Ecotoxicology and Climate
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3.4 Chemicals in Tropical and Arid Regions

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3.4.1 INTRODUCTION

The aim of this work on ecotoxicology and climate is to review the relevance of the principles of ecotoxicology enunciated in the Seventies, based on experience gained largely in temperate regions, to the situation posed by environmental chemicals in regions which have tropical, semi-tropical, arid, and arctic climates. The conceptual approach to the present study leans heavily on the following premises:

(i) temperature and humidity are two of the well-known climatic factors that significantly affect the nature and course of chemical reactions and, in particular, the interactions between the biotic and abiotic components of the environment;

(ii) the ecosystems associated with the tropical, arid, and subpolar climates may present facets of sensitivity and response to the impact of chemicals that are quite different or distinct from those encountered in temperate climates.

While the basis for (i) is embodied in well-established laws of physical chemistry, the validity of the underlying assumption made in statement (ii) requires more quantifiable information on ecotoxic effects as well as pathways of chemicals in the diverse ecosystems sustained or surviving under tropical, arid, or subpolar conditions. Production and consumption data on chemicals, trends of their use pattern, and existing levels of chemical pollution in these regions are urgently needed to make meaningful estimates of exposures. Compilation of the relevant data is by no means an easy task. First of all, one has to face the paucity of reliable information pertaining to the use of chemicals in the traditional or even the newly emerging community of nations in the tropical and arid zones. The information presented in this section is mostly derived from sources in India and some of the tropical and semi-tropical countries of Asia and Latin America. It is hoped that this overview, made within the above constraints, will at least help in identifying the gaps for further studies.

The data from the Indian subcontinent are also useful for constructing models for comparative effects, given the fact that there are regions in India with widely varying temperate, tropical, and arid types of climates.

3.4.2 SOME ECOTOXIC PROBLEMS OF GLOBAL DIMENSION AND CLIMATIC CHANGES

Many ecotoxic problems transcend geographical and climatic barriers. Indeed the transfrontier migration of some chemicals has been implicated in a few ecotoxic problems of a global dimension. That chemicals do not recognize geographic frontiers is evident from the adverse effects of acid rain in the subpolar regions of North America and subarctic Europe as a result of the export of the oxides of sulphur and nitrogen from their origin elsewhere in a temperate region. Two other problems of atmospheric chemistry of current concern are the depletion of ozone and the accumulation of carbon dioxide, both connected with the fast rate of deforestation in the last three decades. The complexity of the underlying chemical reactions is yet to be resolved. Human intervention unquestionably accounts largely for the extensive denudation of tropical forests (Lanly and Clement, 1979). There are no reliable estimates of the consequent emission of particulate matter including carbon and hydrocarbons of the isoprene and terpene class. The adverse effects of these pollutants on the associated ecosystems and on the heat balance of the atmospheric boundary layer are not adequately understood (Bolin *et al.*, 1983).

The 1960s witnessed the rapid emergence of a group of oil-producing countries in the arid zone of the Middle East, which have exerted a powerful influence on the world economy. The large tankers carrying crude oil from the loading harbours of the Persian Gulf or the Red Sea to the Near and Far East, Europe, and America leave their trails of oil pollution causing potential damage to the coastal ecosystems of Asia, Africa, and Australasia. From a survey of the tar pollution of beaches in the Indian Ocean, the South China Sea, and South Pacific Ocean, Oostdam (1984) calculates the standing crop of beach tar in the Indian Ocean to be in the region of $1.5\text{–}0.5 \times 10^6$kg. Buried tar in the coastal tracts of this region is relatively uncommon. Quantitatively, this amount of tar may not stand comparison with the high levels of tar pollution noticed in the coastal zones of the Atlantic, the North Sea, and the Mediterranean.

3.4.3 ECOTOXICOLOGICAL IMPACT OF DEVELOPMENT

Nearly two-thirds of the human race, belonging to what is loosely called the Less Developed or Developing countries, inhabit the tropical and semi-tropical regions of Latin America, Africa, and Asia. The urban clusters in some of these countries are predictably growing at an unprecedented rate, and urban pollution due to the sheer size of the population is likely to touch new heights in the very near future. The developmental strategies adopted by these countries involve the extensive use of chemicals in agriculture, production and storage of food and consumer goods and in meeting the increasing demands from industry, transport, and defence sectors. Very often the environmental impact of such activities has not been assessed prior to their initiation. As a result, acute and chronic problems of environmental pollution have begun to appear in many urban pockets in these countries.

One may refer in this context to the data published by WHO as part of the Global Environment Monitoring System (GEMS). This programme, jointly undertaken with the United Nations Environment Programme, assesses the quality of air, water, and food by measuring the levels of certain chemical pollutants and monitoring the levels of cadmium in human blood and the kidney cortex, or of pesticides in human breast milk. The values of sulphur dioxide and suspended particulate matter in selected samples of the ambient air of Calcutta, Bombay, Sao Paulo, Rio de Janeiro, Seoul, Bogota, and Santiago for the period 1973–1978 (not all cities covered for all the years) indicate levels of air pollution not less than corresponding values in London, Tokyo, or Los Angeles before they were reduced by control measures (WHO, 1976; 1978; 1980; 1983).

3.4.3.1 Modernization of Agriculture

The four major inputs needed for increasing farm productivity in the tropical countries are better seed, water, chemical fertilizers, and pest control chemicals, and these factors do affect the environment adversely (FAO, 1981). Another important feature is that, besides supporting massive human populations, most of the regions where there is a food deficit are also those where vector-borne plant and animal diseases are endemic. This has led to an increasing dependence on chemical weapons to combat pests. Programmes for control of vector-borne diseases in the public health sector are not usually linked to the measures mounted for controlling pests in the agricultural sector. Some of the ecotoxicological problems witnessed in these countries could as well be part of the sequelae of lack of co-ordination and possibly the indiscriminate use of pesticides (Bull, 1982). Although environmental control of vectors of malaria and filariasis has shown promising results (Rajagopalan and Das, 1984), integrated pest management with less reliance solely on chemical control is yet to be accepted as part of the strategy for pest control (Krishna Murti, 1982a).

3.4.3.2 Way of Living and Exposure Levels

Dramatic changes ensuing from development can be seen in the way of living, customs, and food habits. With better means of communication, ways of life associated with urbanization are rapidly introduced into the remotest rural or tribal settlements. The use by rural communities in India of an ever increasing number of consumer products made by modern industrial production techniques is testimony of the influence of the urban way of life on rural people. Exposure to chemicals by human and non-human receptors as a result of shift in life-style in the tropical rural sector remains to be evaluated.

3.4.4 TRENDS AND PATTERNS OF INDUSTRIALIZATION

In the five-year period 1970–75, the rate of growth of industrial activity in some of the developing countries was substantial, although their combined contribution to global output of manufactured goods was only 7%. This figure is expected to rise to between 17.5 and 25% (UNIDO, 1979). Of the total industrial output of the 1970s in the developing countries, Latin America accounted for 50%, Asia and the Middle East together for 33%, and Africa for 13%. The forecast for 2000 AD, however, indicates a shift in favour of Asia. In general, trends of industrialization are evident in 38 countries for which statistics are available, and ten at least out of 38 are in the tropical belt and can be ranked as industrialized on the criterion that manufacturing industries contribute more than 30% of the Gross Domestic Product of the country (UNIDO, 1974).

Certain features characterize the pattern of industrialization in the developing countries:

(a) Industrial activity seems to become concentrated in existing urban settlements and significantly adds to overcrowding and shortage of water, housing, and facilities for sanitary disposal of wastes.
(b) Industrial activity has stimulated the expansion of the unorganized sector, i.e. the sector which relies more on labour-intensive techniques. Thus 40–70% of the urban labour force is employed by this sector.
(c) Industrial growth has attracted hazard-prone technology, which in many instances is banned in the countries from where the technology is imported.
(d) Industrial activity has permeated into regions which have hitherto been free from environmental pollution.

3.4.5 TYPES OF CHEMICALS

Whether they concern the agricultural, the industrial, or the public health sector, development programmes involve the use of a variety of chemicals of which the degree of exposure in the ecosystems differs considerably. Developing countries have adopted diverse measures for generating a continuous supply of industrial chemicals and agrochemicals; these include both indigenous as well as imported production. The control of the use of these chemicals is more often dictated by economic considerations than by a rational consideration of their effect on human health or the ecosystem. In the oil-producing countries of the arid zone of the Middle East, there has been a very rapid expansion of the industries related to refining of crude oil and production of petrochemicals. Most of these industrial units are located in the proximity of harbours of the Persian Gulf. Salt-free water is recovered from seawater, and the waste water of the wells and refineries is discharged back into the Gulf. Marine pollution has begun to surface in this region and the National Institute of Oceanography, Goa, India, has given high priority to related studies in the Arabian Sea and the Indian Ocean.

In the following sections, brief accounts are given of the diversity of chemicals that are diffused into the environment.

3.4.5.1 Chemical Pollution in Energy Production and Domestic Fuel Usage

Coal continues to be the main source of solid fuel for energy and also the raw material for the production of coke used in steel mills. Crude petroleum oil forms the source of liquid fuel. Natural gas is also being used widely in some of the developing countries. Extraction and processing of fossil fuels lead to the release of many by-products, such as phenols, thiocyanates, cyanides, sulphides, ammonia, and others. Approximately 2 tonnes of coking coal are used for the production of 1 tonne ingot steel and with rapid expansion of the steel industry there has been concurrent output of coal and coke.

Carbonization is carried out in coke oven batteries, and the volatile matter containing several fractions of aromatic substances is scrubbed and recovered in by-product recovery systems. The coke oven by-product recovery plant may require 375 litres of water per tonne of steel produced (Parhad *et al.*, 1982). Amounts of waste water to be disposed of are, in low-temperature carbonization, 0.15 m^3/tonne coal processed; in high-temperature carbonization 0.3–0.4 m^3/tonne; and in gasification 1 m^3/tonne. Waste water effluents emerging from the above processes contains inorganics including free ammonia and fixed ammonia, and organics including phenols and pyridines.

The low-temperature carbonization process is increasingly adopted to produce smokeless domestic coke for use in urban and rural areas using low-grade coal, including lignite; this produces pollutants in the form of waste ammoniacal liquor. Approximately 1 kg of phenol is released into the environment for every tonne of fossil fuel processed.

The producer gas process completely gasifies solid fuels. The fuel is heated by the self-generated gases resulting in significant loss of its volatile matter. The coke residue is converted to products of incomplete combustion, principally carbon monoxide. Using 1 m^3 of water for scrubbing the oil, tar, and other aromatic compounds from 10 m^3 of gas, waste water discharged from a modestly sized producer gas plant can be around 100–110 m^3 per day.

Coke oven plant effluents can be divided into three categories:

(i) coke quenching water
(ii) benzol plant water
(iii) ammoniacal liquor

A typical effluent from a coal carbonization plant may contain anywhere up to 130 compounds at concentrations more than 1 mg/litre (Pearse and Punt, 1973). The concentration of pollutants in coke oven wastes depends upon the coking coal used for the process. Increasing coking temperatures as a general rule results in a lower phenol and higher cyanide concentration (Kostenbader and Flecksteiner, 1969; Vaidyeswaran, 1977). The general composition of waste water from a metallurgical coke plant is given in Table 3.4.1, and that of a producer gas plant and domestic coking plant (LTC) is given in Table 3.4.2

Table 3.4.1 Characteristics of waste waters from by-product recovery plant in a steel plant. From Parhad *et al.* (1982)

	Cooling, scrubbing, and refining process waste	Ammonia still waste	Phenols tar distillation waste	Combined waste from by-product recovery
	(All values except pH are in mg/l)			
pH	9–9.5	8.6–9.1	7.0–8.9	8.6–9.0
Dissolved solids	165–400	200–700	60–1000	125–800
Suspended solids	20–730	25–200	20–330	50–500
Total alkalinity CaCo$_3$	1200–3000	200–1000	250–1000	450–2000
Phenols	1000–1600	40–170	10–200	100–1000
NH$_3$-N	100–2700	40–380	100–370	100–1500
Cyanides (CN-)	10–50	1–20	10–20	10–60
Chemical oxygen demand (COD)	800–2000	600–1000	480–1350	800–1800
Biological oxygen demand (BOD)	300–750	350–1300	170–440	200–1100

Table 3.4.2 Characteristics of waste water from producer gas and LTC plants. From Parhad *et al.* (1982)

	Producer Gas	LTC
	(All values except pH are in mg/litre)	
pH	8.2–8.7	9–10.0
Suspended solids	320–680	800
Phenols	870–2020	4692–7360
Ammonia (free)	230	6000–9000
COD	4200–16 640	22 400–42 4000
BOD	1400–4800	15 500–18 500
Thiocyanates	0.5	350–887
Cyanide as CN	1.0	11.5–14.0
Sulphide	–	67–74

Table 3.4.3 Process-related pollution in petroleum refining and petrochemicals industry

Process	Pollutants
Crude processes	NH_3sulphides, oil chrloride, mercaptans, phenols
Cracking	
(a) thermal	high BOD, COD, NH_3
(b) catalytic	high alkalinity, oils
(c) hydrocracking	phenolics, cyanide, mercaptans
Hydrocarbon rebuilding	sulphides, mercaptans
Olefinic conversion	dissolved solids
Alkylation	suspended solids
Hydrotreatment	NH_3, sulphides, phenols
Asphalt production	Oil, high oxygenated phenolics

Aromatic compounds consist mainly of mono-, di-, or tri-hydroxy phenols, substituted phenols, and naphthols. Coke oven effluents contain up to 50% monohydric phenols, with catechol and resorcinol in equal proportion along with cresols, xylenols, and quinols in traces.

Processes involved in the refining of crude oil and manufacture of different petrochemicals produce a variety of pollutants. Waste waters arising from these processes contain oil, grease, sulphides, phenols, pyridines, naphthalenes, and polycyclic hydrocarbons. Water is consumed in enormous quantities and nearly half of it is discharged untreated into adjacent water bodies. Some characteristics of waste water from different refinery processes are summarized in Table 3.4.3.

Traditional fuels, such as firewood and sun-dried cattle dung, constitute a major source of fuel for cooking. Although some progress has been achieved in converting fresh cow dung into biogas, and several thousand demonstration plants have been established, by and large the tradition of using sun-dried cow-dung cakes as domestic fuel has not been supplanted. The health hazards associated with the burning of cow-dung cake or firewood or trash in poorly designed domestic stoves or cooking ovens have been brought to the fore by a recently conducted study in India (Smith *et al.*, 1983). Domestic fuel use also significantly contributes to the air pollution load of the metropolitan cities of Calcutta and Bombay. Release of polycyclic hydrocarbons and arsenic into the environmental compartments has ecotoxicological implications which have not been assessed realistically (Vohra, 1982).

3.4.5.2 Chemical Fertilizers

There has been an unprecedented use of fertilizers in tropical/agricultural countries following the success attending efforts to boost the output of food and cash crops. Fertilizer production (in terms of nutrients) in India is likely to increase from 5.25 million tonnes anticipated in 1984–85 to 19 million tonnes by the year 2000 to achieve a reasonable measure of self sufficiency. The discovery of substantial quantities of pure gas in the offshore Bassein fields in addition to the associated Bombay High Offshore gas has made it possible to plan the expansion of the nitrogen fertilizer capacity from 5.25 million tonnes to 9.9 million tonnes by 1990.

Environmental pollution problems likely to be posed by the naphtha or pure natural based fertilizer plants in India are yet to be identified. In contrast, coal-based fertilizer units have given rise to ecotoxicological problems, such as eutrophication and the toxicity associated with ammonia, nitrate, and urea (Desai and Keshavamurthy, 1982).

3.4.5.3 Petrochemicals

By 1960 the demand for various chemicals in India had far outstripped the supply of chemicals based on alcoholic fermentation, calcium carbide, and coal carbonization. At the same time, with the global expansion of petroleum refining capability, naphtha became available as a starting material for the organic chemical industry. From this basic raw material are produced ethylene, acetylene, and benzene, which in turn are converted into a variety of consumer articles, e.g. polyvinylchlorides, polystyrene, synthetic rubber, dyes, and insecticide intermediates. The commodity chemicals in their turn are chemically transformed into consumer products, such as paints, pipes, drugs, and insecticide formulations. Major petrochemicals produced now in India include ethylene, propylene, butadiene, benzene, methanol, monoethylene glycol (MEG), butyl alcohol, 2 ethyl hexanol, phthalic anhydride, formaldehyde, and ethylene oxide. The intermediates for synthetic fibres are polyester staple fibre, polyester filament yarn, nylon filament yarn, acrylic fibre, dimethyl terephthalate (DMT), monoethylene glycol, acrylonitrile, and capralactum.

3.4.5.4 Plastics

For convenience the Committee of Experts on Plastics of the Council of Europe has divided the large number of ingredients used in the plastics industry into two sections and two appendices. The list of monomers and initiators includes more than 300 items, whereas additives and polymerization aids give a total of over 1000 items. Besides 500 phthalate based plasticizers including di-2-ethyl hexyl phthalate and dioctyl phthalate, many adipates, amide esters of diethanol amine, azelates, benzoates, butane tricarboxylates, chlorinated paraffins, chlorofluoroethanes, and chlorofluoromethanes are also extensively used. Nearly a third of these chemicals rated as highly toxic include monomers, like vinyl chloride and acrylonitrile, and are classified as environmental mutagens and human carcinogens, whereas acrylamide is a powerful neurotoxin. The ecotoxic problems likely to emanate from the spread of plastic-based industries in developing countries have been outlined in an earlier review (Krishna Murti, 1982b).

3.4.5.5 Pesticides

Pesticides in common use today belong to the broad functional groups of insecticides, fungicides, herbicides, algicides, ascaricides, rodenticides, and nematocides. Chemically they belong to two groups: inorganic and organic. The inorganic pesticides include mercuric chloride, selenium compounds, lime sulphur, Paris green, lead arsenate, and calcium arsenate. Among naturally occurring organic insecticides are rotenone and the pyrethrins. The synthetic pesticides include organohalides, organophosphates, carbamates, and some minor compounds, like the quinones and phenols (Krishna Murti and Dikshith, 1982).

3.4.5.6 Dyestuffs

The main groups of synthetic dyestuffs used in the textile industry consist of sulphur dyes, vat dyes, direct dyes, azoic dyes, reactives, disperse pigments, and 1 : 2 metal complexes. Dyes, in general, are resistant to biodegradation, Dyestuffs are made essentially by batch processes involving a wide range of chemical reactions, unit operations, and unit processes. Dyestuffs of the non-azo class involve the use of solvents as reaction media, needing additional processing steps and sophisticated equipment. All these generate wastes.

The present trend in dyestuffs research worldwide does not indicate any major technological changes. In the developed countries the accent has been on increased automation and legislative controls to prevent environmental pollution. In countries like India, where the industry has gained considerable momentum in recent decades, there is broad scope for optimizing the unit processes and reducing the output of liquid effluents and introduction of catalytic hydrogenation instead of non-acid or zinc reductions, which produce considerable quantities of solid wastes. The hazardous waste problem associated with the dyestuff industry in Gujarat, India, has been dealt with in a recent pilot study conducted by the National Productivity Council.

3.4.5.7 Drugs and Pharmaceuticals

Drug and pharmaceutical industries which require environmental control are fermentation plants, synthetic organic plants, fermentation/synthesizer organic chemical plants, biological products units, and formulation plants (Subbiah, 1982). Pharmaceutical products belong to three main groups:

Medicinals: antibiotics, vitamins, anti-infective drugs, central depressants and stimulants—analgesics, antipyretics, barbiturates, gastrointestinal agents.

Biologicals: Serums, vaccines, toxoids, antigens.
Botanicals: Morphine, reserpine, quinine, curare, various alkaloids.

A majority of the pharmaceutical industries produce medicinals both by fermentation and organic synthesis. Fermentation processes produce vitamins B_2, B_{12}, and ascorbic acid; the antibiotics, penicillins, tetracyclines, streptomycin, kanamycin, erythromycin; organic acids (citric and gluconic acids); enzymes (amylases, lipases, proteases); amino acids, and a few others. The plant operations include seed production, fermentation for increased biomass and production of desired metabolites, filtration of biomass, removal of colour of broth, extraction by solvents or adsorption, evaporation, filtration, drying, and formulation (Mohan Rao *et al.*, 1970). Compositions of typical spent fermentation broths and untreated synthetic drug wastes are given in Tables 3.4.4 and 3.4.5.

Table 3.4.4 Characteristics of spent fermentation broth in antibiotic and vitamin B_{12} plants. From Subbiah (1982)

	Penicillin	Streptomycin	Erythromycin	Vitamin B_{12} extract
pH	6.5	5.7	6.5	8.0
Biological oxygen demand (mg/l)	8000–12 000	8000–12 000	4000–5000	72 000
Suspended solids (mg/l)	200–700	6000–10 000	300–500	Slurry
Solid SO_4 (mg/l)		2800–4500	–	–
Phosphate P (mg/l)	500–700	200–300	–	–
Total N_2 (mg/l)	1500–2500	1850	2050–3050	9500–10 500
Carbohydrate (mg/l)	2–2.5	5–10	5–10	5–7.5

Table 3.4.5 Characteristics of untreated synthetic drug waste

Component	Concentration (mg/litre) range
Calcium chloride	600–700
Sodium chloride	1500–2500
Ammonium sulphate	15 000–20 000
Calcium sulphate	800–21 000
Sodium sulphate	800–10 000
Aromatics drug derivation	1870–7300
Various solvents	3500–4400

3.4.5.8 Heavy Chemicals

Next to steel, caustic soda and sulphuric acid determine the level of industrialization of a country. The growth of paper, textile, aluminium, PVC, chemical, and soap industries, among others, depends on the availability of quality caustic soda and chlorine. The production and use of these two chemicals have given rise to significant levels of aquatic pollution from the mercury used in chloralkali cells.

3.4.5.9 Steel and Non-Ferrous Metals

Processing of iron ore and other minerals for the extraction of iron, conversion to steel, and the production of aluminium, zinc, copper, lead, tin, vanadium, titanium, nickel, chromium, and manganese is associated with varying problems of environmental pollution. Ore exporting countries like India also face problems of environmental degradation indirectly due to deforestation required for mining and transport of the ores to shipping harbours on the sea coast. Iron ore deposits of Kudremukh region in the Chikmaglur district of Karnataka are being exploited currently by transferring the ore in a slurry form to the sea port of Mangalore. The ecology of the grasslands under which mining is carried out has been reported to be disturbed. There are also indications of significant pollution of the Bhadra river and its estuaries by colloidal iron.

3.4.5.10 Chemicals and Products based on Processing of Natural Products

Under this category must be included distilleries which produce ethyl alcohol by fermentation of sugar-cane molasses; tanneries which process hides; and wood or paper and pulp plants which process wood, straw, bagasse, and rags to produce a variety of paper and boards, or process timber to produce raw material for construction and furniture. Of these the tanneries are in a class by themselves with chromium used in chrome tanning. Paper and pulp mills use large quantities of water and discharge effluents consisting of both biodegradable and non-degradable organic matter and mercury, where the caustic alkali used for pulping is produced captively by the mercury diaphragm cell process. Wood processing for timber requires the use of copper, arsenic, and glues and resins based on petrochemicals. Characteristics of wastes generated from distilleries, tanneries, and the weak black liquor of paper pulp plants are given in Tables 3.4.6, 3.4.7, and 3.4.8.

3.4.5.11 Natural Toxicants

The tropical humid climate promotes the proliferation of innumerable fungi which attack food and cash crops and produce a variety of mycotoxins (Tulpule *et al.*, 1982). The decay of wood and vegetation contributes to the cycling of

Table 3.4.6 Characteristics of distillery spent wash

Biological oxygen demand (BOD)	39 600 mg/l
Chemical oxygen demand (COD)	120 000 mg/l
Soluble sulphates	2312 mg/l
Total solids	144 840 mg/l
Total dissolved solids	113 200 mg/l
Suspended solids	34 240 mg/l
pH	4.3
Residual sugar	1.3%

Table 3.4.7 Some characteristics of tannery effluents. From Chakraborty *et al.* (1965) Reproduced with permission of the National Environmental Health Association

Process	Volume of waste (1/ tonne of hide)	pH	Total solids (mg/l)	Suspended solids (mg/l)	BOD (mg/l)
Soaking	2112	9.3	21 200	2588	1610
Liming	2088	12.7	48 400	10 322	10 027
Deliming	1408	8.0	5870	1392	1522
Vegetable tanning	1584	5.8	31 800	3510	19 284
Chrome tanning	1892	2.9	11 550	482	1000
Composite waste*,	15 092	9.5	20 000	3170	7000

*Total chromium in the composite waste could be 27 mg/l.

Table 3.4.8 Characteristics of black liquor from paper and pulp industry*. From Subrahmanyam (1982)

pH	11.5–12.4
Colour as Klett units (420 nm)	55 000
Total solids (mg/l)	147 000
Total volatiles (mg/l)	79 435
Organic : Inorganic solids	54 : 46
COD (mg/l)	151 600
BOD_5 (mg/l)	29 150
Lignin (mg/l)	56 580
COD of lignin isolated from black liquor (mg/l)	1.95
COD due to lignin (mg/l)	110 330
BOD rate constant kg/day	0.18
Ultimate BOD (mg/l)	36 320
Organics other than acid-insoluble lignin measured as COD and which do not exert BOD in the test (mg/l)	4950

*Waste waters from unbleached kraft pulp mills contain abietic acid, dehydroabietic acid, isoprimaric acid, palustric acid, pimaric acid, and sandaracopimaric acid. In caustic extraction state waste water one encounters trichloroguaicol, tetrachloroguaicol, monochlorodehydroabietic acid, epoxy stearic acid, and dichlorostearic acid. Minor toxic components in Kraft pulp mill waste water are sodium sulphide, methylmercaptan, hydrogen sulphide, sodium thiosulphate, formaldehyde, sodium hydroxide, and sodium chloride.

Table 3.4.9 Production and consumption figures of fertilizers for some countries in the arid/semi-arid and tropical/semi-tropical regions. From FAO (1982a)

	Nitrogenous (× 1000 tonnes N_2)				Phosphatic (× 1000 tonnes P_2O_5)			
	Production		Consumption		Production		Consumption	
	1978/79	1982/83	1978/79	1982/83	1978/79	1982/83	1978/79	1982/83
1	2	3	4	5	6	7	8	9
ARID/SEMI-ARID								
Egypt	216.0	625.9	490.4	667.8	96.6	47.9	86.7	73.7
Morocco	25.6	40.6	80.7	92.4	34.6	37.5	72.3	80.8
Afghanistan	48.3	49.6	35.5	31.4	28.6	32.0	18.1	14.1
Iran	72.3	21.8	167.2	492.8	7.8	7.4	119.1	400.0
Israel	79.5	74.9	37.6	39.1	29.5	26.7	24.2	15.7
Qatar	104.0	304.5	–	–	–	–	–	–
Saudi Arabia	120.9	161.0	7.0	59.0	–	4.2	4.5	33.1
Syria	24.9	80.0	65.0	95.9	–	53.8	33.0	54.9
TROPICAL/SEMI-TROPICAL								
Zimbabwe	50.0	84.0	55.3	73.1	–	–	34.6	45.0
Cuba	34.3	96.1	225.0	275.0	13.5	4.3	58.8	81.6
Guatamala	6.6	12.4	52.0	58.7	4.5	10.6	23.3	18.1
Mexico	593.0	1067.0	752.2	1254.6	227.0	252.5	258.7	486.0
Brazil	273.0	396.8	705.9	642.3	1185.0	1139.0	1519.0	1210.0
Venezuela	61.7	208.3	91.5	70.8	14.0	38.9	59.0	47.4
Bangladesh	134.0	236.6	227.8	306.0	28.6	32.0	100.9	130.4
Burma	57.5	51.2	67.9	114.7	–	–	14.4	43.1
China	7903.0	10 456.0	9280.0	12 210.0	1108.0	2589.0	1347.0	3191.5
India	2173.0	3429.7	2986.0	4043.0	792.0	1002.0	964.6	1200.0
Indonesia	694.0	951.0	549.0	981.0	–	256.6	137.9	356.1
Pakistan	336.7	994.4	684.3	758.0	27.3	73.5	187.9	265.2
Philippines	45.8	18.1	205.4	231.4	36.2	18.9	49.7	51.0
Malaysia	37.4	19.8	109.5	308.0	28.8	26.0	235.0	149.0
Vietnam	40.0	40.0	209.0	250.0	30.0	30.0	13.0	38.4
Sri Lanka	–	97.0	80.9	79.4	–	4.2	24.4	30.7

Table 3.4.10 Production and consumption of fertilizers in the developed and developing countries of the world

	Nitrogenous fertilizers (1000 tonnes N_2)		Phosphatic fertilizers (1000 tonnes P_2O_5)	
	1978/79	1982/83	1978/79	1982/83
Production				
Developed countries	40 367	41 106	26 146	25 113
All developing countries	15 540	22 242	5375	7876
Consumption				
Developed countries	33 578	34 634	22 740	21 078
All developing countries	20 184	26 386	7174	9755

arsenic (Krishna Murti, 1984a). There are many endemic areas of fluorosis in India due to the presence of high levels of fluoride in water bodies and in the soil (Bulusu *et al.*, 1985). The emphasis hitherto has been to explore the health effects of these toxicants in man and animals. Relatively less information is available on aquatic biotoxins in the tropical region.

3.4.6 PRODUCTION AND USE PATTERN OF CHEMICALS

3.4.6.1 Fertilizers

Realistic estimates for the global production, import, and consumption of this important group of heavy chemicals are available in the FAO yearbook of statistics (FAO, 1982a). The increasing trend of fertilizer consumption in developing countries is more than apparent from the figures given in Tables 3.4.9 and 3.4.10.

The situation in India, may be taken as a case study of the increasing trend in use of fertilizers. From a production of 151 MT (million tonnes) foodgrains in 1983–84 the level targeted for 2000 AD is 225 MT (*see* Table 3.4.11 for trends in the output of important food items). Eighty percent of this increase has come from increased use of fertilizers. The application rates statewise are revealing (*see* Table 3.4.12). From a meagre figure of 65 000 nutrient tonnes in 1950–51 fertilizer consumption has gone up to 7.9 MT (sevenfold increase in seventeen years) in 1983–84, making India the fourth largest producer of nitrogenous fertilizers in the world. The growth of the industry is reflected in the data summarized in Table 3.4.13 (Vittal, 1984).

Nearly 80% of fertilizer consumption in India is in assured irrigated areas, which cover only 30% of the cultivated land. Even in irrigated areas the consumption per hectare varies widely. It is assumed that the increase in fertilizer use will be from 91.4 kg to 120 kg/ha in irrigated areas and from 11.2 kg to 25 kg/ha in rainfed areas. The output from 33 nitrogenous and complex

Table 3.4.11 Increase in output of agricultural products over three decades in India. Values in million tonnes

	1949/1950	1978/1979
Rice	23.5	53.8
Jowar	5.9	11.4
Bajra	2.8	5.6
Maize	2.1	6.2
Wheat	6.4	35.5
All cereals	46.8	119.7
All pulses	8.2	12.2

Table 3.4.12 Fertilizer consumption in major agricultural states of India in 1982/1983. Figures in parentheses indicate total irrigation potential tapped up to 1980–81

	Fertilizer input: kg/ha cropped land (NPK)	Ultimate irrigation potential (million hectares)
Uttar Pradesh	60.6	25.7 (15.8)
Punjab	127.8	6.6 (5.3)
Andhra Pradesh	53.0	9.2 (5.1)
Maharashtra	26.3	7.3 (3.0)
Tamil Nadu	58.6	3.9 (3.1)
Karnataka	38.3	4.6 (2.2)
Gujarat	38.7	4.8 (2.5)
Average for whole country	36.6	

Table 3.4.13 Fertilizer production and consumption* in India from 1951 to 1981/82

	Nitrogenous		Phosphatic		Potassic
	Production (1000 tonnes)	Consumption (1000 tonnes)	Production (1000 tonnes)	Consumption (1000 tonnes)	Consumption (1000 tonnes)
1951/52	28.9	–	9.8	–	–
1960/61	98.0	212	52.0	53.0	29
1965/66	233.0	575	111.0	113.0	77
1975/76	1535.0	2149	320.0	467.0	278
1978/79	2170.0	3420	770.0	1106.0	592
1979/80	2224.0	3498	749.0	1151.0	606
1981/82	3143.3	4069	950.0	1322.0	–

*As of 1983, the level of consumption of all fertilizers stands at 7.2 million tonnes, recording a sevenfold increase in the past 17 years. It is also interesting to note that the percent share of various feedstocks for the production of 5.8 million tonnes of nitrogenous fertilizer in 1982 was natural gas 15, naphtha 50, fuel oil 20, and coal 10 fertilizer plants, six by-product ammonium sulphate plants, three triple superphosphate units, and 40 single superphosphate plants with an installed capacity of 5.17 MT (million tonnes) of N and 1.48 MT of P_2O_5 was 3.4 MT of N and 0.98 MT of P_2O_5 for 1982–83. The gaps will have to be met by imports or by development of biofertilizers (Sohbti, 1983). The land use pattern of a number of countries in the arid and tropical regions indicates a shift towards use of forest land for agricultural use. In all these countries there are efforts to bring more arable land under irrigation and hence one can predict an increasing use of synthetic fertilizers in the coming decades. (Table 3.4.14).

3.4.6.2 Thermal Power Generation

Oil is the principal source of energy and its share in world energy production is nearly 50%. Natural gas and coal account for 19.2% and 30% respectively. One of the imperatives of rapid national development is the availability of

Table 3.4.14 Application rate of fertilizers in some countries of arid/semi-arid and tropical/semi-tropical regions (kg/ha agricultural area). From FAO (1982a)

	Nitrogenous		Phosphatic	
	1974/76	1981	1974/76	1981
World	9.2	13.0	5.6	6.7
Africa	1.2	1.9	0.8	1.3
Egypt	141.8	204.5	25.3	38.5
Morocco	3.4	3.9	3.3	3.8
Afghanistan	0.7	0.7	0.3	0.3
Iran	3.3	6.4	2.5	4.8
Israel	28.7	32.5	14.9	14.6
Qatar	3.2	15.8	–	–
Saudi Arabia	0.1	0.5	–	0.3
Zimbabwe	9.5	14.2	6.0	6.0
Cuba	28.1	53.7	10.1	14.0
Guatemala	15.6	19.4	7.1	10.3
Mexico	7.4	11.3	2.5	3.9
Brazil	5.0	5.6	2.8	3.3
Venezuela	3.2	3.3	2.1	2.2
Bangladesh	13.6	25.8	5.2	12.3
Burma	4.0	10.6	0.7	4.3
China	11.7	29.8	4.0	7.6
India	11.3	21.4	2.8	6.5
Indonesia	10.9	31.7	3.7	10.2
Pakistan	17.8	32.9	3.9	8.9
Philippines	15.6	19.1	3.8	4.7
Malaysia	28.2	39.5	–	–
Vietnam	17.4	18.2	10.1	2.6
Sri Lanka	19.7	34.3	5.4	11.5

abundant energy. With petroleum reserves insufficient to meet today's demand and other forms like nuclear, geothermal, solar, and biomass yet to be developed, India has decided to meet her energy requirements for the foreseeable future by coal. Adequate reserves of coal are known to exist in many coal basins, the most important one being the Jharia coalfield, which is the country's main source of prime coking coal. Total coal output went up from 73 MT in 1970–71 to around 125 MT in 1981–82. The share of non-coking coal increased during this period from a little over 55 MT to over 98 MT, an increase of 78%. On the other hand, production of coking coal rose from about 18 MT to 26.5 MT, recording only a 48% growth. Coking coal production is likely to be around 30 MT in 1984–85 and to rise to 40–42 MT by 1990. The existing thermal capacity is 24 656 megawatts (MW). It is proposed to add another 22 000 MW by the end of 1990. The National Thermal Power Corporation will be implementing schemes resulting in an aggregate capacity of 10 000 MW. Six super thermal stations in Farakka, Korba, Ramagundam, Rihand, Singrauli, and Vindhyachal are under implementation. There are also plans to locate two more super thermal stations at Moradnagar in Uttar Pradesh and at Kahalgaon in Bihar, each with a capacity of 840 MW. The NTPC plans to achieve a target of 28 000 MW by 2000 AD. The balance of the need of 20 000 MW will have to be met by State thermal plants.

A major impediment to the effective utilization of Indian coal in metallurgical industries and thermal power plants has been its poor quality and high ash content ranging from 30 to 45%. With current plans to mine deeper and adopt mechanization progressively, the problem of utilizing poor-quality coal has assumed multi-faceted complexities. As at present only 15% of the country's coal output (that is about 60% of coking coal output) is being beneficiated. The corresponding figures for France, UK, Korea, and Japan vary between 90 and 100%, while those for Canada, Australia, Czechoslovakia, and West Germany are around 60%.

There are 16 operating washeries in India with a total capacity of 20.5 MT/year as against an annual production of 30 MT/year of coking coal. The washeries in operation have a ratio of 50 : 40 : 10 for clean coals, middlings, and rejects. The high yield of middlings creates many problems of waste disposal and pollution. Since beneficiation of non-coking coals may yield middlings and rejects with ash content over 45% and 60% respectively, captive use for these middlings and rejects will have to be built up in order to avoid major pollution problems. By the end of the Seventh Plan (1990) Indian coal output will exceed the 200 MT mark, nearly 170 MT of which will be high-ash non-coking coals, the ash content of an estimated 120 MT of which might exceed 40%.

Technology for conversion of high-ash coal to methanol is also under examination in view of the plans to undertake coal transport by slurry pipelines. The best prospects for slurry pipelines in India appear to be over 1200 km from the Singrauli mines in Uttar Pradesh to the Mankobari power plant (Gujarat) and thence to the proposed Vapi 2000 MW station (over 1000 km). It is estimated that a slurry pipeline project in the north expected to be commissioned towards 1995 will transport 62 MT coal per year over 3897 km to power stations with an aggregate capacity of 13 500 MW. The feasibility of underground gasification of coal deposits in the oil wells of Gujarat is also under wider study (Rajan, 1984).

Problems of pollution related to fuel use in the Indian or African context cannot be divorced from the use pattern of domestic fuels (Table 3.4.15). The potential for supplying cheap domestic cooking fuels to the millions of families in the rural sector has to be sought not only in petroleum products like kerosene or gas but in biomass based on plant or animal life. A case study conducted in 1982 in Bangalore, which houses India's major aircraft factory, the biggest establishment for telephones, machine tools, and electronics as well as two of India's biggest R & D establishments, viz. the Indian Space Research Organization and the Indian Institute of Science, revealed that about 1260 tonnes of firewood are required per day for household consumption, to supply which 10 ha of tropical forests have to be cleared every day. By 1991 the projected need will be 1760 tonnes of firewood per day (Reddy and Reddy, 1982). The interest of India in investing in biomass technology is therefore understandable.

Bagasse and sugar-cane molasses, the by-products of the sugar-cane processing industry, provide respectively 1.2 MT and 0.34 MT of fuel per annum, which can yield 934 million litres of ethanol, although the estimated annual production is only 640 million litres. A total of 203 MT of agricultural residues can be obtained annually from rice, wheat, maize, cotton, jute, barley, sugar-cane, coconut, etc. (Bose *et al.*, 1983).

The common aquatic pest, water lily or water hyacinth, which was once considered as a curse has attracted attention as a source of renewable energy. It is estimated that in India nearly 200 000 ha are covered by this weed. In shallow waters with a temperature range of 38–30°C and pH range of 4–8 the weed grows at prolific rates, absorbing 80% of nitrogen and 60% of phosphorus in five days from secondary effluents, giving a yield of 148 tonnes/ha/year on

Table 3.4.15 Sector-wise and source-wise commercial energy consumption in India, 1978–79. From Statistical Outline of India (1982). Reproduced with permission

	% share of different sources of energy			% share of different sectors
	Coal	Oil	Electricity	
Household	10	71.2	18.8	13.7
Agriculture	–	61.8	38.2	10.6
Industries	44.5	7.9	47.6	38.5
Transport	13.3	83.9	2.8	31.7
Others	11.9	36.2	51.9	5.5

Table 3.4.16 Technologies proposed for using water hyacinth as source of power gas and power alcohol

	Yield (per tonne of dried plants)	Energy value
Saccharification by acid digestion followed by fermentation	56 litres ethanol, 0.2 tonnes residue	7700 Btu
Gasification air and steam with subsequent recovery of ammonia	40–56 kg ammonium sulphate, 40 000 cu ft gas	142.8 Btu H_2, methane, CO_2, CO, and N_2
Bacterial fermentation and utilization of evolved gas for power production	26 500 cu ft gas	600 Btu methane hydrogen CO_2 oxygen

a dry weight basis. Three different technologies, as summarized in Table 3.4.16, are being proposed to convert this biomass into power gas and power alcohol.

Algae, such as *Scenedesmus*, *Chlorella*, and *Spirulina*, can also yield biomass, ranging from 60 to 90 tonnes of dry matter/ha year.

Yet another traditional domestic fuel receiving renewed attention in India is cattle dung. Approximately one million tonnes of cow dung is generated every day by the 85 million livestock population, not all of which is used at present for biogas production. From pilot studies on plants working in remote rural areas it is learnt, however, that the four-day accumulation of the dung of five cows is sufficient to produce 13 cubic metres of biogas (Bose *et al.*, 1983).

3.4.6.3 Petroleum and Industrial Organic Chemicals

In order to indicate the trend in the use of petrochemicals, projected demands and capacity gaps for five items are given in Table 3.4.17. The present low per capita level of petrochemical consumption (0.5 kg) and the large potential market have raised expectations for the rapid growth of the industry in the next decade. It is, therefore, proposed to establish two gas-based petrochemical complexes, one in Maharashtra and the other in Gujarat. The Maharashtra complex will produce 300 000 tonnes of ethylene and 40 000 tonnes of propylene, 80 000 tonnes of low-density polyethylene (LDPE), 135 000 tonnes of linear low-density polyethylene (LLDPE), 5000 tonnes of ethylene oxide, 50 000 tonnes of ethylene glycol, and 60 000 tonnes of polypropylene, whereas the Gujarat complex will produce 158 000 tonnes of ethylene and 17 500 tonnes of propylene a year. In addition three aromatic complexes are being set up for benzene, toluene, and xylene.

Table 3.4.17 Projected demand by 1987–88 of petrochemicals in India. (in 1000 tonnes). From Doraiswamy (1984)

Base chemical	Current licensed capacity	Estimated demand	
		High level	Low demand
Ethylene	268	659	495
Propylene	150	262	197
Butadiene	62	110	83
Benzene	151	467	350
Xylenes	60	212	160

3.4.6.4 Plastics

The foundations for the plastics industry in India were laid during the 1950s, with the establishment of facilities for making polystyrene and LDPE based on industrial alcohol derived from molasses by fermentation. The industry registered rapid growth only after the commissioning of the petrochemical complexes. The ready availability of a large number of commodity plastics stimulated the rapid growth of the plastics processing industries during the sixties and seventies. The trend of polymer consumption during the last five years (Table 3.4.18) indicates an annual growth rate of 10%. The commissioning of petrochemical complexes and ready availability of commodity plastics resulted in the blooming of a large number of small-scale units, particularly in the extrusion sector. Thus as of 1982, 7700 units employing 81 700 workers have been registered. The plastics machinery industry is also well established. New generations of thermoplastics, such PP-homopolymer, PP-copolymer, and linear low-density polyethylene (LLDPE), have also been introduced.

3.4.6.5 Pesticides

Pesticide consumption data (for 1981) for some arid and semi-tropical countries are summarized in Table 3.4.19, indicating an increasing demand for chemicals in pest control in the developing countries. The Indian situation is typical.

Table 3.4.18 Consumption of major plastics in India (1000 tonnes). From Doraiswamy (1984)

	1979–80	1983–84
Low density polyethylene (LDPE)	73.6	115
High density polyethylene (HDPE)	62.7	75
Polyvinyl chloride (PVC)	82.0	137.5
Polypropylene (PP)	15.1	30.0
Polystyrene/High impact polystyrenes (PS/HIPS)	12.5	17.0

Table 3.4.19 Pesticide consumption for 1981 in some countries in arid and semi-tropical zone (× 100 kg). Source: FAO Year Book 1982b

	DDT	HCB	Lindane	Aldrin	Toxaphen	Other chlorinated pesticides
Egypt 1974–76)	993	–	3460	10 187	10	19 157
Sudan (1974–76)	6501	–	–	–	–	1482
Israel	–	–	–	–	–	1630
Zimbabwe	2437	–	–	542	–	2702
Mexico	6000	2500	350	–	18 000	10 350
India	30 000	27 000	500	2000	–	19 000
Pakistan	1034	2062	55	30	–	3294

	Parathion	Malathion	Other OP	Pyrethrin	Other botanicals	Arsenicals
Egypt (1974–76)	397	3573	54 267	–	20	420
Sudan	–	–	6767	–	–	–
Israel	–	–	11 230	–	–	–
Zimbabwe	215	91	3018	–	–	–
Mexico	50 000	12 000	54 520	–	–	–
India	20 000	27 500	64 350	–	–	–
Pakistan	530	2381	8993	–	–	–

	Carbamate	Mineral	Others	Sulphur	Lime
Egypt	–	34 973	29 463	85 207	–
Sudan	1590	–	–	–	–
Israel	2160	13 800	7810	6240	–
Zimbabwe	4837	670	–	232	–
Mexico	21 630	–	–	12 000	–
India	32 800	13 800	–	42 000	–
Pakistan	3511	–	1139	–	–

	Copper Compounds	Dithiocarbamates	Aromatics
Egypt	5027	30	–
Israel	6100	3200	–
Zimbabwe	–	795	856
Mexico	16 500	38 350	10 600
India	49 000	23 250	–
Pakistan	912	370	–

	Other functions	Mercurials	Seed Dressing
Egypt	7210	–	–
Israel	1940	–	305
Zimbabwe	–	–	–
Mexico	22 620	1500	7640
India	4550	100	–
Pakistan	417	41	45

continued

Table 3.4.19 *continued*

	2,4-D	MCPA	2,4,5-T
Egypt	–	–	–
Zimbabwe	–44	300	–
Mexico	13 500	–	300
India	4000	–	–
Pakistan	2	–	–

	Triazines	Carbamate herbicides	Urea derivatives
Egypt	–	–	–
Zimbabwe	5537	209	315
Mexico	9200	1450	4060
India	600	–	3050
Pakistan	184	–	–

	Other herbicides	Bromides	Other fumigants
Egypt	–	–	290
Israel	6220	8270	1000
Zimbabwe	4803	–	–
Mexico	20 890	8000	3880
India	11 760	350	1200
Pakistan	346	8	252

	Anticoagulants	Rodenticides	Other pesticides
Israel	–	60	27 910
Zimbabwe	3	–	22 164
Mexico	50	400	5050
India	350	3000	1250
Pakistan	–	279	114

The relevant figures are given in Table 3.4.20. There were 96 manufacturing units in 1983–84 with an installed capacity of 96 749 tonnes but with an output of only 61 743 tonnes, of which benzene hexachloride alone accounted for 34 802 tonnes.

Insecticides have a dominant share, with over 72%, whereas fungicides account for only 21.3%, weedkillers 3.4%, fumigants 2%, rodenticides 0.7%, and acaricides 0.4%. There are 32 insecticides in use in agriculture, of which 18 are organophosphates. Since 1965 the Indigenous availability of yellow phosphorus, phosphorus pentasulphide, and trichloride has led to the establishment of plants for the manufacture of malathion, parathion, dimethoate, monocrotophos, quinalphos, phosalone, etc. Demand for organophosphates is expected to increase from the present figure of 13 000 tonnes to 20 000 tonnes in the Seventh Plan Period for the public health programme alone. For the agricultural sector the development of microencapsulated slow-release formulations of organophosphates is in progress, with the shift in emphasis from

Table 3.4.20 Capacity and production of pesticides in India. (From Rajan, 1984)

Pesticide category*	No. of Units	Installed capacity (tonnes)	Production established 1983–84 (tonnes)
Insecticides	56	82 700	53 067
Fungicides	11	2460	1070
Herbicides	5	2535	540
Weedkillers	4	685	585
Plant growth regulators	5	200	79
Rodenticides	5	1266	320
Fumigants	10	2188	986
Antibiotics	2	915	–
Total	96	96 740	61 743

*Insecticides include: BHC, DDT, Malathion, Parathion, Metasystox, Fenitrothion, Fenthion, Dimethoate, Phosphamidon, DDVP, Quinalphos, Ethion, Carbaryl, Monocrotophos, Lindane, Endosulphan, Thimet, Dicofol, Phosolone, Fenvelerate
Fungicides include: copper oxychloride, thiocarbamate, nickel chloride, organomercurials, Carbandigine
Herbicides include: 2,4-D and Isoproturon
Weedkillers include: Paraquat, Basalin, and Dalapon
Plant growth regulators include: Cycocil and alphanaphthalene
Rodenticides include: Ratafin and zinc phosphide
Fumigants include: aluminium phosphide, methyl bromide, and ethylene dibromide
Antibiotics include: Aureofungin and Streptocycline

insect to disease control. Demand for dithiocarbamate fungicides is likely to increase. With the successful use of herbicides in Punjab and Haryana, the Green Revolution belt, the use of weedkillers is also likely to spread to cereal crops from their present limited use in plantation crops, such as tea. Of the 200 herbicides registered in developed countries, only 25 are registered in India, of which only 14 are being used. Currently, 2,4-D, butachlor, thiobencarb, and fluchlorabin are used for weed control in rice.

One million hectares are under herbicide coverage and the figure may increase to 2–3 million hectares by 1990. On the basis of consumption data per hectare of total land surface available, the low level of 400 g has always been contrasted against the 10 470 g in Japan, the 1490 g in the USA, or 1870 g in Europe to press for more extensive use of pesticides. However, if the data is recast on the basis of pattern of use in areas where intensive agriculture is practised, as in Punjab, Andhra Pradesh, or Tamil Nadu, the consumption per hectare of actual cultivated area may have to be revised several factors above the oft-quoted figure of 400 g (Sarma, 1983; Rajan, 1984: Krishna Murti, 1984c).

3.4.6.6 Minerals, Metals

The data available for the present discussion are from Indian statistics. Information on the growth of mineral production for the two decades from

1960 to 1980 are given in Table 3.4.21. The country does not produce mercury and its entire requirements are imported. Indigenous production of zinc is around 60 000 tonnes, although the demand is for 120–130 000 tonnes. Nearly 70 000 tonnes of lead are consumed whereas indigenous production is only 25 000 tonnes. Requirements of copper are around 100 000 tonnes although only 25–35 000 tonnes are indigenously produced (Raghavan, 1983). It is of relevance in the context of the present discussion that there has been almost a doubling within a period of 20 years of the rate of production of materials with a potential to diffuse toxic elements in the environment.

3.4.6.7 Chemicals and Products Based on Biomass Technology

Production of alcohol has gone up from 355 million litres in 1979–80 to 534 million litres in 1982–83. For 1989–90 the estimate is 902 million litres. The installed capacity for paper from 121 paper and paper-board mills is 1.54 million tonnes per annum. In addition, there are three rayon grade mills with an output of 120 000 tonnes per annum, and one newsprint mill with 75 000 tonnes per annum. Three more paper mills (233 000 tonnes per annum) and one newsprint mill (30 000 tonnes per annum) are ready to be commissioned. The demand for paper by 1985–86 has been put at 2.5 million tonnes, requiring around 3 million tonnes per annum capacity (Subrahmanyam, 1982).

A total of 58.5 million skins are processes in India annually in about 2160 tanneries. This would mean 314 000 tonnes of leather being processed with an annual discharge of 9.4 million m^3 waste water containing 28 260 tonnes of BOD (Arora, 1982). Another industry which has grown rapidly in the last decade with a high biological pollution potential is the processing of cassava for the preparation of industrial starch.

Table 3.4.21 Mineral production in India. From Statistical Outline of India (1982). Reproduced with permission

	1960	1980
	($\times 10^3$ tonnes)	
Bauxite	387	1532
Chromite	107	305
Copper ore	448	1997
Gypsum	997	817
Lead concentrate	6.2	16.3
Manganese ore	1452	1740
Mica	29	8
Zinc concentrate	9.6	50.3
	($\times 10^6$ tonnes)	
Coal	52.6	107.0
Iron ore	16.6	39.0
Limestone	12.9	28.2
Petroleum crude	0.5	9.5

3.4.7 DISPERSION IN ENVIRONMENTAL COMPARTMENTS

Information on the dispersion of chemicals in the environmental compartments of air, water, and soil has to be compiled with the aid of inventories of the sources and use pattern of a chemical in a given location, supplemented with data on the levels of the chemical in air, water, and soil, or in agricultural and industrial products. Although some limited information has been presented in the preceding section on production and consumption of chemicals, mostly in the light of the Indian experience, the task of compiling reliable data for the entire tropical, semi-tropical, arid, and subpolar zones remains incomplete. The picture in regard to monitoring environmental pollution in countries with a tropical and semi-arid climate is even less satisfactory.

3.4.7.1 Air Quality in Selected Urban Areas

Under the WHO/UNEP Air Quality Monitoring Project, as of 1982, 40 countries with approximately 150 monitoring stations were participating in the programme to measure sulphur dioxide and suspended particulate matter (SPM) or smoke in 40 different regions of the globe (WHO, 1983). This is indeed the only project of global dimension in which a systematic attempt has been made to measure levels of important environmental pollutants in different geographical regions, representing temperate, tropical, and arctic climates. India has also instituted its own national network of air quality monitoring and valuable information has been derived for pollutant levels in urban centres (NEERI, 1983).

By far the most extensive study on air pollution is the epidemiology related investigation of the health effects of air pollutants in Greater Bombay (Kamat *et al.*, 1983). Data on the trends of air pollution levels in Bombay City over a 15-year period are summarized in Table 3.4.22. Seasonal variations in the levels of SO_2, NO_2, sulphation rate, and particulate matter in the city of Ahmedabad have been carried out by the National Institute of Occupational Health (NIOH, 1979–83). An increasing trend of pollution levels as tested by Spearman rank correlation technique was observed for the period 1978–83 (*see* Table 3.4.23). The general levels of SO_2 and NO_2 were lower than those reported for other industrial cities of the developed countries and also well below their respective Air Quality Criteria Levels (SO_2: $80\,\mu g/m^3$; NO_2: $100\,\mu g/m^3$). However, the concentration of suspended particulate matter was definitely higher than those reported from most of the urban centres of the developed countries. Levels of SO_4 ($4.7–15.9\,\mu g/m^3$) were comparable with those reported for other urban centres of the world; however, the values of nitrate ($5.04–22.7\,\mu g/m^3$) were found to be higher than the $3–5\,\mu g/m^3$ reported in temperate regions.

Emission of sulphur dioxide in Delhi from 360 industries in six industrial belts is estimated to be about 175 tonnes per day. Likewise the emission from

Table 3.4.22 Trends in air pollution levels in Bombay City over 15 years. All values in $\mu g/m^3$. From Shetye *et al.* (1984). Reproduced with permission

(a) 1966–75 Eastern Suburb

	1966–69	1970	1972	1973	1975
SPM	316	–	–	–	–
SO_2	65	36	36	39	44
NO_x	8	–	10	–	–
O_3	20	–	13	6	–

(b) 1971–73 All City

	South		Central		Western Suburb		Eastern Suburb	
	1971	1972–73	1971	1972–73	1971	1972–73	1971	1972–73
SPM	–	270	–	364	–	291	–	325
SO_2	61	43	65	78	29	43	54	54
NO_x	10.6	30	12.3	46	9.6	37	7.3	43
O_3	7	9	7.5	14	3.3	11	5.1	12
Sulphation rate	0.94	0.98	0.98	1.01	0.35	0.47	0.70	1.15

(c) 1978–80

	South			Central			Western Suburb			Eastern Suburb		
	1978	1979	1980	1978	1979	1980	1978	1979	1980	1978	1979	1980
SPM	–	–	–	255	270	264	204	204	231	222	238	236
SO_2	–	–	–	97	94	90	35	24	27	59	41	37
NO_x	–	–	–	22.5	12.5	25	18	9.9	16.9	27.1	12.4	22

(d) Benzopyrene levels ($\mu g/1000\ m^3$)

South				Central				Western Suburb				Eastern Suburb			
1972	73	75	80	1972	73	75	80	1972	73	75	80	1972	73	75	80
4.5	39	7.2	–	271	173	211	6.2	–	5.6	–	–	1.9	1.0	0.73	0.82

Table 3.4.23 Trend of air pollution in Ahmedabad

								Spearman rank correlation	
Pollutant†	Area‡	1978–79	1979–80	1980–81	1981–82 (G.M. ± S.G.D.)	1982–83	1983–84	Trend significance	Level of
SO_2	H.P.	29.6 ± 2.67 (77)	22.5 ± 1.62 (82)	22.4 ± 1.52 (63)	26.2 ± 2.00 (38)	22.8 ± 2.10 (23)	39.1 ± 2.31 (48)	Positive	10%
	L.P.	–	10.6 ± 1.50 (25) **	10.8 ± 1.51 (34) **	12.0 ± 2.54 (21) **	12.9 ± 1.80 (18) *	13.9 ± 1.87 (28) **	Positive	1.0%
NO_2	H.P.	10.4 ± 1.50 (77)	17.6 ± 1.48 (82)	17.2 ± 1.64 (63)	26.0 ± 1.48 (38)	30.2 ± 2.17 (23)	32.4 ± 1.61 (48)	Positive	5.0%
	L.P.	–	12.1 ± 1.81 (25) **	10.8 ± 1.90 (34) **	17.6 ± 1.65 (20) **	28.8 ± 1.91 (18) NS	20.5 ± 2.09 (29) **	Positive	5.0%
SPM	H.P.	–	608 ± 1.40 (29)	407 ± 1.88 (14)	526 ± 1.36 (17)	460 ± 2.29 (17)	521 ± 1.66 (46)	Negative	NS
	L.P.	–	331 ± 1.77 (10) **	297 ± 2.00 (9) NS	342 ± 1.15 (10) **	258 ± 2.37 (13) **	293 ± 1.58 (27) **	Negative	NS

†Levels in μg/m$_3$. Figures in parentheses indicate number of observations.
‡H.P. = high-pollution area;, L.P. = low-pollution area.
* = $P < 0.05$; ** = $P < 0.01$, compared to L.P. area. NS = not significant at $P > 0.10$.

Table 3.4.24 Chemical composition (%) of fly ash from different thermal stations in India. From Satapathy and Ramana Rao (1984). Reproduced with permission of the Council of Scientific and Industrial Research, New Delhi

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	P_2O_5	CaO	MgO	SO_3	Unburnt carbon
Bandel	55.84	23.85	4.39	1.05	Traces	2.14	1.28	Traces	10.10
Singareni	50.91	16.05	5.59	1.00	0.16	5.32	1.48	0.73	16.90
Kanpur (KESA)	49.91	21.00	7.50	1.03	0.21	2.84	0.94	0.24	15.60
Madras (Basin Bridge)	46.90	21.55	8.45	1.30	0.33	3.19	1.29	0.73	13.03
Rourkela Steel Plant	46.31	20.57	9.74	1.28	0.95	3.34	1.61	0.56	12.60

Table 3.4.25 Elemental composition of fly ash from Indraprastha Thermal Power Station. From Misra (1984). Reproduced with permission of the National Environmental Health Association

Element	ppm
Copper	155
Chromium	274
Manganese	253
Cadmium	2
Strontium	14
Lead	120
Arsenic	101
Nickel	150
Zinc	177
Iron	26 725
Cobalt	18
Selenium	72
Polyaromatic hydrocarbons	90–130

automobiles is estimated to be about 2 tonnes per day. In nine grids from north to south and six from east to west, each of 4 km, the area source emission was $1.0\,\mu g/m^2/s$ and from vehicular traffic $0.07\,\mu g/m^2/s$. The 24-hour maximum concentrations of SO_2 did not exceed the EPA primary standard ($265\,\mu g/m^3$) but 24-hour maximum values of ground level concentration of SO_2 have exceeded secondary standards ($260\,\mu g/m^3$) during pre-monsoon, post-monsoon, and winter seasons in two pockets (Gupta and Padmanabhamurty, 1984).

Any discussion of air pollution in India cannot be complete without referring to the fly ash and gaseous materials released from the thermal power stations. It is estimated that 8–10 million tonnes of fly ash are released from thermal power plants every year. The fly ash can adsorb cyanide and phenols (Satapathy and Ramana Rao, 1984). Typical composition of fly ash from five different thermal stations is summarized in Table 3.4.24. The fly ash collected from the Indraprastha Thermal Station in New Delhi has been found to contain 60–130 μg of polycyclic hydrocarbons and a variety of toxic metals as shown in Table 3.4.25 (Misra, 1984).

3.4.7.2 Aquatic Pollution

From the flow rate and characteristics of the waste waters generated, estimates of the quantity of effluents and pollutant load as BOD in the water bodies have been made in Table 3.4.26. Since human settlements and industrial units tend to be concentrated in existing urban clusters on the banks of rivers, pollution of rivers has become inevitable.

Table 3.4.26 Approximate estimates of pollutants as BOD from six industries

	Flow (m^3/day)	BOD (kg/day)
Petrochemical	1231	1739
Paper and pulp	310/tonne	50/tonne of pulp
Producer gas plant	110 m^3/day	1.7/tonne of coal
Tannery	30 m^3/tonne	378/tonne of hide
Pharmaceuticals	2200 m^3/day	6606/day
Distilleries	20 m^3/m^3 spirit	900 kg/m^3 spirit

The contamination of existing resources of ground water is being examined, along with the implementation of plans for a rational use of the resources for human, agricultural, and industrial needs. In recent years sophisticated geophysical techniques and remote sensing have been increasingly deployed for mapping water resources and assessing their quality (Pathak, 1983). Infra-red and thermal infra-red imagings are also used now in the detection of freshwater discharge to inland and coastal areas and the effect of pollution on waterways and estuarine systems (Satyanarayana, 1983).

3.4.7.3 Marine Pollution

Acenaphthene, acenaphthylene, benz(a)pyrene, fluoranthrene, methylphenanthrene, phenanthrene, and triphenylene were among the polycyclic hydrocarbons detected along with heavy metals in benthic organisms in the Upper Gulf of Thailand. Benz(a)pyrene was detected in all species at concentrations varying from 1.0 to 8.2 ng/g. No correlation was found between metal concentrations in animals and sediment, with the exception of copper; thus in polychaetes and clams the copper concentrations appeared to correlate with the copper/iron ratio of sediments (*see* Table 3.4.27). Degradation rates of aromatics using labelled chlorobenzene, phenanthrene, and chrysene were significantly lower in the waters and sediments of the Gulf of Thailand than the fast degradation rates of the water and sediment of the Chao Phraya river (Hung Spreugs *et al.*, 1984).

Residues of 2,4-D and 2,4,5-T have been detected in tissues of corals subject to massive mortality in the Gulf of Chiriqui, Panama, due to intense agricultural activity and high herbicide input (Glynn, 1983). Coral mortality was noticed in the Gulf over an area of 10 000 km^2 five to six weeks after corals lost their zooxanthellae. Besides death there was extensive bleaching of corals. Insecticides found in Panamian Pacific coral tissues included lindane, endrin, kepone, dieldrin, ethion, endosulphan, chlordecane, dimethoate, pp′ODT, op′DDT, op′DDD, and pp′DDD. Butyl benzyl phthalate and diethyl hexyl phthalate were found in the tissues. It is significant that relatively high phenoxy acid concentrations (0.01–0.02 ppm) were found in coral tissue in an isolated area with strong tidal flux and warm sea temperature. Herbicides are applied regularly

Table 3.4.27 Content of polycyclic hydrocarbons and toxic metals in benthic organisms of upper Gulf of Thailand. From Hung Spreugs *et al.*, (1984). Reprinted with permission ©1984 Pergamon Books Ltd

	Oyster	Green mussel	Scallop
Polycyclic hydrocarbons (ng/g)			
Phenanthrene	6.7	4.4	4.4
Acenaphthene	16.3	16.2	–
Acenaphthylene	–	–	–
Fluorathrene	470.0	–	–
Methylphenanthrene	3.5	–	2.9
Triphenylene	0.03	–	–
Benz(a)pyrene	3.5	1.0	8.1
Toxic metals (μg/g)			
Cd	1.6	0.41	0.58
Co	0.27	0.50	0.48
Cu	114.00	8.50	3.00
Pb	0.24	0.73	0.01
Ni	0.30	1.50	2.6

by aerial spraying at a recommended dose of 1 l/ha in a total area of 42 000 hectares. During the peak period of mortality, the equatorial surface warming anomaly exceeded 4 degrees over large areas and reached 6 degrees in some places. High levels of herbicide and an unusually prolonged warm spell could have acted synergistically (Glynn *et al.*, 1984). There has also appeared an interesting report on the accumulation of trace metals and chlorinated hydrocarbons in Ross seals collected in Antarctica. Mercury levels were 5 μg/g dry matter in Ross seals as compared to 74.7 μg/g noted in the Californian sea lion or 50 μg/g in Leopold seals. However, Cd levels in Ross seals were more than 100 μg/g as compared to 5–10 μg/g noted in the Californian sea lion. Copper and zinc levels were 80 μg and 200 μg respectively in Ross seals, as compared to 40 μg and 110 μg in Starbour seals of San Francisco. Levels of lead were detected only in traces (Meclurg, 1984). Arsenic enrichment was noticed in two marine microalgae of Phaeophyta (42.2–179 μg/g and 26.3–65.3 μg/g), relative to Rhodophyta (17.6–31.3 μg/g and 12.5–16.2 μg/g) and Chlorophyta (6.3–16.3 μg/g or 9.9–10.8 μg/g) (Maher and Clarke, 1984).

An interesting comparative study of the ecotoxicological effects of organic pollutants versus heavy metals was carried out from 1976 to 1980 using the blood clam *Anadora granosa* and Gobid mudgkept. The levels of Zn, Mn, Cu, Fe, Co, Ni, Cd, Cr, Pb, and Sr in water, sediments, and the two benthic species were found to be far below those that are known to affect adversely the life and quality of benthic communities. The concentration of these elements in various compartments neither revealed any systematic temporal or spatial fluctuation nor reflected the substantial increase in the total pollution budget for the 8–12 year period studied. The poor growth and high mortality in the clam *Anadora granosa* (from the Sewri clam bed may be due to anoxic conditions caused by organic pollutants discharged from the industrial units on Sewri Coast (Patel *et al.*, 1985).

3.4.7.4 Soil Pollution

The rate of land degradation due to human activity currently is 50 000 km^2 per year. However, it is to be noted that 36 million km^2 per year of land, which supports one sixth of the world's population, is ultimately at risk of degradation according to UN estimates (United Nations, 1977). Cultivation of terrestrial ecosystems leads to substantial losses of the major elements. Thus continuous cultivation of land in about a decade in tropical areas has led to the loss of 50% of carbon, 30–40% of sulphur, and 10–30% of phosphorus. The efforts to replenish the lost nutrients by chemical fertilizers require enormous investments. The attendant losses of essential trace metals or interaction with toxic metals by cycling of the latter can give rise to toxicological problems affecting land productivity, animal health, and eventually human welfare.

Population pressures, rapid and often unplanned industrialization without adequate attention being paid to the siting of industries, as well as the search for natural resources have all led to destructive exploitation of tropical ecosystems (Melillo and Gosz, 1983; Vitousek, 1983). One of the primary effects of fossil fuel combustion appears to be the imbalance between the rate of nitrogen fertilization and hydrogen ion loading (by acid precipitation) and heavy metals output. Extensive leaching in tropical soil can lead to losses of phosphorus as unavailable phosphate, resulting in reduced fertility of old soils. There must be innumerable problems associated with such degradation in developing countries in the tropics which remain to be identified. The following examples are given to illustrate the diversity of the pollution encountered.

Soil samples collected from Khetri, India (copper mining and refining town) and Zawar, India (lead and zinc mining town) have been found to be highly enriched with Cu, Pb, and Zn. In Khetri up to 150 ppm Cu is found in soils used for agriculture. In Zawar, Pb and Zn levels could reach levels as high as 1000 ppm (*see* Table 3.4.28) (Haque and Subramanian, 1982). The significance of soil pollution by these metals must be assessed in relation to observations on the differential effect of copper on root growth and shoot growth (Gupta and Mukherji, 1971), as well as the effects on seed germination (Mukherji and Ganguli, 1974; Mukherji and Gupta, 1972; Mukherji and Maitra, 1976). Trace element levels in some representative Indian soils are given in Table 3.4.29.

Considerable amounts of waste water from human settlements are applied to soil for irrigation purposes to recycle the nutrients. The hazards associated with using untreated sewage are evident from the data on increased accumulation of Pb and Cd, not only in the soil but also in the food and vegetable crops

Table 3.4.28 Metal concentration in soils, water, and plants from copper and lead/zinc mining areas in India

(a) Soil

	Exchange (ppm)			Plant available (ppm)			Total available (ppm)		
	Cu	Pb	Zn	Cu	Pb	Zn	Cu	Pb	Zn
	(Ranges for soils from different locations in the mining and refining sites)								
Khetri Copper Mine	0–79	0–7	0–17	0–225	2–20	1–20	20–767	5–41	6–100
Zawar Pb-Zn Mine	0–2.4	0.3–12	1–18	0–44	6–92	35–335	6–127	75–130	60–1050

(b) Water

	Total dissolved (ppm)		
	Cu	Pb	Zn
(Ranges for different locations of the sampling stations)			
Khetri Copper Mine	0–125	0–0.42	0–1.9
Zawar Pb-Zn Mine	0–0.82	0–1.31	0–6.32

(c) Plants

	Total in Plants (ppm)		
	Cu	Pb	Zn
(Ranges for different plants species and for different parts)			
Khetri Copper Mine	6–972	5–30	15–450
Zawar Pb-Zn Mine	3–105	24–951	31–766

Table 3.4.29 Trace elements (ppm) in some Indian soils. From Haque and Subramanian (1982)

Type of Soil	Mn	Cu	Zn	Co	Mo
Black	1081.6	156.0	72.2	47.0	1.5
Black	1426.0	82.5	59.6	38.1	1.84
Red loam	575.6	–	–	–	–
Laterite	805.0	28.0	66.0	36.4	1.28
Alluvial (acidic)	391.0	35.1	76.6	8.0	1.57
Alluvial (alkaline)	495.0	35.3	49.5	29.4	3.01

Table 3.4.30 Cd and Pb content of crops grown on soil irrigated by tubewell and sewage water. Data from Kansal and Singh (1983). Reproduced with permission of CEP Consultants Ltd

	Cd (μg/g dry matter)				
	Maize	Berseem	Cauliflower heads	Cauliflower leaves	Spinach
Tubewell irrigated	0.85	0.69	0.48	0.80	0.50
Sewage irrigated	1.74	1.67	1.60	2.24	2.59
	Pb (μg/g dry matter)				
Tubewell irrigated	1.98	1.93	1.27	2.69	3.29
Sewage irrigated	3.82	4.48	1.80	5.23	6.08

Table 3.4.31 DTPA extractable Cd and Pb (μg/g) in soils receiving tubewell and sewage irrigation. Data from Kansal and Singh (1983). Reproduced with permission of CEP Consultants Ltd

	Cd	Pb
Tubewell irrigation	0.05	0.10
Sewage irrigation*	0.10	1.28

*Average value for six samples from three towns in Punjab where sewage irrigation is used

grown on them. Some illustrative data from Punjab, India are given in Tables 3.4.30 and 3.4.31.

3.4.7.5 Contamination of Food

By and large one of the most serious ecotoxicological consequences of the diffusion of chemicals in the environment is the accumulation in the food chain of recalcitrant chemicals and toxic metals. With the increasing application of pest control chemicals in agriculture there is evidence of accumulation of pesticides in a variety of food and cash crops. The voluminous data in the literature pertaining to the Indian situation has been used recently to present an overview of the problems of residues in foods (Krishna Murti, 1984c). The content of cadmium in common foodstuffs grown in Punjab, India with a relatively high rate of fertilizer application ranges from 0.033 to 2.0 μg/g dry matter (Nath *et al.*, 1982). In the absence of agencies which can regularly monitor the levels of pollutants in foods, it is futile to draw inferences on the levels of contaminants and their impact on health. The problems related to interaction between diverse pollutants, such as mycotoxins, heavy metals, or recalcitrant organic chemicals in the environmental media, including food, remain to be identified.

3.4.8 PERSPECTIVES

Inventories of production, consumption, and diffusion of toxic chemicals have to be continuously updated in order to make reliable estimates of exposure to these chemicals. Although information on the production of aromatics in India for the year 1984–85 from coal carbonization (Table 3.4.32) is available, it is difficult to obtain related information on utilization and ultimate disposal. Similarly, almost the entire quantity of synthetic dyes is produced in one region but their use is spread over thousands of small fabric dyeing units situated all over the country. In regard to pesticides the problem of computing actual use in agriculture is even more acute. Inventories can only be a baseline source of information which has to be supplemented by monitoring programmes designed to give information on levels of selected chemicals in environmental compartments. Exposure can be due to both intentional use as well as by contamination due to various causes.

Table 3.4.32 Aromatics generated from coal carbonization in India, 1984–85

	(Million tonnes)
Coal carbonization on dry basis	16.19
Primary products, crude tar	0.40
Ammonium sulphate	0.15
Crude benzol	0.10
Secondary	
Naphthalene (tonnes)	18 552
Phenol Cresol	250
Anthracene	5230
Pitch	59 200
Tar oils	19 100
Coal tar fuel (million tonnes)	0.34
Benzol products	
Benzene (thousand litres)	68 011
Toluene	9746
Solvents	3397

While it may be relatively simple to compile data on production and consumption, the task of getting reliable information on disposal of wastes from industries or human settlements and their environmental fate is beset with innumerable difficulties. The present review has attempted to highlight the absence of documented data in most of the countries in the tropical or semi-tropical regions.

The examples used here are drawn mostly from the Indian situation, which may not be typical of all developing countries or of all countries in the semi-tropical region. Nevertheless the information can presumably be used to develop guidelines for more meaningful studies. Such studies have to be purposefully oriented towards the objective of helping the countries of the region to devise control measures for preventing the ecotoxicological effects of environmental chemicals. To illustrate this, one may take the example of the use of coal in steel-making in a country like India. By the year 1990, the coal requirements of the steel industry for producing metallurgical coke alone will be 40 million tonnes per annum. Waste discharge at an average rate of 0.25 m^3 per tonne of coal processed will be 10 million m^3 with an average daily discharge of 27 400 m^3. A population of four million living up to 100 km downstream along the Damodar River is likely to be exposed in the Durgapur-Asansol steel complex area, and a population of one million downstream of the Subarnamukhi by the discharge from the steel complex in Jamshedpur.

A recent press notice issued by the Ministry of Industry, Government of India, on environmental clearance of industrial licences prescribes the conditions for the issue of letters of Intent/Industrial Licence. A list of 18 industries has been prepared where it has become obligatory not only to install suitable pollution control equipment but also to identify the site and location of the project. The list includes: primary metallurgical producing industries, vis. zinc, lead, copper, aluminium, and steel; paper; pesticides/insecticides; refiners; fertilizer plants; paints; dyes; leather tanning; rayon; sodium/potassium cyanide; basic drugs; foundry; batteries; alkalis/acids; plastics; rubber; cement; asbestos.

The Central Board of Prevention and Control of Pollution has undertaken investigations on the extent of pollution of the major water bodies, in order to compile inventories of major and minor polluting industries as well as guidelines for waste water and effluent treatment. The Department of Environment, Government of India, has initiated an Integrated Environmental Programme on Heavy Metals to assess the existing levels of ten metallic elements of environmental significance. It is essential to know of the plans or progress of similar efforts in other countries where the climatic features are the same.

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