Chapter 4

Man-made Artefacts and Environment

4.1 Technological Advances and Ever Accelerating Pace of Manufacture of Artefacts

Beehives and bird nests are material artefacts fabricated by animals. But, use of artefacts really started two million years ago, when our hominid ancestors began to use specially fashioned pieces of stone, wood and bone to deal more effectively with their food. This allowed them to greatly expand their range of food items, for now they could dig for tubers as well as wild pigs or cut through the hide of rhinoceros with a facility greater than that of a lion.

However, the number of artefacts employed by hominids remained limited until anatomically modern *Homo sapiens* began to bury their dead and use ornaments some 45 thousand years ago. Since ornaments have no function with respect to the non-human world in the way that a hand axe has, their form and numbers can vary tremendously. Use of ornaments must, from the beginning, have served to enhance social prestige. In that case, prestige would depend on the quality, novelty and

A basket made from bamboo

quantity of ornaments, not in any absolute, but only in a relative sense. That would create possibilities of open-ended competition, under which numbers and variety of artefacts could grow without any limit.

Over the last 2 million years we have been living in a world of three kinds of replicating entities: genes, memes or culturally transmitted patterns of behaviour, and artefacts. Each of these varies in the course of replication. The variation in genes is largely random, the process of natural selection prunes out much of it, favouring the occasional variant that enhances the rate of survival and replication of its carrier. So, new genes spread very slowly. With hominids, variation in memes and artefacts is much more often deliberately directed towards forms, which in some way or other serve the interest of carriers better. The rate of increase as well as change of memes and artefacts can therefore be far more rapid.

There are notable parallels in the evolution of life forms and artefacts. Consider, as an example, means of transport. Living organisms have colonised newer and newer environmental regimes over their evolutionary history. So have transport vehicles. Beginning with logs of wood carrying people across short stretches of water, they now cover all types of terrain on land, fly in the air, dive deep under water, and even move through outer space. In the process their populations have been growing rapidly. Ten thousand years ago there were no transport vehicles on land. Three thousand years ago domesticated oxen and horses and carts had become the most prevalent means of transport on land. At the time there may have been one vehicle for every ten persons in parts of the Old World, and none in the New World. Today motorbikes and automobiles dominate the scene. There is one for every five or so people in a population that has grown a hundredfold. So the population of transport vehicles has grown by a factor of more than 200 in these last few thousand years.

Just as the upper limit of size of living organisms has gone on increasing, the upper limit of size of transport vehicles too has been constantly going up. From a log of less than a cubic meter in size 50,000 years ago, the biggest ships of today, the giant oil tankers are a million times larger in size. Just as the upper limit of the complexity of organisation of living creatures has gone on increasing with time, so has that of means of transport. A log floating over water is a simple, single object only marginally changed from its natural form. An ox-cart has several parts composing it, but one carpenter can fabricate it all by himself using relatively simple tools. A modern airplane has thousands of different parts and only a team of highly trained people can put it together working in a co-ordinated fashion for years. Finally, just as the diversity of life has gone on increasing over evolutionary time, so has that of transport vehicles. A few thousand years ago there were just a few types, dug out canoes, rafts of bamboo or reeds, kayaks of animal skin, simple two-wheeled carts. Today we have a mind-boggling variety not only of canoes, catamarans, kayaks, and animal carts but many designs of sail boats, power boats, submarines, bicycles, motorbikes, cars, trains, balloons, gliders, airplanes and spaceships.

4.2 Impact of Agriculture, Animal Husbandry, Aquaculture

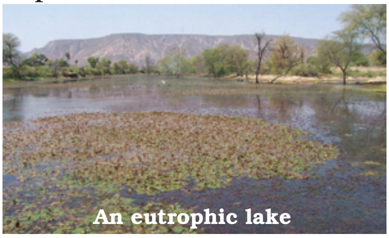
Agriculture is the production of food, feed, fibre and other goods by the systematic growing/harvesting of plants, animals and other life forms. Agriculture plays a key role in human civilisation. Easy accessibility to water for irrigation is one of the major reasons of settlement of almost all the early civilisations on river basins. Until the industrial revolution, agriculture catered as the mode of income for a vast majority of human population. With the high rate of increase of global population, the techniques of agriculture have changed with time to meet the current demand of food. The Green revolution has allowed the world to produce a surplus of food contradicting the prediction of the great economist Thomas Malthus that the earth would not be able to support its increasing population.

The development in agriculture technology has somehow introduced the excessive use of fertilizers and pesticides during cultivation of crops. The uses of these products cause environmental problems by changing the natural environment and producing harmful by-products. There is a long list of environmental impacts of agriculture which starts from encroachment of forest land for agricultural purposes. The use of fertiliser and pesticides in agriculture pollute the air, water and land in different ways. Pesticides generally contain chlorine as one of the constituents. Chlorine, on reaction with hydrocarbons, form organochlorine, which as a group tends to be toxic, persistent and bioaccumulative.

Crop spraying for dusting, pest and weed control cause air pollution by introducing organic phosphates, chlorinated hydrocarbon, arsenic, etc., field burning causes flyash, soot, smokes, etc. The water soluble pesticide and fertilizers are transported in water systems while the insoluble ones get bound to particulates and are carried to the water streams. These pesticides get bio-accumulated at various trophic levels and affect man, animal, soil as well as the aquatic biota. Pesticides being persistent in soil cause adverse damages to the grain quality, thus creating deleterious effects in the soil in long run. The introduction of NPK fertilisers in water systems due to runoff from agricultural fields cause an increase in the nitrate and phosphate levels, leading to eutrophication and death of the water body. Thus the use of these chemicals can be regarded as a necessary evil of the modern agro-technology.

Agriculture has few more environmental impacts like loss of biodiversity due to consolidation of diverse biomass into a few species, depletion of mineral in soil, erosion of top soil etc. The solid waste generated in agriculture which includes waste from vegetable processing, bagasse and pressmud from sugar factories and seeds, rice husks, barn, tea waste, etc., also cause serious management problems.

The rearing of livestock like cows, cattle, pigs and poultry farms etc., have increased manifold with the advent of increased human population pressures. The increasing population of livestock has also created a theft on grassland due to overgrazing. Animal husbandry causes severe water and soil pollution. The waste of animal husbandry is washed off and deposited on soil as wet slurry. This slurry may seep into drains and other water bodies thus deteriorating its quality. The faecal matter consists of phosphate, which in conjunction with nitrate causes serious water pollution leading to eutrophication


An eutrophic lake


Terrace farming

and sometimes massive fish kills. Waste generated by animal husbandry contains several pathogenic bacteria and viruses, which are transmitted to human beings. The feed lot runoff have 1000 ppm BOD, 8000 ppm COD and 700 ppm (approx.) while the values of these parameters for raw sewage is 200 ppm, 400 ppm and 40 ppm respectively. Thus, these wastes cannot be treated with municipal sewage treatment methods.

Aquaculture is a practice of cultivating aquatic animals and plants in managed aquatic environments. It is the farming and husbandry of aquatic organisms like fish, crustaceans, mollusks, seaweed and the production of freshwater and marine pearls. Aquaculture, like any farming activity produces impacts on the environment by use of energy and production of waste. Aquaculture replaces wild habitats and disturbs the ecological balance. Even where aquaculture operations are placed in non-pristine areas, potential exists for exotic (non-native and genetically altered) aquaculture species to escape and adversely affect native species, and spreading diseases. Rearing of wild larvae in aquaculture can decimate the native population of fish, affecting biodiversity. Excessive discharge of organic waste and the use of toxic and bio-accumulative compounds in aquaculture are harmful to people, the fish farmers themselves, and to plants and animals.

Agriculture, aquaculture and animal husbandry collectively cause severe environmental damages, but these practices cannot be stopped due to increasing human population. However, with the use of proper management practices in these fields, the impacts can be surmounted to a great extent. Integrated pest management, where chemical and biological pesticides are used together help check use of toxic chemicals, while ensuring food security through proper crop yield. Similarly, well managed animal husbandry and fish farms have very little environmental impact.

4.3 Impact of Agrochemicals on Environment

Increasing population demands a greater supply of agricultural produce, which in turn increases the use of agrochemicals. The cost paid is, contamination of the environment, which trickles down to affect all forms of life. Pesticides are the most cost-effective means of pest and weed control and so contribute to economic viability. In the last 50 years, the use of pesticides has led to manifold increase in the quantity of food. Today, more than 500 different pesticide formulations are being used in our environment. At present, India is the largest producer of pesticides in Asia and ranks twelfth in the world for the use of pesticides. A vast majority of the population in India (56.7 per cent) is engaged in agriculture and is therefore, exposed to the pesticides. Concern about the environmental impact of repeated pesticide use has prompted research into the environmental fate of these agents, which can be transported from fields to air, land, water bodies and biological systems through food chains.

Pesticides and Human Health

Almost all the pesticides are classified under priority pollutants. In spite of this, there is an indiscriminate use throughout the globe. Acute exposure to high doses of these chemicals is often lethal as per the WHO report. However, at sub-lethal concentrations it is also known to induce carcinogenesis. In a study carried out in South India, farmers, especially those involved in the process of spraying pesticides, reported excessive sweating (36.5 per cent), burning/stinging/itching of eyes (35.7 per cent), dry/sore throat (25.5 per cent), and excessive salivation (14.1 per cent). Non-target pesticide poisoning has been identified as the cause of disease and death in fish, birds, animals and toxicity in humans.

Persistence in Soil

Agrochemicals enter the soil in the process of spraying of crops, as wash-off from treated foliage, or release from granulates applied directly to the soil. Persistence of these chemicals in the soil affect the next cycle of crops, increases the chances of polluting other non-target niches and changes the microbial community profile, thus disturbing the ecosystem. How long the pesticide remains in the soil depends on how strongly it is bound by soil components, the environmental conditions at the time of application, e.g., soil water content, pH etc., and how readily it gets degraded. It is important to analyse the fate of pesticides and their metabolites in the soil to ensure environmental protection.

Contamination of Ground and Surface Water

Surface water contamination by pesticides usually depends on the agricultural season, while ground water contamination has a stronger persistence, which may cause continuous toxicological effects for human health if used for public consumption. The U.S. Environmental Protection Agency (EPA) had reported that normal agricultural use led to the presence of at least 46 pesticides in ground water and 76 in surface water bodies. All pesticides in ground water, and most residues present in surface water enter via the soil. One measure to reduce pesticide inputs into surface waters via both runoff and erosion is the use of vegetated buffer strips along field edges and water bodies; reduce surface runoff and erosion from the field by zero-tillage, mulching, cover crops, contour ploughing/planting etc. To reduce pesticide leaching into ground water, a possible mitigation measure is by increasing the organic matter content of the soil by adopting agronomic practices like incorporation of crop residues, in order to increase sorption of non-ionic pesticides.

Bioremediation Strategies

A large number of bioremediation strategies have been evolved in recent times. Microbial degradation is one of the sustainable options. It primarily involves conversion of the harmful pollutants into harmless substances. However, the process is slow and depends on environmental factors, which may hamper the action of the degradative microbe. Research is on to find out ways to overcome these drawbacks and take the degradation process from the lab to the fields. Other remediation tools include phytoremediation, photodegradation, soil solarisation and use of membrane bioreactors.

An adequate understanding of the problem related to agrochemical pollution requires a multidisciplinary approach to environmental research. It will perhaps then be possible to plan, manage, pursue and integrate the results of the studies that will be necessary for the development of tools and techniques allowing effective environmental pollution control measures.

4.4 Impact of Industry, Mining, Transport

As India's population grows, so does their demand, causing rapid industrialisation. Thousands of chemicals are used in industries each day, many of which cause health hazards when used inappropriately. Industries, apart from noise pollution, also discharge huge amount of pollutants in air, water and soil. Industries have high rates of energy consumption and also require huge amounts of water. Industrial processes produce huge amounts of solid, liquid and gaseous waste. Proper disposal of these wastes is a matter of concern. Industries are generally set up where raw material is easily available. In many cases, this means that the industries are set up away from urban settlements but close to forest agricultural areas. This leads to deforestation and overuse of local resources. Regulatory agencies such as pollution control boards have the mandate to monitor the pollutant emissions of individual industries. There are emission standards set by competent agencies, which give each of the industries appropriate emissions guidelines.

Mining is the extraction of valuable minerals or other geological materials from the earth. Mining can have adverse effects on the surrounding surface and ground water if protection measures are not exercised. The result can be unnaturally high concentrations of some chemical elements, notably arsenic and sulfuric acid, over a significantly large area of surface or subsurface. Acid drainage is one of the most serious environmental impacts associated with mining. Acid is generated at mine sites when minerals are oxidised and sufficient water is present to dissolve the oxides. Mining processes can result in the contamination of streams when dissolved pollutants are discharged to surface waters.

Mining operations also affect ground water quality. Most severe potential impacts of metal extraction perhaps is in quality of water of receiving water bodies thereby


Marble mine

affecting the aquatic ecosystem. The direct impact of mining on forest ecosystems is the removal of vegetation and canopy cover. Indirect impacts include road-building, laying of pipelines and other construction activities which may result in habitat fragmentation and increased access to remote areas. Disposal of large quantities of waste poses tremendous challenges for the mining industry. Modern mining practices aim to lessen environmental impacts from mining, and the ultimate aim is to return the local environment to as close to pristine as is possible.

The transportation sector is becoming increasingly linked to environmental problems. Huge quantities of resources are required for manufacture of the vehicles which is causing depletion of natural resources. Fossil fuels are the primary energy source for transport. Transportation causes high levels of emissions of carbon monoxide, carbon dioxide, nitrogen oxides, unburnt hydrocarbons, particulate matter like lead, heavy metals and volatile organic compounds. These pollutants are released during the combustion of fossil fuels. The only way to lower CO_2 emissions is to use fuels with less carbon content or to reduce fuel consumption by improving engine efficiency. Nitric oxide is usually quickly oxidised in NO_2. NO_x, together with SO_2, play an essential role in acidification. NO_x also reacts with hydrocarbons, producing photochemical smog. CO, which is emitted during the incomplete combustion of fossil fuels, is highly toxic as it binds with the blood haemoglobin, lowering its capacity to carry oxygen. It also has negative impacts on heart, circulation and the nervous system. Transportation can have an adverse impact on biodiversity. Loss of habitat is an inevitable consequence of land use change during the construction of the transport infrastructure. Roads cause fragmentation of habitats, preventing free movement of animals and exchange of genetic material. Noise also has negative effects on wildlife.

Another impact of transportation is an increase in the level of noise. Continuous noise, even if its levels are not too high, increases stress levels by causing annoyance and disrupting communication among people. Continuous exposure to noise can lead to weakening of the auditory system and sleeping disorders.

Alternative fuels in the form of non-crude oil resources are drawing considerable attention as a result of shrinking oil reserves, increasing petroleum costs and the need to reduce emissions of harmful pollutants. The next phase would perhaps see changes in commuting patterns (e.g., car pooling), switch over to use of public transport, a rapid adoption of vehicles with high energy efficiency and a search for alternative fuels.

4.5 Generation and Provision of Energy, Water and other Natural Resources

Energy

We know that almost all the energy that we use comes from the sun directly or indirectly, including the energy that is stored in the food that we consume. We also use solar energy for cooking, heating and generating electric power. The solar energy is the most readily available renewable source of energy. In fact wind and hydro energy are also due to the energy of the sun. Wood is also

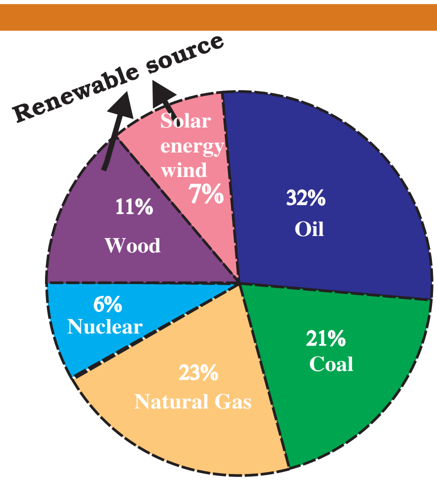


Fig. 4.5a: Energy generation from different sources

used as source of energy, although it is renewable but its replenishment is slow. Other renewable sources of energy are wind, hydro and geothermal. The percentage of total energy generated through renewable sources amounts

A wide disparity is observed in the commercial energy consumption pattern. Industrialised countries with only 25 per cent of global population account for 70 per cent of commercial energy consumption. The US having just 4.6 per cent of the world's population is the largest energy consumer in the world consuming a staggering 24 per cent of the total commercial energy produced. While India, with 16 per cent of the world's population, accounts for just 3 per cent of total energy consumed.

to approximately 18 per cent (Fig. 4.5a). While most of the commercial energy comes from non-renewable fossil fuels like oil, coal, and natural gas, nuclear energy, etc., amounting to nearly 82 per cent of the total energy generated (Fig. 4.5a).

Energy consumption pattern in different sectors is also discussed in 7.2 of Chapter 7.

Inspite of the huge energy production both from renewable and non-renewable sources, about two billion people (i.e., one-third of the world's population) lack access to adequate energy supply forcing them to rely on locally available sources of energy like fuelwood, dung, agricultural residue and charcoal for cooking and heating. The efficiency of these energy sources is much less compared to commercially produced energy. Besides, the users of these energy sources are more prone to pollution and other health hazards. In India, it is estimated that 47 per cent of the total energy consumed by households is from firewood, 17 per cent from animal dung and 12 per cent from crop residues. Thus commercial energy consumption is just 24 per cent.

Whatever be the source of energy, its generation, transportation and ultimate consumption always affects the environment adversely. Combustion of fossil fuels like coal and petroleum to generate electricity release air pollutants like oxides of sulphur and nitrogen, particulates like ash and smoke. They also produce toxic and radioactive flyash as a by-product. Combustion of petrol, diesel and aviation fuel in automobiles, locomotives and aircrafts also produce many of these air pollutants. Mining and extraction of fossil fuels, their refinement and storage cause habitat loss and destruction of flora and fauna besides causing land and air pollution.

There is always some loss in transportation of electricity to distant places from the power plants. Most of these losses are in the form of heat released to the atmosphere. Moreover, whatever is the source of energy and whatever may be its mode of consumption, almost all, sooner or later gets converted into heat in unusable form. This heat in the environment has far-reaching consequences on climate, vegetation, rainfall and living organisms.

The ever increasing global energy consumption is a serious matter of concern since more than 80 per cent of energy is produced from non-renewable fossil fuels. All non-renewable sources will last only for another 200 to 300 years if consumption of energy continues in the same trend. These non-renewable fossil fuels also release huge volumes of emissions leading to pollution. It is high time we switch-over to safer renewable sources such as solar and wind power. With this in mind, huge amounts are being invested to improve R&D so as to overcome the shortcomings encountered with renewable sources of energy.

There is urgent need to adopt energy efficient practices. For example, using fuel efficient *chullah*/ hearth in place of traditional ones, replacing incandescent bulb with compact fluorescent lamp, using fuel efficient automobile engines and proper maintenance of all gadgets, machines, etc.

Water

Water is a renewable resource without which life cannot exist. The availability of water decides many aspects of life such as economic growth, environmental stability, biodiversity conservation, food security and health care. It is estimated that the total water in the world is 1400 million cu. km. Of this, approximately 97 per cent is found in oceans and seas as saline water, 2 per cent is locked up in icecaps and glaciers and less than 1 per cent available to us as fresh water in rivers and lakes and under the ground. The main source of freshwater is through precipitation. Annually, about 430, 000 cu. km. of water evaporates from ocean of which, 40, 000 cu. km. falls on the land as rain and snow which is potable. The rain water seeps through the soil and is stored in spaces between the soil particles, as ground water. Non-judicious use of ground water for domestic, industrial as well as agricultural practices has resulted in lowering of the water table drastically.

Water requirement varies for different purpose. The amount of water required for domestic purposes (drinking, bathing and sanitation), agriculture, industrial processes and energy production varies (Fig. 4.5b).

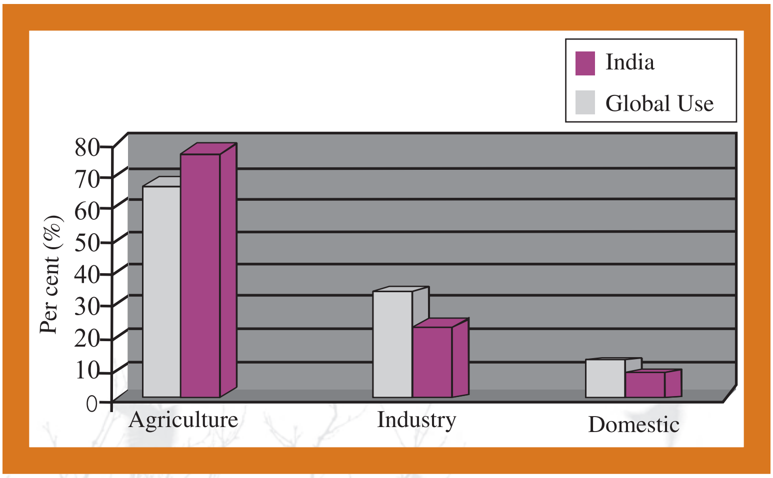


Fig. 4.5b: Water consumption pattern by different sectors

Further, climate, lifestyle, culture, tradition, diet, technology and wealth also decide the water requirement. It is calculated that the average amount of water required by an individual per day is about 100 litres. Adding the needs of agriculture, industry and the energy sector, the recommended minimum annual per capita requirement, according to the World Health Organisation (WHO), is about 1700 cu. m. With the annual supply of fresh water amounting to 40, 000 cu. km. for a world population of 6 billion, about 6, 600 cu. m. of fresh water is theoretically available per person per year which is more than 3 times the recommended amount of WHO. But in reality the situation is different. Many countries in the world are facing water scarcity problem. In 1990, 28 countries, with populations totalling 335 million, experienced water scarcity. It is estimated that by 2025, about 50 countries (including India) with more than 3 billion people will be affected by water scarcity. In India, the per capita water availability figure dropped from 5177 cu. m. in 1951 to 2464 cu. m. in 1990 and further down to 1820 cu. m. in 2001. This per capita water availability figure indicates that people in India should be comfortable with water situation. Yet, we are experiencing water scarcity in many cities, towns and villages. This is also true with other countries whose per capita water availability is above 1700 cu. m. and are yet facing problem of water scarcity.

With the supply of fresh water remaining constant, the problem of increasing scarcity faced by world over, cannot be attributed to decreasing availability. The reasons for scarcity are manifold, one of the reasons being unequal distribution of water in different parts of the world. Concentration of human settlements in particular areas have led to over-extraction of ground water (for irrigation or domestic purpose) in those areas leading to scarcity. Another reason that attribute to scarcity of water is non-percolation of water into the ground. With development, more buildings, pavements, roads cover most of the land because of which the amount of water percolating into the ground has drastically reduced. In hilly regions, also, due to deforestation rain water is not seeped into the slopes and flows quickly down. Changes in rainfall pattern due to global warming are another major concern attributing to scarcity of water.

Besides the above mentioned reasons, pollution of water bodies due to agricultural practices, industries, landfills, sewage disposal etc., has rendered available fresh water non-potable due to contamination.

Other Natural Resources

Forests: Forest is a natural resource that has been ruthlessly exploited for various purposes such as to obtain timber (wood for commercial use: furniture, paper, etc.) and fuelwood; to obtain non-timber products such as food, fibre, honey and medicinal plants, clearing and burning for agriculture, cattle rearing, etc.

The world's forest cover in 2000 was about 3.9 billion hectares, or approximately 0.6 hectare per capita. About 95 per cent of the forest cover was in natural forest and 5 per cent in forest plantations. Deforestation in the 1990s was estimated at 14.6 million hectares per year. Expressed in another way, during the 1990s, the world lost 4.2 per cent of its natural forests but gained 1.8 per cent through expansion of forests. The State of Forest Report, 2001, prepared by the Forest Survey of India (FSI), Dehradun, estimates the country's forest cover at 676,000 sq. km, constituting 20.55 per cent of the geographic area of the country. Of this cover, 417,000 sq. km is dense forest, 259,000 sq. km open forest, and 4490 sq. km mangroves. The report claims that, between 1999 and 2001, the total forest cover increased by 6 per cent.

The effects of such exploitation ranges from landslides and floods affecting people in the forests and on the plains, increases the siltation of rivers, destruction of natural habitat of many flora and fauna, decline of species and biodiversity. Due to deforestation carbon cycle is affected. The amount of carbon stored in terrestrial vegetation and soil organic matter in forests is also declining simultaneously.

With the alarming decline in forest cover and its consequences on the environment, different initiatives have been taken up at the international and national levels towards conservation of forests.

The International Tropical Timber Organisation (ITTO) was set up in 1983 under the United Nations Commission for Trade and Development (UNCTAD). ITTO brings together the producer and consumer countries and is a major platform for issues concerning sustainable forest management. In 1985, Food and Agriculture Organisation (FAO), United Nations Development Programme (UNDP), the World Bank and the World Resources Institute came up with the Tropical Forestry Action Plan, later revamped and renamed as the National Forest Action Programme.

The Kyoto Protocol, Convention on Biological Diversity and the Convention to Combat Desertification are three of the international agreements that have a bearing on forests. The UN Forum on Forests, created in October 2000, is a permanent high-level inter-governmental body with universal membership. The Kyoto Protocol on Climate Change is expected to have a great impact on forest management since it provides provision to a country with forests to earn carbon emission credits, which are tradeble.

Sustainable Forest Management (SFM) is another initiative to fully involve local communities in forest management. By 2000, 149 countries were engaged in nine international initiatives to develop and implement criteria and identify indicators for SFM, covering 85 per cent of the world's forests.

Certification of timber is another approach to halt deforestation and save the remaining forests.

In India, conservation of forests at the community level is done through joint forest management, social forestry and through sacred groves.

Land: Land is yet another natural resource that has been used indiscriminately. The land area covering about 140 million sq. km. occupies less than a third of the earth's surface. Land harbours terrestrial biodiversity, forms the basis for human settlements and transport activities, and acts as the store of basic resources like ground water, minerals and fossil fuels. Studies indicate that one-fourth of all usable land (excluding mountains and deserts) has been degraded to such an extent that its productivity is affected. The main causes of this degradation are attributed to deforestation, fuelwood consumption, overgrazing, agricultural mis-management (planting unsuitable crops, poor crop rotation, poor soil and water management, excessive use of chemicals, frequent use of heavy machinery like tractors, etc.), the establishment of industries and urbanisation. Soil erosion and degradation, which occur due to loss of green cover, strong winds, chemical pollution, etc., have severe effects on the environment, desertification being one resultant effect.

Some of the initiatives undertaken to combat desertification include the support extended in the Earth Summit in 1992 which emphasise action to promote sustainable development at the community level. The UN Convention to Combat Desertification was adopted in 1994 and came into force in 1996. Over 180 countries are now parties to the Convention. Some of the measures undertaken to prevent and restore degraded land include the prevention of soil erosion, sustainable pasture, forest and livestock management; afforestation and reforestation, etc.

Minerals: Minerals are natural resource present in the earth's crust and are not formed from animal or vegetable matter. These minerals have been formed over millions or billions of years and hence they are non-renewable. Minerals are extracted and processed by mining. Minerals that are mined include coal, metals like gold, iron, copper and aluminium and non-metals such as stone, sand and salt. Both underground and surface mining have effects on the environment and renders the workers at great risk physically. The environmental impacts on mining on environment include pollution of aquifers, floods, destruction of vegetation, pollution, lowering of water table, etc.

4.6 Impact of Synthetic Chemicals

Humans have been synthesising chemicals for several thousand years now, beginning with the Bronze Age when oxidised forms of metals were reduced to metallic substances. The whole range of mining and metallurgical activities over the last few millennia have had profound environmental impacts.

A new era of synthetic chemicals started with the development of modern chemistry and synthesis of

a tremendous variety of chemicals, now running into hundreds of thousands. The problem that is currently the most important challenge in this context is that of Persistent Organic Pollutants (POPs). POPs are toxic chemicals that adversely affect human health and the environment around the world. Because they can be transported by wind and water, most POPs generated in one country can affect people and wildlife far from where they are used and released. They persist for long periods of time in the environment and can accumulate and pass from one species to the next through the food chain. To address this global concern, 90 countries and the European Community have come together to sign a global treaty in Stockholm, Sweden, in May 2001. Under the treaty, known as the Stockholm Convention, countries agreed to reduce or eliminate the production, use and/or release of 12 key POPs. The Convention specifies a scientific review process that could lead to the addition of other POPs of global concern.

What are POPs?

Many POPs were widely used during the boom in industrial production after World War II, when thousands of synthetic chemicals were introduced into commercial use. Many of these chemicals proved beneficial in pest and disease control, crop production and industry. These same chemicals, however, have had unforeseen effects on human health and the environment.

The best known POPs include PCBs, DDT, and dioxins. POPs include a range of substances that include: aldrin, chlordane, dichlorodiphenyl trichloroethane (DDT), dieldrin, endrin, heptachlor, hexachlorobenzene, mirex, toxaphene, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (dioxins), and polychlorinated dibenzofurans (furans).

The above mentioned substances have been collectively named as the “Dirty Dozen”. Chemicals that include these substances may be:

(1) Intentionally produced chemicals currently or once used in agriculture, disease control, manufacturing

or industrial processes. Examples include PCBs, which have been useful in a variety of industrial applications (e.g., in electrical transformers and large capacitors, as hydraulic and heat exchange fluids, and as additives to paints and lubricants) and DDT, which is still used in some parts of the world to control mosquitoes that cause malaria.

(2) Unintentionally produced chemicals, such as dioxins, that result from some industrial processes and from combustion (for example, municipal and medical waste incineration and backyard burning of trash).

The DDT Dilemma

DDT is probably the most famous and controversial pesticide ever made. An estimated 4 billion pounds of this inexpensive and historically effective chemical have been produced and applied worldwide since 1940. DDT came into use to protect soldiers from insect-borne diseases such as malaria and typhus during World War II, and it remains a valuable public health tool in parts of the tropics. The heavy use of this highly persistent chemical, however, led to widespread environmental contamination and the accumulation of DDT in humans and wildlife — a phenomenon brought to public attention by Rachel Carson in her 1962 book, Silent Spring. A wealth of scientific laboratory and field data have now confirmed research from the 1960s that suggested, among other effects, that high levels of DDE (a metabolite of DDT) in certain birds of prey caused their eggshells to thin so dramatically they could not produce live offspring.

One bird species especially sensitive to DDE was the North American bald eagle. Public concern about the eagles' decline and the possibility of other long-term harmful effects of DDT exposure to both humans and wildlife prompted the U.S.A. to cancel the registration of DDT in 1972. The bald eagle has since experienced one of the most dramatic species recoveries in human history.

Transboundary Travellers

A major impetus for the Stockholm Convention was the finding of POPs contamination in relatively pristine Arctic regions — thousands of kilometers from any known source. Tracing the movement of most POPs in the environment is complex because these compounds can exist in different phases (e.g., as a gas or attached to airborne particles) and can be exchanged among environmental media. For example, some POPs can be carried for many kilometers when they evaporate from water or land surfaces into the air, or when they adsorb to airborne particles. Then, they can return to earth on particles or in snow, rain, or mist. POPs also travel through oceans, rivers, lakes, and, to a lesser extent, with the help of animal carriers, such as migratory species.

How do POPs Affect People and Wildlife?

Studies have linked POPs exposures to declines, diseases or abnormalities in a number of wildlife species, including certain kinds of fish, birds and mammals. Wildlife can also act as sentinels for human health: abnormalities or declines detected in wildlife populations can sound an early warning bell for people. Behavioural abnormalities and birth defects in fish, birds and mammals in and around the Great Lakes region of U.S.A., for example, led scientists to investigate POPs exposures in human populations.

In people, reproductive, developmental, behavioural, neurologic, endocrine and immunologic adverse health effects have been linked to POPs. People are mainly exposed to POPs through contaminated foods. Less common exposure routes include drinking contaminated water and direct contact with chemicals. In people and other mammals alike, POPs can be transferred through the placenta and breast milk to developing offspring. It should be noted, however, that despite this potential exposure, the known benefits of breast-feeding far outweigh the suspected risks.

In addition, sensitive populations, such as children, the elderly, and those with suppressed immune systems, are typically more susceptible to many kinds of pollutants, including POPs. Because POPs have been linked to reproductive impairments, men and women of child-bearing age may also be at risk.

POPs and the Food Chain

POPs work their way through the food chain by accumulating in the body fat of living organisms and becoming more concentrated as they move from one creature to another. This process is known as "biomagnification". When contaminants found in small amounts at the bottom of the food chain biomagnify, they can pose a significant hazard to predators that feed at the top of the food chain. This means that even small releases of POPs can have significant impacts.

Biomagnification in Action: A 1997 study by the Arctic Monitoring and Assessment Programme, called Arctic Pollution Issues: A State of the Arctic Environment Report, found that caribou in Canada's Northwest Territories had as much as 10 times the levels of PCBs as the lichen on which they grazed; PCB levels in the wolves that fed on the caribou were magnified nearly 60 times as much as the lichen.

4.7 Life Cycle Analysis of Newspaper, Household Consumables, House Construction, Transport, Personal Computer, Cell Phones, etc.

Life cycle analysis is the study of how some object that we (regularly) use makes demands on the environment, from the viewpoint of usage of materials and energy, starting from when it is manufactured, during its life-time of use and finally when it is discarded. Materials can be water, air, metals; energy can be produced from renewable or non-renewable (fossil) sources. Hence, it is important to consider such flows of material when shortages appear. This is a simple (and incomplete) case of water life cycle analysis. Similar life cycle analysis can be attempted with respect to energy and carbondioxide (CO_2) emission, the latter in the present day, an issue of considerable concern due to its contribution to "global warming".

Semi-Conductors: Let us next consider modern materials like semi-conductors (computer chips). Big semi-conductor fabs (fabrication units) require about 40 million litres (ML) of water per day to clean the chip wafers; hence, over a year it requires about 14.6 gigalitre, per year. So the amount needed is about 1 per cent of the water that Hyderabad needs, not much but this can be tricky to handle if there is scarcity of water. We will not discuss other aspects (energy, etc.) here.

Computer vs Papers: Next consider the use of internet. You may have heard that use of computers saves trees as we can create messages and send them without having to use paper (a notorious environmentally destructive material that, for example, has decimated many of the bamboo forests in India and caused considerable pollution of rivers). While this is true to some extent, it hides many critical aspects (especially how it may be more environmentally destructive than paper!). For example, the current personal computers (PC) as the vehicle of Internet use needs to be re-evaluated, as it is not power efficient. It has to be redesigned to be an order of magnitude more efficient or replaced by the use of cellphones for Internet access. Most PCs consume power even when not in use. Energy is at a premium in developing countries. Energy saved reduces costs, allowing expenditures on other priorities. Furthermore, lower energy usage also results in less pollution and less import energy dependence. The cost of setting up additional electric power capacity in India is currently Rs 4 crores per megawatt (MW). For every 120W needed for a PC (a conservative number), an investment of Rs 4800 is required; essentially a tax of Rs 480-960 per annum (assuming interest and maintenance costs are between 10 per cent to 20 per cent) that has to be paid by society.

Next, we need to understand societal cost of information dispersal through traditional paper based mechanisms and digital/computer mechanisms. For illustration, let us consider the use of PCs for reading online newspapers. While intuition suggests that web-browsed news is far superior to the costs of printing and distributing newspapers, some simple calculations reveal otherwise if a life cycle analysis is attempted. We estimate the energy costs of delivering news through the traditional print media as follows (many details such as assumptions for the calculations are omitted).

Energy cost of paper: The energy cost of making newsprint paper is estimated to be 10 giga joule (GJ/tonne); a single A 4 sheet, equivalent then requires 2.75 Wh (Watt-hour, which is equivalent to 3600 joules) for the production of the paper itself (without printing).

Printing: Printing requires about 1.1 Wh per A 4 sheet.

Distribution: Assuming 2 mega joule MJ/tonne-km for road transportation and as much as 200 km travel (much higher than average distance) before the newspaper is delivered, results in 0.025 tonne-km per A 4 sheet, hence the transportation energy spent per A 4 sheet is 0.35 Wh. Adding the three energy costs of paper-production, printing and transportation gives us a total energy cost of approximately 4.2 Wh per A 4 size page.

Next, let us consider online browsing of the same newspaper. Using the 80W power consumption (a very conservative low estimate) for an online PC and an average of five minutes of reading per page results in 6.67 Wh per page. This is more than the per-page energy cost of the print version. The PC browsing energy cost above is actually underestimated, as we have not done any life cycle analysis for the PC as we have done for the newspaper. Of course, the actual value to the user browsing the web may be higher with the additional information provided conveniently through links. Note also that newspapers are extensively recycled in India and also used to wrap goods; hence, its ecological impact could be considered milder when compared to the toxic waste produced in non-recyclable electronics. By way of contrast, consider the energy consumption of small devices such as cellphones that operate at 1 watt or below. Ignoring the inconvenience of reading on the current cellphones (this is being addressed in newer designs such as iPhone), and assuming twice the reading time per page, this results in 0.16 Wh per page, a much lower figure than for PCs. Note that we have not done any life cycle analysis for both the PC as well as for the cellular phone, but the PC would have a much higher cost if life cycle analysis is attempted. A similar analysis comes up with a surprising result that laptops may be better than PCs for casual use with respect to energy consumption.

Another issue is that of permanence of data. While paper has been preserved over multiple centuries in many parts of the world successfully (and without too much need of active energy for the preservation), digital information has yet to achieve anything close to what paper can do. First, PC software and hardware change. What was on an 8 inches floppy of the 1980s can hardly be read by anybody with a new PC of 2007. Next, data preservation requires active energy to move it from one format to the next new generation format and this may need to be done every few years! This cost is so high that many movies shot digitally are being stored in the analog form as a fallback in case the migration does not successfully go through. The US Academy of Motion Picture Arts and Sciences released the results of a yearlong study of digital archiving in the movie business: to store a digital master record of a movie costs about $12,514 a year, versus the $1,059 it costs to keep a conventional film master stored in a saltmine or a limestone mine.

e-waste: We also need careful analysis of when machines need to be replaced to reduce the impact on the environment. We will not discuss this further here but it seems as though a 4-year cycle seems appropriate with respect to avoiding obsolescence of the PC. However, even at this rate, we can see some problems. When we attempt to do a life cycle analysis of a PC, one increasingly important issue is what is to be done with obsolete PCs. Greenpeace estimates that 5 per cent of all waste worldwide is now electrical equipment and this has serious environmental implications. Toxic metals such as lead, mercury, cadmium and other chemicals found in the average machine cause serious problems such as ground water pollution that are difficult to remedy and that, in turn, cause cancer and other diseases. Since India and other developing countries are being used to recycle old PCs from rest of the world (India is estimated to have handled about 0.5 M (million) tonnes of e-waste in 2006), it can devastate the ecology of the countryside unless some regulation is introduced.

In India, we buy about 6M PCs every year. Forrester's 2007 worldwide PC adoption forecast shows that there will be more than a billion PCs in use by the end of 2008 and more than 2 billion by 2015, a 12 per cent compound annual growth rate between 2003 and 2015. Since PCs have been becoming obsolete in about 4-5 years, about 200 million PCs have to be recycled every year. This is a lot of computer chips and these have been manufactured using toxic chemicals. When we think about cellphones, we may have a still difficult problem, since about 500 million cell phones may have to be recycled per year (there are about 2.5 billion cellphones worldwide). Since these come with batteries, disposing such a large number of batteries manufactured with toxic chemicals such as Li, Ni and Cd is also a critical issue. The energy cost of retiring PCs and cellphones is another aspect for study.

Housing: An important aspect of current Indian economy is the construction of houses as this provides jobs for so many. However, this can be problematic too. In the past, "middle-class" families would stay in compact houses but the size of an average house or apartment has been generally increasing amongst the current "middle-class" (along with increased consumption of petrol and other products of a richer lifestyle). We have seen a similar situation with cars where the smaller Maruti car is no longer considered desirable for the current "middle-class". Generally, the aspirations of the "middle-class" have been increasing worldwide and India is no exception. Larger houses or apartments mean larger quantities of steel, cement, and other building materials, water, etc. Also, India is moving from a large proportion of low energy rural construction (which is close to "zero" energy base) to the high energy urban construction (high energy intensity based construction).

We do not have sufficient data about how housing impacts India ecologically. But in the US, the Union of Concerned Scientists ranks housing third among destructive human enterprises, just after transportation and agriculture; forty per cent of all the raw materials that are used in construction and building an average house adds seven tons of waste to the landfill. Construction materials can be classified as having very high embedded energy: (> 100 GJ/tonne such as aluminium: 200-250; stainless steel: 50-100), high: (5-100 GJ/tonne such as steel: 30-60, glass: 12-25, cement: 5-8, plasterboard: 8-10), medium: (0.5-5GJ/tonne such as lime: 3-5, clay bricks and tiles: 1-4; gypsum plaster: 1-4; concrete precast: 0.1-5, concrete in situ: 0.8-1.5; concrete block 0.8-3.5); and low: (<0.5 GJ/tonne such as sand, flyash and blast furnace slag). (These data have been taken from a study by Mili Majumdar at The Energy and Resources Institute, TERI.) Depending on the house constructed, we can use these numbers to compute the energy intensity of a house. As mentioned earlier, "modern" construction in India is mostly turning towards use of materials with high embedded energy. If we consciously build a small number of very well designed square feet of housing, we can reduce the impact in the most direct way. However, commercial interests usually push in the opposite direction.

In addition, we need to factor the cost of transportation of the materials. In India, road (truck) costs about 2.85MJ/tonne/km whereas for railways it is 0.9MJ/tonne/km. By waterways it is 0.09MJ/tonne/km (by sea) and 0.9MJ/tonne/km (inland). Again, rail transport is much cheaper ecologically than road or air but the latter two are becoming more common.

Conclusion

So it can be concluded that ecological design approach would take the most inherently simple solution, which can be implemented. This is almost always the cheapest.

But this, in general, goes against the "modern" tradition. There has been some speculation that post-industrial societies consume less but data from a study "Driving the Human Ecological Footprint," by Dietz, Rosa and York (2007) published in "Frontiers in Ecology and the Environment" shows the opposite. The study concluded that increases in population and affluence ("lifestyle") worldwide, is likely to expand human impact on the environment by over one-third; to counter these driving forces would require increase in the efficiency of resource use of about 2 per cent per year. India currently has an ecological footprint much less than the world average but future development has to be managed carefully to lessen the impact on the environment as India is already close to its carrying capacity.