monkeys in the world. It is found only in the southern half of the Western Ghats. The survival of the monkey became an issue contested by the pro- and anti-Silent Valley dam campaigners. Questions were raised about the importance given to the monkey over the benefits that would accrue to humans by building the dam. The debate attracted wide attention, and ultimately a resolution was passed by IUCN (the World Conservation Union) asking the Indian government to conserve more effectively the forests areas of the Western Ghats, including the undisturbed forests of Silent Valley in Kerala.

As the debate grew more heated, both sides began to pressurise the central government which had the final say in approving the proposal. Finally, on the basis of an examination of the costs and benefits, as well as the Prime Minister's support, the scales tilted against the project. The Government of India advised Kerala to abandon the project. Silent Valley was declared a National Park in 1985—which meant that no project could come up in the area.

But no battle in the field of conservation is ever final, and there is no guarantee that the Valley will remain silent for all time to come. There have been faint rumblings in recent years to revive the Silent Valley project. But should the need arise, the people of Kerala, with a well-planned strategy and dogged determination, will undoubtedly be able to achieve what they did in the past.

(Darryl D'Monte. 1991. *Storm over Silent Valley*; M.K. Prasad, The Silent Valley Crusade: A case study.)

## Seeking Legal Redress

A powerful tactic available to individuals and groups concerned about the environment, and one which they have increasingly used in recent years, is **public interest litigation**. Whereas in the past, lawsuits could be filed only by those directly affected or aggrieved by an action, now any individual or group can go to court to seek redress or intervention in actions that are likely to be harmful to public interest.

### Constitution of India on environment

The Constitution of India guarantees every citizen the fundamental right to life and personal liberty. Under Article 48 (A) of the Constitution, the State of India is also required to endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country. The Constitution also makes it the duty of every citizen of India to protect and improve the natural environment, including forests, lakes, rivers and wildlife, and to have compassion for living creatures.

The Right to Life is guaranteed under Article 21, which states that 'No person shall be deprived of his life or personal liberty except according to the procedure established by law.' Over the last two decades, this Article has undergone progressive interpretations to include a number of rights, which interpret the right to life and liberty in the broadest sense.

The Supreme Court in a landmark judgement *(Francis Coralie vs The Administrator, Union Territory of Delhi and others, AIR 1981)*, observed, 'We think that the Right to Life includes the right to live with human dignity and all that goes along with it .... The magnitude and content of the components of this right would depend upon the extent of development of the country, but it must, in any view of the matter, include the right to the basic necessities of life.'

Drawing upon the relevant articles in the Constitution, the Supreme Court now recognizes public interest litigation (PIL) as a constitutional obligation of the courts. PIL is a form of writ petition which can be filed by anybody, even if the person is not directly affected by the perceived injustice. This has enabled environmentally conscious, public-spirited individuals or groups, to have easy access to the highest court of the nation. PILs have become a collaborative effort between the petitioner, the state or public authority, and the court, to redress the breach of a fundamental right.

The Supreme Court has played a proactive role in enhancing the use of PILs. To ensure that expensive and complicated court procedures do not stand in the way of ordinary citizens seeking access to justice, Justice P.N. Bhagwati observed that '... this court will not insist on a regular writ petition and even a letter addressed by a public spirited individual or a social action group acting *pro bono publico* would suffice to ignite the jurisdiction of this court.' Any member of the public can thus move the court for a social cause even through a letter, which would be entertained as a writ petition by the court. Moreover, the fees in the case of a PIL are very nominal.

There are also instances where media reports having been accepted by the courts as adequate for initiating public interest proceedings. In 1994, the High Court of Gujarat initiated action against the Ahmedabad Municipal Corporation and the Ahmedabad Urban Development Agency on the basis of newspaper reports and letters to the editor about the appalling condition of roads in the city after the heavy rains that year. As a result, most of the roads were resurfaced.

Perhaps the first case which directly addressed the conflict between environmental balance and misguided development through such litigation was the Doon Valley case.

### Saving the Doon Valley

Doon Valley (in the state of Uttaranchal) receives plentiful rainfall during the monsoon season. In the valley, the roots of trees helped water to infiltrate the soil, and the limestone beds occurring below the ground acted as large aquifers. The streams originating from this valley used to flow even in the dry season, and provided a perennial supply to the river Yamuna. But uncontrolled limestone quarrying in the region and large-scale deforestation endangered the delicate ecological balance of the area, causing the streams to dry up.

In 1983, the Rural Litigation Entitlement Kendra (RLEK), a voluntary organization based at Dehra Dun, wrote a letter to the Supreme Court about the situation. The Court treated this letter as a writ petition. It directed the District Magistrate of Dehra Dun to stop quarrying operations in the valley, taking note of the fact that the excavation of limestone was adversely affecting the perennial water springs. Further, the Court directed the state to pay RLEK a sum of Rs 10,000 for the service rendered by the organization. The Court in its judgement also reminded citizens of their duty with respect to the environment. The verdict states: 'Preservation of the environment and keeping the ecological balance unaffected is a task which not only Governments, but also every citizen must undertake. It is a social obligation and let us remind every Indian citizen that it is his fundamental duty as enshrined in Article 51–A (g) of the Constitution.'

The story of M.C. Mehta bears out how, with dogged determination and perseverance, a lone individual can effectively use the provision of public interest litigation to secure far-reaching judgements to protect and assert the right of citizens to a clean and healthy environment.

For several long years, starting in 1984, M.C. Mehta battled in the Supreme Court every Friday on behalf of the Taj Mahal. His crusade was to convince the Supreme Court to either move or shut down the iron foundries, glass factories and the Mathura Petroleum Refinery, situated in the vicinity of the Taj, which were enveloping it in sulphurous, acidic smoke.

In 1993, after nearly a decade of court battles, the Supreme Court ordered the closure of 212 small factories surrounding the Taj Mahal because they had not installed pollution control devices. Another 300 factories were given notices to install the necessary devices. The Agra thermal power plant was also shut down. Over the years, nearly 50,000 trees

have been planted around the Taj to provide a green cover against the surrounding pollution.

The Taj campaign was only the beginning; environmental cases have now become Mehta's forte. A few years later, on discovering that some stone quarries in Delhi were responsible for the widespread incidence of the dust-caused cough that had become a major local problem, he succeeded in getting the quarries to close down. In another case, he has secured a Supreme Court order closing 30 polluting factories in the State of West Bengal on the basis of a PIL against the industrial pollution of the river Ganga. Mehta's Ganga case, which reportedly began the cleaning up process of the river, is possibly one of the biggest PILs in India, affecting people, towns and villages, all the way from the northern states of Uttaranchal and UP, to Bihar and West Bengal on the east coast of India. Apart from the 30 units that were hauled up in West Bengal, 157 other factories have been indicted and 300-odd municipalities have been asked to clean up their operations.

There have been a number of other significant cases where Mehta has been given favourable judgements for his petitions. In the Shriram Gas Leakage Case, not only was the unit ordered to close but compensation was also granted for the victims. Acting on another of his PILs in 1991, the Supreme Court directed the Union of India to disseminate information relating to the environment in national and regional languages through the audio-visual media, and also to introduce the environment as a compulsory subject in schools and colleges.

In April 1996, the Goldman Environmental Foundation in the USA honoured Mehta with the seventh annual Goldman environmental prize. Every year the prize goes to six leading environmentalists, one from each of the inhabited continents of the earth. The foundation described Mehta as an 'unstoppable public interest attorney' and 'the most successful environmental litigator in the world.' In 1997, Mehta won the coveted Magsaysay Award.

Perhaps the most significant outcome of Mehta's successes has been that they have created an atmosphere of sympathy for environmental concerns among the judiciary. Article 21 of the Indian Constitution has emerged as an endorsement of the contention that 'right to life' includes the right to a healthy environment. Thanks to Mehta's legal crusade, living free from pollution is emerging as a new civil right.

## Advocacy and Action Support

**Advocacy** is a form of persuasion to influence opinion and policy. A variety of individuals and organizations provide such support to environmental groups working on field and action projects. These include **activists** (a term now used for individuals working in association with others, committed to bringing about radical change through direct action), social scientists, lawyers, consumer groups and journalists. Through media exposure and by assisting with legal support, providing information and training, mobilizing public opinion and influencing the actions of the state, they have lent powerful support to the environmental movement in India.

What follows is a story of how a combination of a sustained media campaign, networking and legal action was able to save a part of a wildlife sanctuary threatened by a substantial reduction in its area by a government denotification order.

### Bid to save a Sanctuary

The Narayan Sarovar Sanctuary in the Kachchh district of Gujarat is characterized by scrub forest typical of a semi-arid ecosystem. It supports a rich variety of vegetation and wildlife, including the highly endangered chinkara (Indian gazelle), pangolin and caracal. In 1993, the state government issued a denotification order reducing the area of the sanctuary to 94 sq km from its original size of 765.79 sq km. This was done in order to permit limestone mining and to set up cement factories in the area.

A press campaign was initiated in 1993 by the Centre for Environment Education's News and Features Service (CEE-NFS), alerting the public about the denotification and its likely impact on the fragile ecosystem of the area.

The news report by CEE-NFS attracted a number of petitions filed by concerned citizens challenging the denotification. CEE-NFS provided legal analysis on the progress of court actions. One of the important strategies of the campaign was to highlight the issue as one requiring immediate attention. The campaign kept the issue alive by keeping track of the political and legal drama that surrounded this clash of commercial, developmental and conservation interests.

It later networked with the Consumer Education and Research Society (CERS—an NGO involved with consumer and environmental protection through the use of media, research and law), providing them with information to back their petition against the denotification. The CERS filed a public interest litigation, challenging the legality of the denotification under Section 48A of the Constitution, which makes it the duty of the state to preserve the environment, and also Section 26A of the Wildlife Act.

CERS succeeded in procuring a stay. In March 1995, the Gujarat High Court cancelled the denotification on the grounds that it ignored the Wildlife Protection Act which requires the approval of the state legislature before the boundaries of a sanctuary can be altered. But on 27 July 1995, the state government approached the legislative assembly and pushed through the denotification. The only concession was that the area denotified was reduced and 444 sq km of the original area was to remain a part of the sanctuary.

Another example of the effective use of media to inform the public and influence policy is the *Down to Earth* magazine brought out by the Delhi-based NGO, Centre for Science and Environment (CSE).

### Down to Earth

In the early 1990s, after the Earth Summit, media coverage of environmental issues increased rapidly. The Centre for Science and Environment (CSE), working to raise awareness about environment and development issues, felt that while these issues did get media coverage,

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the process of reporting was, by and large, event-oriented, and lacked depth and analysis. It also strongly felt that grass-roots efforts were not given adequate coverage.

To fill this gap, the CSE, in May 1992, launched a science and environmental fortnightly magazine named *Down to Earth*. The magazine attempts to cover the latest developments in the fields of environment, science and technology. The range of issues includes those that affect development and sustainability—environment, energy, health, population, forestry, pollution, habitat degradation, wildlife management, water management, traditional knowledge, women, tribal communities, nomads and other marginalized groups, agriculture and animal care, community participation, legal and financial institutions and others.

Since its launch in May 1992, the magazine has covered national as well as international issues related to science, environment and development at the macro-level, and documented innovative efforts at the grass roots. It continues in its mission to bring all this information to the policy makers and the public, quickly and accurately.

## Power of Youth

Students have played key roles in environmental and social campaigns around the world. Young people have enormous potential to work for change. They tend to be more idealistic and enthusiastic than older people. They have bright ideas, energy and courage, and are often better informed than adults. Most young people believe they can change the world. All these characteristics lend them a force which, if harnessed, would make students ideal agents of change. Political parties recognize this power. Many political parties in India have youth wings through which they recruit students and channelize their enormous potential in constructive (and sometimes destructive) activities.

But students do not necessarily need outsiders to channelize their power. There are several instances of students deciding to take on issues which they feel strongly about. It could be an injustice or a problem in their school or college or in their community. For example, the members of the Forest Youth Clubs (FYCs) of Saurashtra achieved what most considered impossible. They opposed the plans of a highly respected and popular religious leader, and won.

### Youth takes on religious might

The Girnar hill, in the Junagadh district of Gujarat, is a popular destination for pilgrims. Covered by a dry deciduous forest, the area is home to a variety of flora and fauna. At the top of the hill is a cluster of temples. Hundreds of devotees visit these temples every day, and leave behind a lot of litter. Members of the Junagadh FYC go up the hill once a week to clear up the mess.

In February 1994, Morari Bapu, a highly respected and popular *kathakar*, planned to hold a ten-day-long *katha* (religious discourse) at Girnar. At least 10,000 followers were expected

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to attend the *katha*. Knowing what a few hundred visitors could do to the environment, the school and college students who were members of the Junagadh FYC feared that such a large influx would create havoc on the natural environment. Rare flowers would be plucked, innumerable insects would be trampled, and animals and birds would be disturbed. Twigs and branches would be indiscriminately cut to light fires for cooking. Cigarette butts not properly extinguished could cause forest fires. Dirt and soap added to the water of the clear streams would affect not only the forest denizens, but also innumerable people downstream.

Concerned about the damage that the prolonged presence of so many people would cause to Girnar, the young members of the FYCs launched an intensive campaign to prevent the *katha* from being held there.

Considering the large following of Morari Bapu all over Gujarat, the FYC of Junagadh decided to seek the support of all the FYCs in the state. Members of the youth clubs organized public meetings at several places, at which they explained the environmental damage that the *katha* would cause. They argued and urged that as no religion encourages or approves of harm being caused to Mother Nature, the *katha* should not be held at Girnar.

FYC members contributed money and bought 10,000 postcards. They set up counters in different parts of Junagadh city and distributed the postcards free of charge with the request that people write to Morari Bapu opposing the venue of the *katha*. At least 8,000 complied. The intense concern and involvement of these young people won them the support of their families, relatives and friends in their campaign. So determined were these youngsters that they refused to yield even to political pressure. Realizing that he faced such overwhelming opposition, Morari Bapu finally gave in. The *katha* at Girnar was called off. The determination of the youth of Saurashtra had won the day.

## INDIVIDUAL ACTION

It is important to recognize that we do not have to be activists to bring about change. Mahatma Gandhi once said:

> I think it is necessary to emphasize this fact: No one need wait for anyone else to adopt a human and enlightened course of action. Men generally hesitate to make a begin-ning if they feel that the objective cannot be achieved in its entirety. It is precisely this attitude of mind that is the greater obstacle to progress—an obstacle that each man, if he only wills it, can clear a way himself and so influence others.

Collective action, in fact, is often seen to have snowballed from individual initiative which provided the leadership.

Students acting individually or collectively can make a difference. They can participate in the work of environmental groups or organize themselves and mobilize others in their own community. They can contribute by:

- writing letters to the editor about local environmental issues and what can be done about them,

- bringing local environmental issues to the attention of the local radio or television station,
- participating in citizen action campaigns,
- setting up an environmental group or 'Eco Club' and recruiting other members,
- lobbying decision makers at the local level, such as the municipal commissioner, corporators, *panchayat* members, and MLAs,
- studying disciplines useful for future careers in voluntary work (other Indian languages, economics, ecology, rural management, social work, public health, natural resource policy, hydrology, anthropology, etc.) and,
- when necessary, by seeking court intervention through public interest litigations.

There are several actions that an individual can take to make a difference. For real effectiveness and wider impact, it is necessary that actions of individuals coalesce into collective action.

## Collective Action

People have long recognized that there is power in numbers. They have organized themselves, formally or informally, temporarily or on a long-term basis, around specific issues or broader ideological considerations, whenever they have felt the need to do so.

When working towards a common goal, there is synergy in working together. By pooling their skills, experience, knowledge and resources, people can usually achieve much more than they would if each one worked alone. Together people can plan, organize and act to demand or create change.

Citizen action is becoming important in influencing environmental and development policy in many parts of the world. It is likely to assume an even greater role in the future.

The stories in this chapter bear out what the famous anthropologist Margaret Mead once said, 'Never doubt that a group of thoughtful, committed individuals can change the world. Indeed it is the only thing that ever did.'

### Working for change

The difference between the success and failure of an action campaign can lie in the organizing techniques. The following are some components of effective local citizen action campaigns.

**Identifying issues and goal(s)**

- Begin with an understanding of overall concerns, and narrow the issues as much as possible.
- Set a specific, simple goal.
- Start with a local objective.

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**Identifying the target audience**

- Find out which part of the larger community has the power to make the required change—a government agency, an industry, an elected official, or college authorities.
- Find out how the target audience works, and what motivates its actions.

**Identifying secondary audience**

- Find out who has influence over the target audience. It could be the press, public opinion, NGOs, boards of governors, stockholders, etc.
- Research the secondary audience. What are their interests, what will get them to lend their assistance?
- Analyse who and what factors are supporting the cause, and which are likely to pose obstacles.

**Tailoring the communication**

- Become well informed about the issues.
- Research and communicate technical information carefully. Sloppy preparation can lead to wrong decisions, damage credibility, and negate efforts.
- Recognize the fact that people join a citizen action campaign or group for many reasons; take these into account.
- Sharply focused and clearly spelt out issues help to enlist the support of a wide range of individuals and groups, cutting across ideological differences.

**Recruiting allies**

- Persuade other groups that want the same changes to join forces.
- Look for groups that can contribute the different skills that might be needed such as legal advice, funding, access to large audiences, etc.
- Identify other groups that have power and influence over the target audience.

**Choosing strategies and tactics**

- Design an overall strategy. Most social change efforts require a series of events, not just one big effort. It is best to combine a number of tactics and communications tied to the goal and strategy and work out the sequence of events.
- Create group identity. Make everyone feel they are participating in a common cause.
- Involve members in planning. People who need to be involved in the campaign will be more willing to carry out the plan if they took part in forming it.
- Choose actions appropriate for membership and budget. Don't expect members to do something they cannot do or cannot afford.
- Choose tactics that will hit the target. Tactics range from quiet deeds that members can do at home to mass political actions that appear on the front pages of newspapers and on the local radio and TV news.

**Tactics that have helped citizen action battles**

- Letters-to-the-editor campaigns (newspapers, magazines).
- Letters to lawmakers at local, state and national levels.

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- Inviting radio, television, newspapers, etc., to cover events, and sending them news releases about the activities.
- Petition drives.
- Endorsing or disclaiming political candidates.
- Organizing marches and rallies.
- Boycotting environmental offenders.
- Setting good examples, such as tree-planting, clean-up drives, etc.
- Workshops to demonstrate alternatives (alternative technologies, agricultural methods, community hygiene methods).
- Performing protest drama, street plays and dance dramas.
- Filing legal actions, such as public interest lawsuits.
- Creating physical barriers (such as tree-hugging in the Chipko movement).
- Theme parades, celebrations.
- Creating music. Spontaneous and catchy songs about environmental or social change can have a powerful effect.

Make sure that your tactics are lawful. If the plans ignore laws about public gatherings, parades, demonstration and boycotts, members may be put at legal risk.

### Evaluating Action Campaigns

Review and consider: Did the campaign work? Did it achieve the goal? Why or why not? Which tactics worked? Why? Which steps failed? Why? How could it have been organized better? What's the next step?

## I QUESTIONS

1. List five actions that you can take or initiate as an individual that would make a difference to your immediate environment at home.
2. List five actions that can be undertaken collectively to tackle environment-related problems or improve the environment in or around each of the following: your college, your hostel, your residential neighbourhood, your community, your town or city.
3. What are some of the common components that you can identify in all the stories described in this chapter? Which of these are essential for the success of any citizen action? Why?
4. How did the KSSP create support for its campaign to save the Silent Valley?
5. Advertisers make effective use of persuasion techniques—an essential component of most campaigns. Review at least five advertisements of products that you find very appealing or convincing or both. Which elements

or techniques of communication used in the ads make them persuasive? Which of these elements or techniques could be effectively used in a citizen action campaign? How?

6. Do you know of any environmental NGOs in your area? What are they working on? If you would like to find out, e-mail envis@ceeindia.org or write to ENVIS, Centre for Environment Education, Thaltej Tekra, Ahmedabad—380054, Gujarat.

## II EXERCISES

1. Think of an environment-related issue in your college (it could be water wastage, unkempt and littered surroundings, unnecessary use of petrol-driven vehicles, or any other). Plan and work out a strategy for a campaign to involve all the students as well as staff in tackling the identified issue. Describe the steps in the campaign, in the planned sequence, and discuss the different tactics/media you would use for this. Develop a systematic strategy document.
2. Review the newspapers for a citizen action campaign that is currently taking place, or has taken place in the recent past, in your area. It need not necessarily be an environmental campaign. Collect all the information you can about it through news reports, organizational literature and interviews with leaders. Based on all the information, do you think the campaign will be (or was, depending on whether it is continuing or is over) successful or not, and why? What are your criteria of success?

## III DISCUSS

The Silent Valley campaign raised questions that added a new dimension to the environmental movement in the country. The debate on environmental issues began to criticize more sharply the economic and industrial growth-oriented model that developing countries had adopted from the industrialized world. During the Silent Valley movement a new paradigm was articulated: 'Development without Destruction', that is, development that can be sustained without compromising the interests of either the environment or the people who depend on it.

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# Appendix 1

# Environmental Laws in India

Environmental laws are generally framed and implemented to protect natural resources. In effect, they may be framed to regulate the production or emission of pollutants, to minimize the effect of pollutants or to regulate production processes that affect the environment. However, it is to be noted that the implications of enforcing environmental laws are also reflected on the economic, political, social and cultural status of a country. Hence, laws as an instrument for enforcing cleaner and efficient practices to safeguard the environment will keep on evolving and being modified as new concepts in environment and development emerge. In a way, laws that are currently evolving in India reflect the role of an informed judiciary that is sensitive to inputs from national and global scientific research, peoples' needs and socio-economic issues.

Given ahead is a list of the various environmental laws in India. It has been arranged chronologically to give some idea of how environmental laws have evolved in our country. We need to keep in mind the political, social and economic status of the country at the time each of these laws was being framed. There could be many challenges in fulfilling the purpose of the law. They could be apparent (inbuilt) flaws existing in the framing of the law; differences in the perception of stakeholders for the need for a particular law; inadequate understanding and awareness of complex environmental issues amongst the public, the judiciary and enforcement agencies; inadequate enforcement of the laws or the implementation machinery, etc. Therefore, it is necessary to view environmental laws from a broader perspective.

## Environmental Legislation, Acts, Rules, Notifications and Amendments

The Constitution of India clearly states that it is the duty of the state to 'protect and improve the environment and to safeguard the forests and wildlife of the country'. It also imposes a duty on every citizen 'to protect and improve the natural environment including forests, lakes, rivers and wildlife'. Reference to the environment has also been made in the Directive Principles

of State Policy as well as the Fundamental Rights. Over the years, the Government of India has promulgated a number of Acts, Rules and Notifications for the preservation and protection of the environment.

## I. Environmental Acts

**The Indian Forest Act (1927)** deals with the setting up and management of reserved, protected and village forests, and controls the movement of forest produce. The Forest Act is administered by forest officers who are authorized to compel the attendance of witnesses and the production of documents [*sic*], to issue search warrants and to take evidence in an inquiry into forest offences. Such evidence is admissible in a magistrate's court.

**The Forest (Conservation) Act (1981)** provides for the protection of and the conservation of the forests.

**The Forest (Conservation) Act (1984)** primarily focuses on prohibiting or regulating non-forest use of forest land.

**The Mines and Minerals (Regulations and Development) Act (1957)** provides for the regulation of prospecting, grant of lease and for mining operations under the control of the central government.

**The Atomic Energy Act (1962)** requires the central government to prevent radiation hazards, guarantee public safety and the safety of workers handling radioactive substances, and ensure the disposal of radioactive wastes.

**The Insecticides Act (1968)** regulates the manufacture and distribution of insecticides through licensing, packaging, labelling and transporting. It also provides for workers' safety during the manufacture and handling of insecticides.

**The Wildlife Protection Act (1972)** and **The Wildlife (Protection) Amendment Act (1991)** provide for the protection of birds and animals and for all matters that are connected to it, whether it be their habitat or the waterhole or the forest that sustains them. These also deal with the setting up and management of sanctuaries and national parks, setting up of the Central Zoos Authority, control of zoos and captive breeding. They also control trade and commerce in wild animals, animal articles and trophies. An amendment to the Act in 1982 introduced provisions permitting the capture and transportation of wild animals for the scientific management of animal populations. Comprehensive amendments to the parent act in 1991 resulted in the insertion of special chapters dealing with the protection of specified plants and the regulation of zoos. The new provisions also recognized the needs of tribals and forest dwellers, and introduced changes to advance their welfare.

**The Water (Prevention and Control of Pollution) Act (1974)** establishes an institutional structure for preventing and abating water pollution. It establishes standards for water quality and effluent. Polluting industries must seek permission to discharge waste into effluent bodies. The Pollution Control Board was constituted under this Act.

**The Air (Prevention and Control of Pollution) Act (1981)** provides for the control and abatement of air pollution. It entrusts the power of enforcing this Act to the Central Pollution Control Board (CPCB).

**The Environment Protection Act (1986)** was formulated in the wake of the Bhopal Gas Tragedy in December 1984. It is considered as an umbrella legislation, which was put forward by the Ministry of Environment and Forests to create comprehensive legal measures for safeguarding the environment, through the framing of rules, notification of standards, notification of environmental laboratories, delegation of powers, identification of agencies for management of hazardous chemicals, setting up of Environmental Protection Councils in the States, etc. The laws have been made so stringent that even an individual or organization not directly affected by the pollution may bring before the authorities a 'Public Interest Litigation'.

**The Factories Act (1948)** and **The Amendment Act (1987)** concern the working environment of the workers. The 1987 amendment empowers the states to appoint site appraisal committees to advise on the initial location of factories using hazardous processes. The occupier of every hazardous unit must disclose to the workers, the factory inspector and the local authority all particulars regarding health hazards at the factory, and the preventive measures taken. These preventive measures must be publicized among the workers and nearby residents. Every occupier must also draw up an emergency disaster control plan, which must be approved by the chief inspector. The Factories Act, after its 1987 amendment, defines 'occupier' as a very senior-level manager. Such a person is held responsible for compliance with the Act's new provisions relating to hazardous processes. Non-compliance exposes the occupier to stiff penalties.

**The Motor Vehicles (Amendment) Act (1989)** states that all hazardous waste must be properly packaged, labelled and transported.

**The National Environmental Tribunal Act (1995)** was passed to award compensation for damages to persons, property and the environment arising from any activity involving hazardous substances. The Act empowers the Centre to establish a national tribunal at New Delhi with powers to entertain applications for compensation, hold an inquiry into each such claim, and make an award determining the compensation to be paid.

**The Energy Conservation Act (2001)** aims at promoting the efficient use of energy and its conservation by adopting energy efficiency measures in various sectors of the economy. Appropriate guidelines for energy conservation, creating consumer awareness and disseminating information on efficient use of energy, certification procedures, etc., have been incorporated into the Act.

**The Biological Diversity Act (2002)** aims at regulating access to biological resources to ensure equitable sharing of benefits arising from their use. The main intent of this legislation is to protect India's rich biodiversity and associated knowledge against their use by foreign individuals and organizations without sharing the benefits arising out of such use, and check bio-piracy. The Act provides for the setting up of a National Biodiversity Authority (NBA), State Biodiversity Boards (SBBs) and Biodiversity Management Committees (BMCs) in local bodies. The NBA and SBB are required to consult BMCs in decisions relating to the use of biological resources/related knowledge within their jurisdiction and the BMCs are to promote conservation, sustainable use and documentation of biodiversity.

## II. Environmental Rules

**The Forest (Conservation) Rules (1981)** provide for the protection of and the conservation of the forests.

**The Forest (Conservation) Rules (1984)** focus primarily on prohibiting or regulating non-forest use of forest land.

**The Environment (Protection) Rules (1986)** lay down procedures for setting standards of emission or discharge of environmental pollutants. Broadly, there are three types of standards: source standards, which require the polluter to restrict at source the emission and discharge of environmental pollutants; product standards, which fix the pollution norms for new manufactured products such as cars; and ambient standards to set maximum pollutants loads in the air, and to guide regulators on the environmental quality that ought to be maintained for healthy living.

**The Hazardous Waste (Management and Handling) Rules (1989)** seek to control the generation, collection, treatment, import storage and handling of hazardous waste.

**The Manufacture, Storage and Import of Hazardous Chemical Rules (1989)** define the terms used in this context, and sets up an authority to inspect, once a year, the industrial activity connected with hazardous chemicals and isolated storage facilities. The Rules spell out the responsibilities of those handling hazardous waste. Under these Rules, a hazardous industry is required to identify major accident hazards, take adequate preventive measures and submit a safety report to the designated authority. An importer of hazardous chemicals must furnish complete product safety information to the competent authority and must transport the imported chemicals in accordance with the Central Motor Vehicle Rules of 1989.

**The Manufacture, Use, Import, Export and Storage of Hazardous Micro-organisms/ Genetically Engineered Organisms or Cells Rules (1989)** were introduced with a view to protect the environment, nature and health, in connection with the application of gene technology and micro-organisms.

**The Hazardous Bio-medical Waste (Management and Handling) Rules (1998)** bind health-care institutions to streamline the process of the proper handling of hospital waste such as segregation, disposal, collection and treatment.

**The Public Liability Insurance Rules (1992)** were drawn up to provide for public liability insurance for the purpose of providing immediate relief to the persons affected by accident while handling any hazardous substance. The Rule obligates every owner to take out an insurance policy covering potential liability from an accident. The 'owner' is defined to mean a person who owns or has control over the handling of any hazardous substance at the time of the accident.

**The Environment (Siting for Industrial Projects) Rules (1996)** provide guidelines for the establishment of new units with certain conditions, and prohibit the setting up of some industries in certain locations.

**The Recycled Plastic Manufacture and Usage Rules (1999)** were notified to regulate the use of plastic carry bags, containers, packaging materials, etc. The Rules prohibit the use of

carry bags or containers made of recycled plastics by vendors for storing, carrying, dispensing or packaging foodstuffs.

**The Ozone Depleting Substances (Regulations) Rules (2000)** regulate production of ODS, use and sale of ODS, export and import, and new investment on ODS.

**The Noise Pollution (Regulations and Control Rules) (2000)** deal with ambient air quality standards in respect of noise for different areas/zones and enforcement of noise pollution control measures. The state government may categorize the areas into industrial, commercial, residential or silence areas/zones for the purpose of implementation of noise standards. The state government shall take measures for [the] abatement of noise including noise emanating from vehicular movements and ensure that the existing noise levels do not exceed the ambient air quality standards specified under these rules. All development authorities, local bodies and other concerned authorities, while planning developmental activity or carrying out functions relating to town and country planning, shall take into consideration all aspects of noise pollution as a parameter of quality of life to avoid noise menace and to achieve the objective of maintaining the ambient air quality standards in respect of noise. An area comprising not less than 100 m around hospitals, educational institutions and courts may be declared as [a] silence area/zone for the purpose of these rules.

## III. ENVIRONMENTAL NOTIFICATIONS

**The Coastal Regulation Zone Notification (1991)** regulates various activities, including construction. It gives some protection to the backwaters and estuaries. This regulation strictly controls development activity including tourism within a strip of 500 m from the seashore, along the entire coast of India. While some activities such as setting up a new industry and the expansion of existing factories are completely prohibited, other types of commercial activity are restricted. Building activity is regulated depending upon the level of urbanization and the ecological sensitivity of the coastal region.

**The Environmental Standards Notification (1993)** gives industry specific standards adopted for effluent discharge and emissions for 24 designated industries.

**The Environmental Impact Assessment (EIA) of Development Projects Notification (1994)** makes it mandatory to get environmental clearance from the MoEF for 30 categories of projects including paper and pulp, dyes, cement, etc. The guidelines set out certain areas to be avoided, i.e. where these 30 industries cannot come up. These include ecologically sensitive areas, coastal areas, major settlements, flood plains, etc. The notification mandates a public hearing and requires the project proponent to submit an EIA report, an environment management plan, details of the public hearing and a project report to the impact assessment agency for clearance, with further review by a committee of experts in certain cases.

**The Dumping and Disposal of Fly Ash Notification (1999)** seeks to protect the environment, conserve topsoil and prevent the dumping and disposal on land of fly ash discharged from coal or lignite-based thermal power plants.

***Some definitions:***
Act—Statute which has been approved by a law-making body; decision which has been approved by Parliament and so becomes a law.
Rules—General order of conduct which says how things should be done.
Notification—A formal announcement; a notice.
Amendment—An alteration or change of something proposed in a Bill or approved in an Act.

**Sources:** *State of the Environment, India, UNEP 2001*; <http://edugreen.teri.res.in>; Shyam Divan and Armin Rosencranz 2002, *Environmental Law and Policy in India*. New Delhi: Oxford University Press.

*(Compiled by Shriji Kurup)*

# Appendix 2

# International Environmental Agreements

There has never been a single overarching blueprint for the evolution of international law and institutions. Environmental conventions and treaties have been adopted in response to a specific environmental challenge at a specific point of time.

The world's governments have adopted several multilateral treaties and conventions on the environment over the past 70 years. From protecting wild animals, to reducing toxic industrial emissions, these legally-binding agreements form the basis for international environmental law.

They also play a vital role in setting international norms and strengthening cooperation amongst countries with differing national interests. This has also in a way helped in the development of national policies and legislation, environmental-risk management and solutions.

## What are Conventions and Protocols?

**Convention** is a term generally used for formal multilateral treaties with a broad number of parties. Conventions are normally open for participation by the international community as a whole, or by a large number of states. Usually the instruments negotiated under the auspices of an international organization are entitled conventions (e.g., The Convention on Biological Diversity of 1992, the United Nations Convention on the Law of the Sea of 1982, the Vienna Convention on the Law of Treaties of 1969). The generic term 'convention' is synonymous with the generic term **treaty**.

The term **protocol** is used for agreements less formal than those entitled 'treaty' or 'convention'. The term could be used to cover the various kinds of instruments. A protocol deals with ancillary matters such as the interpretation of particular clauses of the treaty, those formal clauses not inserted in the treaty, or the regulation of technical matters.

A protocol based on a framework treaty is an instrument with specific substantive obligations that implements the general objectives of a previous framework or umbrella convention. Ratification of the treaty will normally *ipso facto* involve ratification of such a protocol.

# Other Terms

## Adoption

'Adoption' is the formal act by which the form and content of a proposed treaty text are established. As a general rule, the adoption of the text of a treaty takes place through the expression of the consent of the states participating in the treaty-making process.

## Acceptance and Approval

The instruments of 'acceptance' or 'approval' of a treaty have the same legal effect as ratification and consequently express the consent of a state to be bound by a treaty. The practice of certain states is to use 'acceptance' and 'approval' instead of 'ratification' when, at a national level, constitutional law does not require the treaty to be ratified by the head of state.

## Accession

'Accession' is the act whereby a state accepts the offer or the opportunity to become a party to a treaty already negotiated and signed by other states. It has the same legal effect as ratification. Accession usually occurs after the treaty has entered into force.

## Party

By signing a convention, a state expresses, in principle, its intention to become a 'party to the convention'. However, signature does not, in any way, oblige a state to take further action (towards ratification or not).

## Entry into Force

Typically, the provisions of the treaty determine the date on which the treaty enters into force. In cases where multilateral treaties are involved, it is common to provide for a fixed number of states to express their consent for entry into force. Some treaties provide for additional conditions to be satisfied, for example, by specifying that a certain category of states must be among the consenters.

## Ratification

Ratification defines the international act whereby a state indicates its consent to be bound to a treaty if the parties intend to show their consent by such an act.

## Some important international conventions and protocols

| *Convention/ Protocol* | *Objective* | *Contracting parties* | *Secretariat* | *Comments* | *Entry into force* |
|---|---|---|---|---|---|
| Basel Convention | The Basel Convention on Transboundary Movements of Hazardous Wastes and their Disposal was adopted in response to concerns about toxic waste from industrialized countries being dumped in developing countries and countries with economies in transition.<br>Its objectives are<br>to minimize the generation of hazardous wastes in terms of quantity and hazardousness;<br>to dispose of them as close to the source of generation as possible;<br>to reduce the movement of hazardous wastes. | 158 *as of 17 October 2003* | Secretariat of the Basel Convention administered by UNEP www.basel.int | India ratified on 24 June 1992 | Entry into force in 1992 |
| Stockholm Convention on POPs | The Stockholm Convention on Persistent Organic Pollutants (POPs) is a global treaty adopted to protect human health and the environment from POPs chemicals that are highly toxic, persistent, bioaccumulate and move long distances in the environment. The Convention seeks the elimination or restriction of production and use of all intentionally produced POPs (i.e., industrial chemicals and pesticides). It also seeks the continuing minimization and, where feasible, ultimate elimination of the releases of unintentionally produced POPs such as dioxins and furans. | 151 signatories | Interim Secretariat of the Stockholm Convention, UNEP www.pops.int | India signed on 14 May 2002 | Yet to enter into force |

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| *Convention/ Protocol* | *Objective* | *Contracting parties* | *Secretariat* | *Comments* | *Entry into force* |
|---|---|---|---|---|---|
| UNCCD | The United Nations Convention to Combat Desertification in those countries experiencing serious drought and/or desertification, particularly in Africa. The treaty acknowledges that the causes of desertification are many and complex, ranging from international trade patterns to the unsustainable land management practices of local communities. | 190 parties | UNCCD Secretariat Bonn, Germany www.unccd.int | India: entry into force on 17 March 1997 | Entry into force on 26 December 1996 |
| UNFCCC | The United Nations Framework Convention on Climate Change (UNFCCC) is the foundation of global efforts to combat global warming. The objective of this Convention is stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. | 188 parties *as of 17 February 2003* | Climate Change Secretariat Bonn, Germany www.unfccc.int | India: entry into force on 21 March 1994 | Entry into force on 21 March 1994 |
| Ramsar Convention | The Convention on Wetlands, signed in Ramsar, Iran, in 1971, is an intergovernmental treaty which provides the framework for national action and international cooperation for the conservation and wise use of wetlands and their resources. It is known popularly as the 'Ramsar Convention'. | 138 parties *as of September 2003* | Ramsar Convention Bureau, Gland, Switzerland www.ramsar.org | In India it entered into force on 1 February 1982. There are 19 Ramsar sites in India covering a surface area of 648,507 sq km | Entry into force in 1975 |

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| *Convention/ Protocol* | *Objective* | *Contracting parties* | *Secretariat* | *Comments* | *Entry into force* |
|---|---|---|---|---|---|
| Kyoto Protocol | In December 1997, more than 160 nations met in Kyoto, Japan, to negotiate binding limitations on greenhouse gases for the developed nations, pursuant to the objectives of the Framework Convention on Climate Change of 1992. The outcome of the meeting was the Kyoto Protocol, in which the developed nations agreed to limit their greenhouse gas emissions, relative to the levels emitted in 1990. | 120 parties *as of 26 November 2003* | Climate Change Secretariat www.unfccc.int | It shall enter into force when not less than 55 parties to the Convention, which accounted in total for at least 55 per cent of the total carbon dioxide emissions for 1990, have ratified or acceded. The 120 parties that have so far ratified or acceded to the Kyoto Protocol account for 44.2 per cent emissions. | Yet to enter into force |
| Convention on Biological Diversity (CBD) | The three objectives of the CBD are: the conservation of biological diversity, the sustainable use of its components, the fair and equitable sharing of the benefits arising out of the utilization of genetic resources. | 188 parties *as of December 2003* | CBD Secretariat administered by UNEP www.biodiv.org | India ratified on 18 February 1994 | Entry into force on 29 December 1993 |
| CITES | The Convention on International Trade in Endangered Species of Wild Fauna and Flora, CITES, aim is to ensure that international trade in specimens of wild animals and plants does not threaten their survival. Since the trade in wild animals and plants crosses borders between countries, the effort to regulate it requires international cooperation to safeguard certain species from over-exploitation. | 164 parties | CITES secretariat administered by UNEP, www.cites.org | India ratified on 20 July 1976 | Entry into force in July 1995 |

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| *Convention/ Protocol* | *Objective* | *Contracting parties* | *Secretariat* | *Comments* | *Entry into force* |
|---|---|---|---|---|---|
| Montreal Protocol | The Montreal Protocol on Substances That Deplete the Ozone Layer stipulates that the production and consumption of compounds that deplete ozone in the stratosphere, chlorofluorocarbons (CFCs), halons, carbon tetrachloride, and methyl chloroform be phased out.<br><br>The Vienna Convention for the Protection of the Ozone Layer (1985), which outlines states' responsibilities for protecting human health and the environment against the adverse effects of ozone depletion, established the framework under which the Montreal Protocol was negotiated. | 186 parties *as of 12 January 2004* | Ozone Secretariat, UNEP www.unep.org/ozone | India acceded on 19 June 1992 | Entry into force on 1 January 1989 |

*(Compiled by Rajeswari Namagiri)*

# GLOSSARY

**abiotic components:** The non-living components present in the biosphere. These include soil, water, air, and energy from the various sources.

**acid rain:** Acidic fumes from automobile exhaust and industrial combustion combine with water vapour in the atmosphere and fall on the earth as droplets of acid or acid-forming compounds.

**activist:** An individual, often working in association with others, committed to bringing about change through direct action.

**adaptation:** Any genetically controlled structural, physiological, or behavioural characteristic that helps an organism survive and reproduce under a set of environmental conditions.

**advocacy:** A form of persuasion to influence opinion and policy.

**agroforestry:** Plantation on individual farmlands of appropriate tree species chosen for their fuel value.

**appropriate technologies:** Form of technology that is typically fairly simple, locally adaptable, gentle, earth-friendly, resource-efficient, and culturally suitable; that depends mostly on local resources and labour; that can be easily expanded, reduced, moved, and repaired; and whose failure temporarily jeopardizes or inconveniences a fairly small number of people.

**aquaculture:** Farming of plants and animals that live in water, such as fish, shellfish, and algae.

**aquifer:** Porous, water-saturated layers of sand, gravel or bed rock that can yield an economically significant amount of water.

**bioaccumulation/biomagnification:** The process by which certain chemicals in the environment become concentrated as they move from one organism to another in the food chain.

**biodegradable:** Substances that can be readily decomposed by living organisms.

**biodiversity:** Short for biological diversity, it is the totality of genes, species and ecosystems in a region or the world.

**bioenergy:** Short for biomass energy, it includes energy from all plant matter (tree, shrub, crop) and animal dung. Currently biomass energy is characterized by a low efficiency of use and a low quality of life due to the drudgery associated with its gathering and use. However, biomass, unlike other renewables, is a versatile source of energy which can be

converted to 'modern' forms such as liquid and gaseous fuels (biogas, methanol), electricity, and process heat.

**biogas digester:** A device which converts organic matter such as cattle dung or agricultural waste by way of fermentation into a gas which is a 60:40 mixture of methane and carbon dioxide.

**biogeochemical cycle:** Natural processes that recycle nutrients in various chemical forms from the non-living environment, to living organisms, and then back to the non-living environment, e.g., carbon cycle, nitrogen cycle.

**biogeographical region** *or* **bioregion:** A land and water territory whose limits are defined not by political boundaries but by the geographical limits of human communities and ecosystems.

**biological oxygen demand (BOD):** The amount of dissolved oxygen needed by aerobic decomposers to break down the organic materials in a given volume of water at a certain temperature over a specified time period.

**biological resources:** Genetic resources, organisms, or parts thereof, population, or any other biotic component of the ecosystem that have actual or potential value for humanity.

**biomass:** Organic matter produced by plants and other photosynthetic producers; wood, wood wastes and by-products; agricultural and animal wastes; and municipal solid waste that can be burned to provide heat or electricity, or converted to liquid or gaseous biofuels.

**biomass gasifier:** A device in which biomass can be converted to a high-energy combustible gas.

**biomes:** Major ecosystems of the biosphere, they are usually spread over large geographic areas with distinctive climates and are characterized by a dominant vegetation and animal life.

**biosphere:** That part of the earth and its atmosphere that is inhabited by living organisms. The earth's surface and the top layer of the hydrosphere (water layer) have the greatest density of living organisms.

**biosphere reserves:** Areas designated by the Man and Biosphere Programme of UNESCO. These areas are meant to conserve biodiversity while allowing local communities to continue to live within the reserve and follow their traditional lifestyles.

**biota:** Living organisms.

**biotechnology:** Any technological application that uses biological systems, living organ-isms, or derivatives thereof to make or modify products or processes for specific use.

**biotic components:** All life forms present in the biosphere constitute the biotic component.

**blow-out:** The term is used to describe the explosive effect of rising oil or gas at a well that is insufficiently capped or controlled. This can happen accidentally during the exploration and production of oil and natural gas.

**BOD:** *See* **biological oxygen demand.**

**buffer zone:** The region near the border of a protected area in which some human settlement and resource use is allowed.

**by-law (***also* **bye-law):** Law or regulation made by a local, not a central, authority.

**carbon sink:** Land, forests and oceans which absorb carbon dioxide and act as its reservoirs.

**carcinogen:** Chemicals, ionizing radiation, and viruses that cause or promote the development of cancer.

**carnivores:** Meat-eating animals.

**carrying capacity:** The maximum number of individuals of a given species that can be supported by a particular environment.

**catalytic convertor:** A pollution-control device fitted near the exhaust pipe of automobiles to reduce the amount of carbon monoxide and hydrocarbons in the exhaust. The convertor contains a catalyst (a substance that promotes a given chemical reaction without itself being consumed or changed by the reaction) that oxidizes these compounds to carbon dioxide and water as the exhaust passes through. Catalytic convertors need unleaded petrol, which is at present available only in a few cities in India.

**chlorofluorocarbons (CFCs):** Organic compounds made up of atoms of carbon, chlorine, and fluorine.

**city:** Large group of people with a variety of specialized occupations, who live in a specific area and depend on a flow of resources from other areas to meet most of their needs and wants.

**climate change:** According to FCCC usage, a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.

**cogeneration:** The production of two useful forms of energy such as high-temperature heat or steam and electricity from the same fuel source.

**coliforms:** All aerobic and anaerobic, gram-negative, non-spore-forming, rod-shaped bacteria that ferment lactose with gas formation within 48 hours at 35°C.

**commensalism:** The cooperative relationship between organisms where one partner gains from the arrangement while the other is neither benefited nor harmed.

**commercial fuels:** Fuels used commercially include the fossil fuels: oil, coal and natural gas; nuclear energy; and hydro, wind and geothermal power.

**community:** A collection of interacting populations within a specific habitat.

**competition:** The struggle between two or more individuals or populations in a habitat for the same resource.

**compost:** Partially decomposed organic plant and animal matter that can be used as a soil conditioner or fertilizer.

**conservation:** The management of human use of the biosphere so that it may yield the greatest sustainable benefits to present generations, while maintaining its potential to meet the needs of future generations.

**contour:** An imaginary line that connects points of equal value, e.g., the elevation of the land surface above or below some reference value.

**contour bund:** A narrow-based embankment built at intervals across the slope of the land on a level, that is, along the contour. It is an important measure that conserves soil and water in arid and semi-arid areas.

**contour farming:** Ploughing and planting across the changing slope of land rather than in straight lines to help retain water and reduce soil erosion.

**core zone:** The region within a protected area that is 'sacrosanct' and free of all human interference.

**coriolis force:** An apparent force which, due to the rotation of the earth, acts normal to, and to the right of the velocity of a moving particle in the northern hemisphere, the movement of the particle being considered relative to that of the earth.

**covenant:** A formal agreement that is legally binding.

**DDT:** Dichlorodiphenyltrichloroethane, a chlorinated hydrocarbon which has been widely used as a pesticide but is now banned in some countries.

**decomposers:** Organisms that feed by degraded organic matter.

**deforestation:** The removal of trees from forested areas without adequate replanting; converting forest land to other uses such as agriculture.

**demographic transition:** The hypothesis that as countries become industrialized, they first experience a decline in death rates, which is followed by a decline in birth rates.

**desertification:** The conversion of rain-fed cropland or irrigated cropland to desert-like land, with a drop in agricultural productivity of 10 per cent or more.

**dissolved oxygen (DO):** The amount of oxygen gas dissolved in a given volume of water at a particular temperature and pressure.

**domesticated** *or* **cultivated species:** Species in which the evolutionary process has been influenced by humans to meet their own needs.

**drip irrigation:** Also termed as 'trickle irrigation', it involves the slow application of water, drop by drop, as the name signifies, to the root-zone of a crop. In this method, water is used very economically, since losses due to deep percolation and surface evaporation are reduced to the minimum.

**drought:** A condition in which an area does not get enough water because of lower-than-normal precipitation or higher-than-normal temperatures that increase evaporation.

**eco-efficiency:** The production of goods in ways that damage the environment less and use less resources without increasing the cost of the goods.

**ecological niche:** The unique functions, roles and habitat of an organism in an ecosystem.

**ecology:** The study of the interrelationships among micro-organisms, plants and animals, and the interactions between living organisms and their physical environment.

**ecosystem:** A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit with the non-living components including sunlight, air, water, minerals and nutrients. The term implies a partly bounded system, with most interactions inside it. Ecosystems can be small and ephemeral; for example, water-filled holes in trees or rotting logs on a forest floor, or large and long-lived, like forests or lakes (IUCN 1992).

**ecosystem diversity:** Differences among groups of organisms in different physical settings.

**ecotone:** The transitional area between two or more communities.

**effluent:** Liquid waste matter like sewage or industrial discharge.

**endemic species:** A species that is native to a particular region, and found only in that region.

**energy:** The capacity to do work by performing mechanical, physical, chemical or electrical tasks, or to cause a heat transfer between two objects at different temperatures.

**energy conservation:** Reducing or eliminating unnecessary energy use and waste.

**energy efficiency:** The percentage of the total energy input that does useful work and is not converted into low-quality, usually useless heat in an energy-conversion system or process.

**equity:** Fairness in the allocation of and unhindered access to resources so that their benefits are enjoyed by all, especially the weak and the deprived.

**erosion:** The process or group of processes by which loose or consolidated earth materials are dissolved, loosened, or worn away and removed from one place and deposited in another.

**estuary:** The tidal mouth of a river where the salt water of the tide meets the fresh water of the river current. Estuaries are a delicate ecosystem.

**ethnobotany:** The study of how different human societies utilize plants.

**eutrophication:** The enrichment of a body of water with plant nutrients—mostly nitrates and phosphates—from natural erosion and run-off from the surrounding land. This leads to an increase in the growth of organisms to a level where the oxygen supply in the waterbody is depleted.

***ex-situ* conservation:** Preserving life forms away from the natural habitat, in a zoo, botanic garden, aquarium, gene bank or other facility.

**exotic organism:** A species, subspecies, or a lower taxon that occurs outside its natural ranges and dispersal potential.

**extinction:** The death of a species, which occurs when the last individual of the species dies.

**flood:** The rising of a body of water and its overflow on to normally dry land.

**fluorescent light:** Light generated when an electric current excites gaseous mercury atoms; these atoms then emit ultraviolet radiation that causes a chemical called a phosphor to glow.

**fly ash:** Fine particulate, essentially non-combustible material, carried out in a gas stream from a furnace, as opposed to the ash that remains at the bottom.

**food chain:** A series of organisms, each eating or decomposing the previous one.

**food pyramid:** A graphical representation of the food relationships of a community, with producers (plants, etc.) forming the base of the pyramid, and successive levels representing consumers (animals—herbivores and carnivores).

**fossil fuel:** Any substance, such as oil, coal or natural gas, generated by the decay of organic matter over millions of years.

**gene:** The basic unit of hereditary information.

**gene pool:** The collective name for all the genes of a particular population.

**genetic diversity:** The variation of genes within a species.

**genetic engineering:** The technique of altering the genetic make-up of an organism to suit a specific purpose.

**genetically modified organism (GMO):** An organism whose genetic make-up has been modified by genetic engineering.

**geologic fault:** A crack or fracture in the rocks of the earth's crust with an associated movement of the strata on either side. Faulting is caused by plate tectonics, when movements in the crust create stress and tension in the rocks, causing them to stretch and crack.

**geothermal power:** The use of steam produced naturally in deep underground wells to run a turbine and generate electricity.

**germplasm:** Genetic material, especially its specific molecular and chemical constitution, which comprises the physical basis of the inherited qualities of an organism.

**global warming:** The warming of the earth's atmosphere as a result of increases in the concentrations of one or more greenhouse gases.

**greenhouse effect/gases:** A natural effect that traps heat in the atmosphere (troposphere) near the earth's surface. Some of the heat flowing back towards space from the earth's surface is absorbed by water vapour, carbon dioxide, ozone, and several other gases in the atmosphere, and is then radiated back towards the earth's surface. If the atmospheric concentrations of these greenhouse gases rise, the average temperature of the lower atmosphere will gradually increase leading to global warming.

**green revolution:** A popular term for the introduction of scientifically bred or selected varieties of grain that, with high enough inputs of fertilizer and water, can greatly increase crop yields.

**gross domestic product (GDP):** A measure of the total flow of goods and services produced by a country's economy over a specified time period, normally a year. It is the sum of the final outputs of the various sectors of the economy (agriculture, manufacturing, government services, etc.) after subtracting inputs to production. GDP includes only domestic production. **Gross national product (GNP)** includes overseas production.

**groundwater:** Water that sinks into the soil and is stored in slowly flowing and slowly renewed underground reservoirs called aquifers.

**gully plug:** An artificial structure constructed on the gullies (channels) to check the speed of running water, thereby preventing erosion and increasing percolation. It can be made of wood, metal or stones.

**habitat:** A place or site where an organism or population naturally occurs.

**hazard:** Something that can cause injury, disease, economic loss or environmental damage.

**herbicide:** A chemical that kills a plant or inhibits its growth.

**herbivores:** Plant-eating animals.

**homeostasis:** The tendency of an ecosystem to return to a state of equilibrium.

**humus:** The complex mixture of decayed organic matter that is an integral part of healthy soil.

**hydrocarbon:** Organic compound of hydrogen and carbon atoms.

**hydroelectric power (*also* hydropower):** The production of electricity using the force of water falling from a height. The falling water turns huge turbine blades, which in turn create the power to turn a magnet inside an AC generator.

**hydrosphere:** All the water on the earth—liquid water (oceans, lakes, other bodies of surface water, and underground water), frozen water (polar ice caps, icebergs, glaciers ice in soil), and the water vapour in the atmosphere.

**immigration:** The migration of people into a country or area to take up permanent residence.

**incandescent light:** Light generated by the electrical heating of a thin filament; as the filament heats up it gives off light, as in an ordinary light bulb.

**insecticides:** Chemicals that kill insects.

***in-situ* conservation:** Preserving wild plants and animals in their natural habitat, or domesticated plants and animals in their areas of domestication or cultivation, and use.

**invasive:** A species occurring as a result of human activities beyond its accepted normal distribution and which threatens valued environmental, agricultural or personal resources by the damage it causes.

**isotopes:** Two or more forms of a chemical element that have the same number of protons but different mass numbers due to different numbers of neutrons in their nuclei.

**land-use planning:** The process for deciding the best present and future use of each parcel of land in an area.

**least-cost end-use energy planning:** The planning of an energy system that delivers energy services using the least possible energy.

**limiting factor:** An environmental factor which, when in excess or insufficient amounts, inhibits the growth or reproduction of an individual or a population.

**lumens:** A measure of the amount of light produced by a light source. The efficiency of a light source is indicated by the unit lumens per watt—a measure of the relation between the amount of light produced and the amount of energy consumed.

**mass transit:** Buses, trains, trolleys, and other forms of transportation that carry large numbers of people.

**mechanical energy:** The energy of a moving object. It is the moving force behind all machinery.

**metabolism:** The ability of a living cell or organism to capture and transform matter and energy from its environment to supply its needs for survival, growth, and reproduction.

**micro-watershed:** *See* **watershed**.

**monoculture:** The cultivation of a single crop, usually on a large area of land.

**mutagen:** The chemical or form of ionizing radiation that causes inheritable changes (mutations) in the DNA molecules in the genes found in chromosomes.

**mutualism:** An interaction between two species in such a manner that both species are mutually benefited.

***nala* bund:** A permanent structure made of stones and cement to check the flow of water in the low-lying area between two hillocks. The arrested water percolates underground, raising the groundwater level. The bund has a causeway for draining surplus water.

**national park:** A category of protected area designated under the Wildlife (Protection) Act, 1972, e.g., Corbett National Park. It is given a high level of protection, and certain activities such as grazing are not permitted within the national park.

**native species:** A species that normally lives and thrives in a particular ecosystem.

**niche:** *See* **ecological niche**.

**nitrogen fixation:** The conversion of atmospheric nitrogen to nitrogen compounds that can be used by plants.

**noise pollution:** Any unwanted, disturbing or harmful sound that impairs or interferes with hearing, causes stress, hampers concentration and work efficiency or causes accidents.

**non-degradable pollutant:** Material that is not broken down by natural processes.

**non-native species:** A species that has been accidentally or deliberately introduced into an ecosystem from another place, and does not naturally occur there.

**non-renewable resource:** A resource that exists in a fixed amount in various places in the earth's crust and has the potential for renewal only by geological, physical and chemical processes taking place over hundreds of millions to billions of years. Examples include copper, aluminium, coal and oil.

**nuclear energy:** A method of generating electricity in which the heat from radioactive decay is used to boil water; the resulting steam is used to spin a turbine.

**nutrient:** Any food or element an organism needs to take in to live, grow or reproduce.

**occupational hazard:** A condition in an occupation that increases the peril of accident, sickness, or death.

**organic compounds:** Compounds containing carbon atoms combined with each other and with atoms of one or more other elements such as hydrogen, oxygen, nitrogen, sulphur, phosphorous, chlorine, and fluorine.

**organic farming:** Producing crops and livestock naturally by using organic fertilizer (manure, legumes, compost) and natural pest control instead of using commercial inorganic fertilizers and synthetic pesticides and herbicides.

**ozone depletion:** The decrease in the concentration of ozone in the stratosphere.

**parasitism:** Individuals of one species living in or on individuals of other species.

**patent:** The sole right for a term of years to the proceeds of an invention.

**pathogen:** An organism that produces disease.

**perpetual resource:** A resource, such as solar energy, that is virtually inexhaustible on a human timescale.

**pest:** Unwanted organism that directly or indirectly interferes with human activities.

**pesticide:** Any chemical designed to kill or inhibit the growth of an organism that people consider to be undesirable.

**pH:** Numeric value that indicates the relative acidity or alkalinity of a substance on a scale of 0 to 14, with the neutral point at 7. Acid solutions have pH values lower than 7, and basic or alkaline solutions have pH values greater than 7.

**photochemical smog:** *See* **smog**.

**photovoltaic cell:** A device in which the sun's radiant energy (sunlight) is directly converted into electrical energy.

**photovoltaic conversion:** The conversion of the sun's radiant energy into electrical energy, usually through a device called a photovoltaic or solar cell.

**plankton:** Small plant organisms and animal organisms that float in aquatic ecosystems.

**point source:** A single identifiable source that discharges pollutants into the environment.

**pollutants:** Material or heat, the presence of which in undesirable amounts causes the contamination of air, water, or soil. It may be a natural substance, such as phosphate, in excessive quantities, or it may be very small quantities of a synthetic compound, such as dioxin, which is exceedingly toxic.

**pollution:** An undesirable change in the physical, chemical or biological characteristics of air, water, soil or food that can adversely affect the health, survival or activities of humans or other living organisms.

**population:** A group of naturally interbreeding individuals of one species of plant or animal living in a defined area and usually isolated to some degree from similar groups.

**population density:** The number of organisms in a particular population found in a specified area.

**population distribution:** The variation of population density over a particular geographic area.

**population dynamics:** Major abiotic and biotic factors that tend to increase or decrease the population size and the age and sex composition of species.

**poverty line:** A level of income below which people are deemed poor. A global poverty line of $1 per person per day was suggested in 1990 (World Bank 1990). This line facilitates the comparison of how many poor people there are in different countries. But, it is only a

crude estimate because the line does not recognize differences in the buying power of money in different countries, and, more significantly, because it does not recognize other aspects of poverty than the material, or income poverty.

**predation:** The consumption of one animal by another.

***pro bono publico*:** For the public good.

**producers:** These are organisms which make their own food (also called autotrophs).

**protected area:** A geographically defined area which is designated or regulated and managed, to achieve specific conservation objectives, primarily the conservation of wildlife.

**public interest litigation:** Lawsuits filed by any individual or group to seek redress or intervention in actions that are harmful to public interest.

**radioactivity:** The energy released when an atomic nucleus breaks up.

**rainwater harvesting:** The process of collecting and storing rainwater from rooftops, land surfaces or rock catchments using simple techniques.

**recycling:** Collecting and reprocessing a resource so that it can be made into new products.

**renewable energy:** Energy derived from sources which have the potential of being continually replenished, for instance, solar radiation, energy from flowing or falling water, from wind, etc.

**renewable resource:** A resource that theoretically can last indefinitely without reducing the available supply because it is replaced rapidly through natural processes. Examples include trees, grasses, wild animals, fresh surface water in lakes and streams, most groundwater, fresh air and fertile soil. If such a resource is used faster than it is replenished, it can be depleted and converted into a non-renewable resource.

**reserves:** Resources that have been identified and from which a usable mineral can be extracted profitably at present prices with current mining technology.

**run-off:** Fresh water from precipitation and melting ice that flows on the earth's surface into nearby streams, lakes, wetlands, and reservoirs.

**salinization:** The accumulation of salts in soil, which can eventually make the soil unable to support plant growth.

**sanctuary:** A category of protected area designated under the Wildlife (Protection) Act, 1972, e.g., the Shoolpaneshwar Wildlife Sanctuary. Sanctuaries are accorded a lower level of protection than national parks.

**seismic activity:** Activity pertaining to or produced by an earthquake or other vibrations of the earth and its crust.

**sludge:** A mixture of toxic chemicals, infectious agents, and settled solids removed from waste water at a sewage treatment plant.

**smog:** Originally a combination of smoke and fog; but the term is now used to describe other mixtures of pollutants in the atmosphere. Photochemical smog, for example, is a complex mixture of air pollutants produced in the atmosphere by the reaction of hydrocarbons and nitrogen oxides under the influence of sunlight.

**social forestry:** A term used by the National Commission on Agriculture in 1976 to denote tree-raising programmes to supply firewood, fodder, small timber and minor forest produce to rural populations.

**solar cell:** *See* **photovoltaic cell**.

**solar power:** The process of generating electricity from the sun. Heat from the sun can be used to turn water into steam to drive a turbine, or sunlight can be used to power a solar cell.

**solid waste:** Any unwanted or discarded material that is not a liquid or a gas.

**species:** The unit used to classify the millions of life forms on earth.

**species diversity:** The variety of species within a region.

**styrofoam:** A light, resilient foam of polystyrene.

**subsistence economy:** An economic system where the primary goal is to produce enough goods to meet basic survival needs.

**succession:** The process by which ecosystems and their communities evolve over time, altered by, while at the same time altering, their local environment.

**sustainable development:** Development that 'meets the needs of the present without compromising the ability of future generations to meet their own needs'.

**sustainable management:** The use and management of natural resources in a way and at a rate that do not lead to the long-term decline of the resources, thereby maintaining their potential to meet the needs and aspirations of present and future generations.

**sustainable use:** The use of components of biological diversity in a way and at a rate that does not lead to the long-term decline of biological diversity, thereby maintaining its potential to meet the needs and aspirations of present and future generations.

**symbiosis:** The relationship between two or more species that have a mutual interaction.

**synergisms:** The phenomenon in which two factors acting together have a very much greater effect than would be indicated by the sum of their effects separately.

**taxon (*plural* taxa):** Any group of organisms or population considered to be sufficiently distinct from other such groups to be treated as a separate unit.

**thermal inversion:** The layer of dense, cool air trapped under a layer of less dense, warm air. This prevents upward flowing air currents from developing.

**tiger reserve:** A management category designated under Project Tiger and not under the Wildlife (Protection) Act, 1972. A tiger reserve may include within it national parks and sanctuaries. For example, the Ranthambhore Tiger Reserve includes the Ranthambhore National Park and the Kela Devi Sanctuary.

**toxin:** A poisonous substance.

**traditional fuel:** Firewood, dung and agricultural wastes, which are traditionally gathered and not bought. Since it is difficult to monitor, traditional fuel use is not included in most assessments of national, regional or global energy use.

**transpiration:** The process in which water is absorbed by the root systems of a plant, moves up through the plant, passes through pores (stomata) in the leaves, and then evaporates into the atmosphere as water vapour.

**trophic level:** Those organisms in a food chain that are the same number of steps away from the original source of energy.

**tropical rainforest:** A dense forest that is comprised of tall trees, developed in hot, totally frost-free conditions, where rainfall is both abundant and well distributed throughout the year. The forests are dominated by broadleaved evergreen trees, which shed old leaves and grow new leaves continuously.

**turbidity:** A measure of fine suspended matter in liquids.

**United Nations Framework Convention on Climate Change (UNFCCC):** Also called the **Climate Change Convention**, the UNFCCC is the centrepiece of global efforts to combat global warming. It was adopted in June 1992 at the Earth Summit in Rio de Janerio, and entered into force on 21 March 1998. The convention's primary objective is the stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner.

**urban growth:** The rate of growth of an urban population.

**vascular plants:** Plants with a vascular system, i.e., vessels that translocate water and nutrients from roots to stems and leaves, and products of photosynthesis to other parts of the plant. They include seed-bearing plants and ferns or fern-like plants.

**water cycle:** The process by which water travels in a sequence from the air (condensation) to the earth (precipitation) and returns to the atmosphere (evaporation).

**water table:** The upper surface of the zone of saturation, in which all available pores in the soil and rock in the earth's crust are filled with water.

**waterlogging:** The saturation of the soil with irrigation water or excessive precipitation, so that the water table rises close to the surface.

**watershed:** Land area from which water drains towards a common watercourse in a natural basin. The size of a watershed forms a basis for classification into different categories. One such classification is: sub-watershed (100–500 sq km), milli-watershed (10–100 sq km), micro-watershed (1–10 sq km) and mini-watershed (less than 1 sq km). The size helps in computing many parameters, e.g., precipitation received, retained and drained off.

**watershed development:** The process of carrying out a soil and water conservation programme with optimal physical measures within the boundaries of a watershed for enhanced agricultural production.

**watershed management:** Planning development and other activities for an entire water-shed so as to maintain the overall water-flow characteristics of the area.

**wetland:** Land that is covered all or part of the time with salt water or fresh water, excluding streams, lakes, and the open ocean.

**wind farm:** A cluster of wind turbines set up to generate electricity.

**windmill/wind machine:** A device that generates electricity inexpensively, reliably, and in a non-polluting way by capturing the power of the wind. A basic windmill consists of one or more blades, a mechanism to keep the blades rotating at a constant speed in the face of changing winds, and a generator.

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# INDEX


Abiotic components, 23, 36 37
Acid rain, 138
Aesthetic pleasure, and biodi versity, 51 52
Agarwal, Anil, 78
Agrawal, G.D., 97
Agricultural crops, diversity of, 165
Agricultural droughts, 85
Agricultural sector, energy conser vation in, 126; energy ineffi ciency in, 114; use of water in, 78 80
Agriculture, challenge ahead, 170 71; classification of, 154; defin ition of, 153; environment and, 161 67; evolution of, 153; ferti lizers, 161 62; genetic diversity, 164 67; Green Revolution, 157 61; in India in post Independ ence period, 157 61; inputs effi cient use, 168; modern system, 155 56; pesticides, 162 64; pro duction process, 156 57; Save Our Seeds, 168 69; shifting agriculture, 154; site, species and variety selection, 167; soil management, 168; soil pollution due to, 141 42; sustainable agri culture, 167; traditional agricul ture, 154 55
Air pollutants, sources and effects of, 139 40
Air pollution, 138 40, 185 86; level in selected cities, 185
Ali, Salim, 286
Aquaculture, 268 70
Aquatic ecosystem, 24
Aquifer, 77
Arya Vaidya Pharmacy (Coimba tore) Ltd., 67
Ashoka Trust for Research in Ecol ogy and Environment (ATREE), 66
Autecology, 21
Autotrophs, 21

Basel Convention, 306
Bhagwati, P.N., 288
Bhatt, Seema, 47, 55
Bhopal Gas Tragedy, 206, 300
Bichhri village, water pollution in, 91
Biodiversity, aesthetic pleasure and, 52; conservation of, 61 69; definition of, 47; domesticated, 49; ecological services, 52; eco system, 48 49; erosion of, 53 54; ethical reasons, 52; food secu rity and, 51 52; genetic, 47 48; greenhouse gases, and, 221 22; health, healing and, 50 51; hot spots of, 29; importance of, 50 53; of India, 27; loss of, 15, 54 60; micro organism, 49 50; religious and culture purposes, 52 53; survival and, 50
Biodiversity Act, 2002, 61
Biodiversity Conservation Net work (BCN), 66
Biofertilizers, 162
Biogeochemical cycles, 36 37
Biohazard symbol, 144
Biological Diversity Act, 2002, 65, 300
Biomass, 106 07, 115 16, 121; potential of, 121
Biomedical wastes, pollution due to, 143 44
Biopesticides, 164
Biosphere, 20
Biotic components, 21 22, 36 37
Birth rate, 240
Blue Revolution, 268 70
Bombay Natural History Society, 59, 286
Bose, Ashish, 243
Buildings and architecture, energy conservation in, 126 27

Carbon dioxide, 217
Catchment area, 76
Causes of loss of biodiversity, changing agricultural and for estry practices, 56; environ mental pollution, 57 58; global climate change, 58; growing de mands, 60; habitat destruction, 54, 56; international trade, 60; invasion by introduced species, 56 57; loss of traditional know ledge, 58; management systems, 60; nature of legal systems, 58 59; over exploitation for com mercial gain, 57; unplanned development, 54, 56
Central Council for Research in Ayurveda and Siddha (CCRAS), 64

Central Pollution Control Board (CPCB), 100, 268
Centre for Environment Education, 13
Centre for Environment Education's News and Features Service, 290
Centre for Science and Environment, 290
Chemical fertilizers, 162
Chemical pollution, indirect effects of, 90
Chernobyl disaster, 119 20
Cherrapunji, wettest spot on earth, 87
Chhokar, Kiran B., 104, 215
Chipko Andolan, 283 84
Chlorination, 94
Chlorofluorocarbons, 218 19, 231
Cities, 176; migration into, 180
Climate change, Convention, 224 25; Indian concerns and, 223 24, 228 29; study of, 216
Coal, environmental costs of use of, 116 17; source of commercial energy, 110 11
Coastal Regulation Zone Notification (1991), 302
Coasts, ecology of, 31
Commensalism, 43
Commercial energy, 108
Commercial farming, 156
Communities, 20; characteristics of, 41 43; commensalisms, 43; competition, 42; ecological succession, 42; exploitation, 42; interference, 42; living interactions, 42; mutualism, 43; parasitism, 43; predation, 42; species diversity, 41 42; symbiosis, 42 43
Community based conservation, 282 83
Community participation, in biodiversity conservation, 65 66
Conservation and management, of water, 95 100
Conservation strategies, at international level, 67 69; at national level, 61 66; building on indigenous knowledge, 65, 67; community participation in, 65 66; legislation for, 61 64; livelihoods link with, 66
Constitution of India, 74th Amendment Act, 1992, 196; article, 21, 289; article 48, 288, 290; article 51, 287
Consumer Education and Research Society (CERS), 290
Consumers, 21
Consumption, change in patterns of, 255 56; climate change and, 250; deforestation and, 248 49; impact on environment, 248 51; in India, 251; needs, wants and luxuries, 246; over consumption, 245 47; population and environment links, 238 39, 248 51, 257; soil erosion and, 249 50; strategies for change, 255 56; sustainable consumption, 254
Contaminated drinking water, diseases from, 88
Contract farming, 156
Convention Concerning the Protection of the World Cultural and Natural Heritage, 68
Convention on Biological Diversity (1992), 68, 304, 308
Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES), 68, 256, 308
Convention on Wetlands of International Importance, 68
Cook, Earl, 105
Corbett National Park, 57, 62
Crop based livestock rearing systems, 155
Crop genetic diversity, 164
Cultural heritage, loss of, 184

DDT, impact on ecosystem, 45
D'Monte, Darryl, 286
Dal Lake, Srinagar, 37
Daly, Herman, 257
Damodar river, pollution of, 89
Death rate, 240
Deccan Peninsula, ecology of, 30
Decomposers, 22
Degradable pollutants, 137
Desert Development Programme (DPP), 100
Desert region, ecology of, 27
Desertification, 160
Development, economic growth and, 264 66; environment and, 266 69; international initiatives, 272; meaning of, 263 64; quality of life and, 266; sustainable development, 270 72, 274
Disease causing agents, 140
Domestic sector, energy inefficiency in, 114
Domestic use of water, 81 82
Domesticated biodiversity, 49
Doon Valley case, 288
Double cropping, 158
*Down to Earth*, 290 91
Drinking water, availability of, 82 83; quality of, 92 94; quality specifications for, 92 93; treatment, 94
Drought Prone Areas Programme (DPAP), 100
Droughts, 84 87
Dumping and Disposal of Fly Ash Notification (1999), 302

Early marriage, and high birth rate, 241
Eco Development Committee, 66
Eco Development Project, 66
Eco fridge, 234
Ecological footprints, 254 55
Ecological profile, coastline and sea, 31; Deccan Peninsula, 30; desert region, 27; Gangetic Plain, 28; Himalayas, 26 27; islands and wetlands, 30; of India, 24 31; semi arid zone, 27 28; Trans Himalaya region, 24, 26; Western Ghats, 29
Ecological services, 52
Ecology, definition of, 18; levels of organization, 18 21
Ecosystem, abiotic component, 23; aquatic, 24; biochemical processes in, 32 37; biodiversity, 48 49; biological magnification, 37; biotic components, 21 22;

classification of, 23 24; com ponents of, 21 23; concerns for, 37 38; energy flow in, 32 36; food chains, 34 36; greenhouse gases and, 221 22; living components, 21 22, 36 37; non living components, 23, 36 37; nutrient cycling in, 32, 36 37; of India, 24 31; productivity of, 33; terrestrial, 23 24; transitional zones, 31
Ecotones, 31
Ehrlich, Paul, 45
Energy, alternative resources and technologies, 122; biomass, 115 16, 121; coal, 116 17; commer cial energy, 108, 125; conserva tion, 124 29; consumption in development of human society, 104 05; conventional resources, 121; daily per capita consump tion of, 105; dependence on im ported oil, 112; environmental costs of use of, 115 20; flow in ecosystems, 32 36; future sce nario, 120, 129 30; hydroelectri city, 118; inefficiency, 114 15; inequities, 112 14; ladder, 108 09; non commercial energy, 107; non renewable sources, 106; nuclear power, 119 20; oil and natural gas, 117 18; problems, 111 15; renewable sources, 106 08; scenario in India, 108 11; shortage, 111 12; solar energy, 122 23; sources of, 106 08
Energy Conservation Act (2001), 129 30, 300
Energy efficient equipment, 128
Energy efficient products, 128
Energy wasting habits and life styles, need for change in, 129
Environment, advocacy and sup port action, 289 91; agriculture and, 161 67; campaigns for, 283 86, 293 95; citizen action towards, 279 93; climate change, 250 51; collective ac tion for, 293; deforestation, 248 49; development and, 14 15, 263 74; health and, 197 98; individual action for, 292 93; industries affect on, 202 05; in spiring models to protect, 280 83; international agreements on, 304 09; law in India, 298 300; legal redress, 287 89; noti fications, 302; population and consumption links, 238 39, 248 51, 257; role of youth in, 291 92; rules, 301 02; sense of place in, 14, 16 17; soil erosion, 249 50; understanding of, 13 16
Environment (Protection) Act, 1972, 59, 61
Environment (Protection) Act, 1986, 61, 116, 148, 208, 300
Environment (Protection) Rules, (1986), 148, 301
Environment (Siting for Industrial Projects) Rules (1996), 301
Environment (Siting for Industrial Projects) Rules, 1999, 208
Environmental impact assessment (EIA), 206 07
Environmental Impact Assessment (EIA) of Development Projects Notification (1994), 302
Environmental studies, multi disciplinary nature of, 13
Estuaries, disturbances in, 32
Ethical reasons, for biodiversity, 52
Eutrophication, 37 38, 87
Eutrophy, 38
*Everybody Loves a Good Drought*, 86

Factories Act (1948), 300
Famine, 85
Farming areas, expansion, 158
Fertilizers, 161 62
Filtration, 94
Fisheries Act, 1897, 61
Floods, 83 84
Fly ash, 117
Food chains, 34 36; types of, 34 35; understanding of, 35 36
Food security, and biodiversity, 51
Forest Act, 1927, 61
Forest based agriculture, 154
Forest Youth Clubs (FYCs), 291 92
Forests (Conservation) Act, 1980, 61
Forests (Conservation) Rules (1981), 301
Forests (Conservation) Rules (1984), 301
Forests Protection Committee (FPC), 65
Foundation for the Revitaliza tion of Local Health Traditions (FRLHTs), 63
Framework Convention on Cli mate Change (FCCC), 224, 229
French, Hilary F., 151
Fresh water, 76
Fuels, energy efficiency of, 109
Fuller, R. Buckminster, 133
Fungicides, 162

Gandhi, Indira, 14, 285 86
Gandhi, Mahatma, 292
Ganga Action Plan (GAP), 95, 100
Gangetic Plain, ecology of, 28
Genetic biodiversity, 47 48
Genetic diversity, 159, 164 67
Genetic farming, 156
Genetically Modified Organisms (GMOs), 166
Gir ecosystem, 20
Gir Lion Sanctuary Project, Gujarat, 62
Gir National Park, Gujarat, 20
Global warming, 217, 229; con troversies, 225 27; differing contributions, 226 27; ozone depletion and, 228; scientific uncertainty, 225 26; solutions, 227 28
Globe, potent warmers of, 217
Godd, William, 157
Goldemberg, Jose, 133
Green Revolution, in India, 157 61
Greenhouse effect, 216
Greenhouse gases (GHGs), 216 24; agricultural production and, 221 22; carbon monoxide, 219; carbon dioxide, 217; chloro fluorocarbons, 218 19; ecosys tems and biodiversity, 221 22; effects, 220 23; human health and, 223; human sources of, 219 20; hydrofluorocarbons, 219; methane, 217 18; nitrous

oxide, 218; ozone, 219; per fluorocarbons, 219; sea level and, 220 21; species and, 222 23; sulphur hexafluoride, 219; water resources and, 221; weather and, 220
Gross domestic product (GDP), 264
Gross national product (GNP), 264
Groundwater, 75 77, 80 81, 91

Hall, D.O., 112
Halons, 232
Hawkes, Nigel, 133
Hazardous Bio medical Waste (Management and Handling) Rules (1998), 301
Hazardous waste, 204
Hazardous Waste (Management and Handling) Rules (1989), 208, 301
Hazare, Baburao, 271
Herbicides, 162
Herbivores, 21
Heterotrophs, 21
Himalayas, ecology of, 26 27
Housing and Urban Development Corporation (HUDCO), 194
Human society, consumption of energy in development of, 104 05
Hydroelectric power, 110 11
Hydroelectricity, 118
Hydrofluorocarbons, 219
Hydrological cycle, 74
Hydrological droughts, 85
Hydrosphere, 73

Illiteracy, and high birth rate, 241
Imported oil, dependence on, 112
India, biodiversity, 27; biogeo graphic zones of, 25; ecological profile of, 24 31
Indian Council for Agricultural Research, 158
Indian Renewable Energy Devel opment Agency (IREDA), 123
Indian treasure house, 52
Indigenous systems of medicine, 51
Indore Development Authority, 193
Indore Habitat Project, 193
Indus Civilization, 176
Industrial effluents, 142
Industrial sector, use of water in, 80
Industries, causes of soil pollution, 142 43; cleaner production practices, 209; common effluent treatment plant, 206; consum ers responsibility, 211; eco efficiency, 208; eco industrial networking, 209 10; effect on environment, 202 05; energy conservation in, 124 25; en vironment impact assessment, 205 06; environmental impact of product use, 204 05; environ mental management plan, 206; laws and rules, 208; location of, 205; packaging, 204; produc tion process, 204; raw material, 202 03; reducing environmental impact, 205 10
Infant mortality, 240 41
Informal sector and slums, 180 82
Inorganic chemicals, 140 41
Inorganic plant nutrients, 141
Insecticides, 162
Inter governmental Negotiating Committee (INC), 224
Inter governmental Panel on Cli mate Change (IPCC), 215, 220, 228
International Convention on Bio logical Diversity, 61 62
International Organization for Standardization (ISO), 209
International Rice Research Insti tute (IRRI), 159, 161
Irrigated agriculture, 154
Islands, ecology of, 30

Jacob, Sunil, 175
Jacobson, Jodi L., 134
Jagadeesan, Hema, 136
Jain, Shivani, 18
Jambaji, Guru, 59
Jardhari, Vijay, 169
*Johads*, revival of, 96 97
Joint forest management (JFM), 65 66

Kandula, Kalyani, 153, 238, 263
Kaziranga National Park, Assam, 69
Keoladeo National Park, Rajasthan, 57, 59, 69
Kerala Kani Samudaya Kshema Trust, 67
Kerala Sastra Sahithya Parishat (KSSP), 285
Khadpekar, Vivek S., 175
Kumar, Avanish, 73
*Kunds*, in Rajasthan, 98
Kurien, John, 269
Kyoto Protocol, 225, 308

Land use patterns, change in, 159, 189
Livestock based pastoral systems, 155
Livestock genetic diversity, 166

Madras Crocodile Bank, 64
Maganbhai's story, 172 74
Malthus, Thomas, 244
Manas National Park, Assam, 64, 69
Manufacture, Storage and Import of Hazardous Chemical Rules (1989), 301
Manufacture, Use, Import, Export and Storage of Hazardous Micro organisms/Genetically Engineered Organisms or Cells Rules (1989), 301
Markham, A., 223
Mechanized and chemical based farming, 155 56
Medicinal Plants Conservation Areas (MPCAs), 63
Megacity, 178
Mehta, M.C., 288 89
Mendha Lekha village, community based conservation in, 281 83
Menon, Sanskriti, 192
Mesotrophy, 38
Meteorological droughts, 84 85
Methane, 217 18
Metropolis, 178
Micro organism diversity, 49 50
Migration into cities, 180
Miller, Tyler G., 24
Minamata Bay, pollution of, 90

Mining, source of soil pollution, 143
Ministry of Non Conventional Energy Sources (MNES), 123, 125
Mono cultures, 159
Monsoon, 75 77
Montreal Protocol, 1987, 233 34, 309
Motor vehicles, in India, 190
Motor Vehicles (Amendment) Act (1989), 300
Mutualism, 43

Nanda Devi National Park, Uttar Pradesh, 69
Narayan Sarovar Sanctuary, 290
National Agriculture Policy of 2001, India, 228
National Biodiversity Authority (NBA), 61
National Biodiversity Strategy and Action Plan (NBSAP), 62
National Bureau of Animal Genetic Resources (NBAGRs), Karnal, 64
National Bureau of Plant Genetic Resources (NBPGRs), New Delhi, 64
National Environmental Tribunal Act (1995), 300
National Forest Policy of 1988, India, 228
National Lake Conservation Plan (NLCP), 100
National Population Policy, India, 242
National River Conservation Plan (NRCP), 100
National water policy, 99
Natural gas, source of commercial energy, 110 11
Nature, levels of organization in, 18 21
Nitrous oxide, 218
Noise pollution, 144 45, 188
Noise Pollution Regulations and Control Rules (2000), 302
Non commercial energy, 107 11
Non degradable pollutants, 137
Non renewable sources, of energy, 106
Non timber forest produce (NTFP), 66
Nuclear power, 110 11; environ mental costs of use of, 119 20

Occupational health and hazards, 207
Oceans, 99
Oil, source of commercial energy, 110 11
Oil and natural gas, environmental costs of use of, 117 18
Oil spills and accidents, 118
Oligotrophy, 38
Omnivores, 21
Operation Kachhapa, 63
Organic (carbon containing) com pound, 141
Organic fertilizers, 162
Organism, 20; adaptations, 39; at trophic level, 36; features of, 39
Over consumption, 245 47
Overpopulation, 245, 247
Oxygen demanding waste, 140
Ozone, depleting substances, 231 33; depletion of, 229 31; effects of depletion of, 231; Global warming and, 229; hole, 230; India and issue of, 233 34; inter national efforts to save, 233
Ozone Depleting Substances (Regulations) Rule (2000), 302

Padwardhan, Sujit, 192
Pandya, Mamata, 215
*Pani Panchayat* programme, 280 81
*Paryavaran*, 198
Peoples' Biodiversity Registers (PBRs), 65
Perfluorocarbons, 219
Persistent pollutants, 137
Pesticides, 162 64; pollution, 163
Pollutants, 137
Polluter Pays Principle, 210
Pollution, air pollution, 138 40, 185 86; causes of, 137; control, 146 49; due to war, 146; eco friendly traditional practices and, 147 48; education and awareness to control, 149; ef fects of, 137 38; environmental monitoring programmes, 147; industrial contribution of, 204; laws to control, 148; noise pollu tion, 144 45, 188; radiation pol lution, 145 46; soil pollution, 141 44; technological solutions to, 148; types of, 138 46; water pollution, 87 94, 140 41, 186 87
Pollution Control Boards, 208
Pollution Under Control (PUC) certificates, 147
*Pols*, 184
Population, 20; characteristics of, 41; climate change and, 250 51; deforestation and, 250; environ ment and consumption links, 238 39, 248 51, 257; factors responsible for high birth rate, 240 42; growth pattern, 243; impact on environment, 248 51; limits to growth, 244; of India, 243, 251, 260 61; over population, 245; patterns, 240; soil erosion and, 250
Poverty, and high birth rate, 241; line, 251 52
Power sector, energy conservation in, 126; energy inefficiency in, 114
Prasad, M.K., 285 86
Prevention and Control of Water Pollution Act, 208
Prevention, Control and Abate ment of Air Pollution Act, 208
Project Crocodile, Breeding and Management, 62
Project Elephant, 62
Project Tiger, 62 63
Protection and Improvement of the Environment Act, 208
Public Liability Insurance Rules (1992), 301
Purchasing power parity (PPP), 266
Pygmy Hog Conservation Pro gramme (PHCP), 64

Radiation pollution, 145 46
Radioactive substances, 141
Raghunathan, Meena, 202, 215
Rainwater harvesting, 86, 97 98
Ralegan Siddhi, case of sustainable development, 271 72

Ramsar Convention, 68, 307
Ranthambhore National Park, Rajasthan, 59, 69 70
*Rashtriya Barh Ayog* (National Flood Commission), 84
Ravindranath, N.H., 112
Recycled Plastic Manufacture and Usage Rules (1999), 301
Reddy, Amulya K.N., 133
Retreat, residential training facility of TERI, 127 28
Rice field, and methane, 218
Rich and poor, 253
Richharia, 165
River action plans, 95
Rodenticides, 162
Rural Litigation Entitlement Kendra (RLEK), 288

Sainath, P., 86
Salinization, 160
Salunke, Vilasrao, 280 81
Sanjay Gandhi National Park, 52
Sarabhai, Kartikeya V., 13
Sea and coasts, 31
Sedimentation, 94
Self Employed Women's Association (SEWA), 194
Self feeders, 21
Semi arid zone, ecology of, 27 28
Shifting agriculture, 154 55
Ship breaking industry, 267 68
Silent Valley campaign, 283 86
Singh, M.P., 158
Slum networking, in Indore, 193 94
Slums, 180 82
Socio economic droughts, 85
Soil pollution, 141 44
Solar energy, 122 23
Solar radiation, 94
Solid waste, 187
Sons, preference for, 241
Species, 20; biodiversity, 48; characteristics of, 39 40; climate change and, 222 23; diversity, 41 42; ecological niche, 39; evolution and extinction of, 40
Stockholm Convention on POPs, 306
Sugarcane power, 124 25
Sulabh International, 198
Sulphur hexafluoride, 219
Sunderbans, West Bengal, 69
Survival, and biodiversity, 50
Sustainable agriculture, 167
Sustainable development, 270 72, 274
Swaminathan, M.S., 157, 170
Symbiosis, 43
Synecology, 21

Taj Mahal case, 288 89
*Tankas*, in Gujarat, 98
Temples pond, 98
Terrestrial ecosystem, 23 24
Thakore, Sarita, 73
Thermal Luminescent Dosimetry (TLD) badge, 146
Thermodynamics laws, 33
Towns, *see*, Urban places
Traditional agriculture, 154
Trans Himalayan region, ecology of, 24, 26
Transport sector, energy conservation in, 125 26; energy inefficiency in, 114
Tropical Botanic Garden and Research Institute (TBGRI), 67

UN Conference on Environment and Development (UNCED) (Earth Summit), Rio de Janeiro, 15, 68, 224, 272 74, 307
UN Conference on Human Environment, Stockholm, 14
UNFCCC, 307
United Nations Convention on the Law of the Sea (1982), 304
United Nations Development Programme (UNDP), 266
United Nations Environment Programme (UNEP), 62, 146
United Nations Population Fund (UNPF), 244
Urban environment, air pollution, 185 86; issues in, 183; land use change, 189; loss of cultural heritage, 184; noise pollution, 188; pressure on infrastructure, 183; public spaces and assets, 184; resource consumption and waste, 183; solid waste, 187; vegetation, 189; water availability and pollution, 186 87
Urban growth, 177 80; urbanization and, 178 80
Urban Local Bodies (ULBs), 195 96
Urban places/areas, advent and evolution of, 175 76; classification of, 177; environment and health, 197 98; growth, 177 80; informal sector and slums, 180 82; management of, 195 96; migration into cities, 180; planning for, 189 95; transport planning, 191 94; urban environment issues and, 183; urbanization and growth of, 178 80, 182; waste management, 197 98
Urban solid waste, causes of soil pollution, 143
Urban transport planning, 191 94
Urban waste, participatory management of, 197 98
Urbanization, in India, 182 83; urban growth and, 178 80

Vegetation, 189
Vienna Convention on the Law of Treaties (1969), 304
Vivekanandan, V., 269

WWF India, 62
Wars, pollution due to, 146
Waste water treatment, 94
Water, agricultural run off, 90; agricultural use, 78 80; conservation and management of, 95 100; domestic sewage pollution, 88; domestic use, 81 82; drinking water quality, 92 94; droughts, 84 87; floods, 83 84; fresh water, 76; government initiatives for conservation of, 99 100; groundwater pollution, 91 92; groundwater, 76 77, 80; hydrological cycle, 74 75; importance of, 73; in nature, 73 74; industrial effluents, 88 90; industrial use, 80; logging, 80; pollution, 87 94, 140 41, 186 87; problems, 82; quality, 87 94; quality measurement, 93 94;

quantity, 82 87; rainwater harvesting, 97 98; reviving *johads* for conservation of, 96 97; sources of, 75 77, 79; surface water pollution, 87; sustainable future, 100 01; table, 77, 79; treatment of, 94 95; use, 78 82
Water cycle, 74
Water pollutants, 140 41
Water pollution, 87 94, 140 41, 186 87; agricultural run off, 90 91; availability and, 186 87; causes of, 87; domestic sewage pollution, 88; drinking water, 92 93; ground water pollution, 91; industrial effluents, 88 90; surface water pollution, 87; natural contaminants, 91; prevention, 94
Water (Prevention and Control of Pollution) Act (1974), 100
Watershed Management Programme, 76, 86, 100
Western Ghats, ecology of, 29
Wetlands, ecology of, 30; uses and threats, 77
Wildlife (Protection) Act of 1972, 52, 59, 61, 290
Wildlife (Protection) Amendment Act, 1991, 61
Wildlife (Protection) Amendment Act, 2002, 61
Wildlife Protection Society of India, 63
World Charter for Nature, 52
World Heritage Convention, 68 69
World Heritage Site, 69
World Population Day, 244
World Summit on Sustainable Development (WSSD), 273 74
Worldwatch Institute, 133