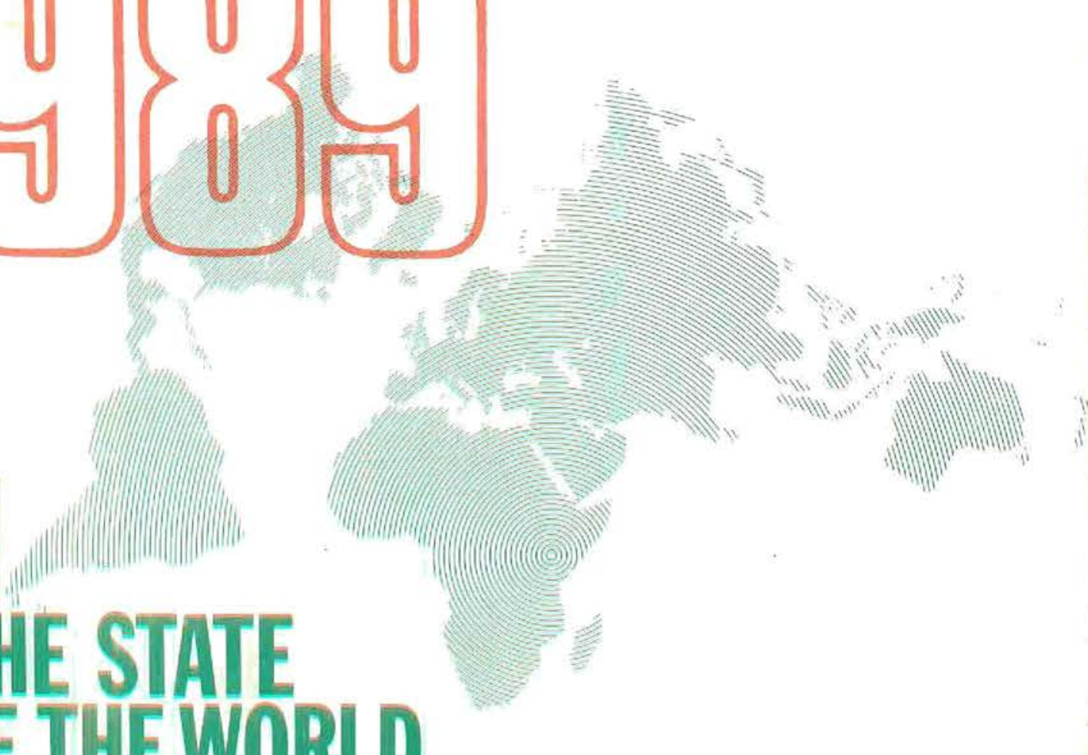
United Nations Environment Programme

1989



THE STATE
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April 1989

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UNEP/GC.15/7/Add.2

Printed by United Nations Environment Programme
P.O. Box 30552, Nairobi, Kenya

ISBN 92 807 12187 ISSN 0252 3310

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PREFACE

One of the main functions assigned to the Governing Council of the United Nations Environment Programme by the General Assembly in resolution 2997 (XXVII) of 15 December 1972 is:

> *"To keep under review the world environmental situation in order to ensure that emerging environmental problems of wide international significance receive appropriate and adequate consideration by Governments."*

Accordingly, the United Nations Environment Programme issues each year a report on the state of the environment.

At its thirteenth session, the Governing Council of UNEP decided that the state-of-the-environment reports should alternate in successive years between a report on economic and social aspects of the environment and a report on environmental data and assessment (decision 13/9 D, para. 2). Accordingly, UNEP published in 1986 a state-of-the-environment report dealing with health and environment, and in 1987 a report on the state of the world environment in which the changes that took place in the environment in the period 1981-1986 were discussed. In 1988, the state-of-the-environment report dealt with the public and environment.

At its fourteenth session, the Governing Council of UNEP decided that the 1989 state-of-the-environment report should be an update of the 1987 report on the state of the world environment with more in-depth treatment of specific subject and/or geographical areas (decision 14/9 B, para. 7).

The present report has been prepared in compliance with that decision. The report highlights the developments that took place since 1987 and as such, it complements the 1987 state of the world environment report. Two topics that have been receiving world-wide attention have been selected for in-depth treatment. These are: (a) possible climatic changes due to increase in emission of carbon dioxide and other trace gases—known as the greenhouse gases—and the environmental consequences of such changes, and (b) hazardous wastes and their management.

In the preparation of this report we have relied on relevant information included in reports published by GEMS and other units of UNEP, other United Nations bodies, regional intergovernmental and non-governmental organizations, and some scientific institutions in addition to scientific publications. It should be noted that in most time-series analyses data are only available up to 1985 or 1986, since it normally takes one to two years before such data are completed and published. A major publication which should be read in conjunction with this report is the "World Resources, 1988-1989" report, prepared by WRI and IIED in collaboration with UNEP.

Mostafa Kamal Tolba
Executive Director
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Nairobi, February 1989

SUMMARY

Environmental indicators reveal mixed signals: improvement, stabilization, and deterioration. Thus, air quality monitoring shows that levels of sulphur dioxide, suspended particulate matter, nitrogen oxides, and carbon monoxide emissions declined or at least stabilized in most urban areas as a result of environmental control measures introduced since the 1970s. Yet cities like Milan, Tehran, Seoul, Rio de Janeiro, Sao Paulo, Paris, Beijing, Madrid and Manila still have ambient sulphur dioxide in the air above the upper exposure limit established by WHO, while such cities as Kuwait, New Delhi, Beijing, Calcutta, Tehran, Jakarta, Shanghai and Bangkok have ambient suspended particulate matter above the upper WHO level. Cities in the developing countries are generally more polluted with sulphur dioxide and suspended particulate matter than most of their counterparts in developed countries. World-wide, about half of the population of urban areas—some 990 million people—live in areas with marginal or unacceptable levels of sulphur dioxide in the air.

Acidic deposition continues to be a major international environmental issue. It threatens fisheries, agriculture and wildlife, and has been implicated as one of the reasons behind the extensive dieback of forests in Europe and elsewhere. In 1987 the Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution entered into force, requiring participating nations to reduce either national sulphur emissions or their transboundary flows by 30 per cent from 1980 levels by 1993. This marks a milestone in efforts to reduce pollution by sulphur oxides.

Concern over the possibility of chlorofluorocarbons (CFCs) reducing stratospheric ozone triggered extensive research and action, culminating in the adoption of the Montreal Protocol on substances that deplete the ozone layer in 1987. The protocol—a landmark in international co-operation to protect the environment—came into force on 1 January 1989.

The overall quality of water in rivers and streams is generally satisfactory. Data show that about 10 per cent of the rivers monitored are polluted, in terms of their biological oxygen demand and chemical oxygen demand. Nearly all rivers, however, contain high amounts of nutrients. European rivers contain nitrates 45 times higher than the natural average for unpolluted rivers, while rivers outside Europe contain nitrates 2.5 times higher than the background. Although the concentration of organic pollutants is generally low in most rivers, some contain high concentrations of pesticides and/or polychlorinated biphenyls.

The state of water supply and sanitation continues to be a matter of deep concern. In 1985, only 42 per cent of the world's rural population and 75 per cent of its urban people had access to clean water. In the same year, only 16 per cent of the rural population and 59 per cent of those living in urban areas were provided with adequate sanitation services. The progress in achieving the goals set by the International Drinking Water Supply and Sanitation Decade (1981-1990) has been slow; the objective of providing all people with clean water supplies and adequate sanitation facilities by 1990 will not be realized. The unfavourable world economic situation and the debt burden of developing countries are among the main factors slowing down investments in infrastructure projects for drinking water and sanitation.

Concern over marine pollution, especially in coastal areas and regional seas continues. By 1988 there were 820 marine and coastal protected areas in the world, varying in size from less than a square kilometre to hundreds of thousands of square kilometres. The outbreak of algal blooms in 1987 and in 1988, whether due to natural factors or triggered by pollution, deepened concern about marine pollution. In 1987, eight North Sea countries agreed to reduce waste incineration in the sea by at least 65 per cent by the end of 1990—and to phase it out by 1994. In

December 1988, an international agreement to stop ships dumping plastic debris in the ocean (Annex V to MARPOL) took effect.

Soil degradation continues to be a major environmental problem in many countries. The Global Assessment of Soil Degradation initiated by UNEP in 1987 will considerably improve knowledge of its extent.

The Tropical Forestry Action Plan, initiated in 1985, is slowly gaining recognition from concerned countries. An intergovernmental meeting convened in Bellagio in 1987 listed several measures to alleviate deforestation. The International Tropical Timber Agreement which came into force in 1985 under the auspices of UNCTAD is now being implemented by the International Tropical Timber Organization (ITTO) established in 1987. Ecological considerations have now been firmly embedded in the ITTO's objectives and activities largely due to the efforts of UNEP, IUCN, WWF and many NGOs.

Rapid destruction of natural environments is reducing the number of species and the amount of genetic variation within individual species. So biological diversity is declining. If this trend is not halted and reversed, it could have serious and far-reaching repercussions for humanity. Biological diversity must be seen as a global resource, like the atmosphere or the oceans. All nations have a common interest in it and all have a common responsibility towards it. Despite such action as has already been taken to promote conservation, there is a pressing need for a comprehensive strategy, including a global convention to provide a strong legal basis for international co-operation in conserving biological diversity.

The world's population continues to grow rapidly. It passed the 5 billion mark in 1987 and is expected to reach 6 billion by the year 2000. Substantial progress has been made in improving health conditions throughout the world. Infant mortality has fallen and life expectancy risen in almost every nation. Yet there are still big gaps between the rich and the poor and between developed and developing countries.

World-wide, agricultural production outpaced population growth between 1980 and 1985; it increased by 4 per cent per person. However, substantial regional differences exist. Per capita food production in Asia grew 12 per cent between 1980 and 1985, but fell by 5 per cent in many African countries over the same period. The per capita supply of food generally improved (2660 calories per capita per day in 1985 as compared to 2450 in 1971), but nevertheless about 500 million people are estimated to have remained undernourished in 1985 and the number may reach 550 million in 2000.

Economic turbulence and uncertainty persist as the 1980s draw to a close. The global economy remains fragile despite reasonable short-term growth prospects. Poverty is rising. Since 1980 things have gone from bad to worse in most developing countries: economic growth rates have slowed, real wages have dropped, and employment growth has faltered. All this has serious implications for the environment. Economic problems cause or aggravate environmental despoliation and this, in turn, makes economic and structural reform difficult to achieve. Given the prevailing environmental degradation and economic confusion, it will be extremely difficult to put the world on the path to sustainable development. A breakthrough could, however, be achieved by tackling two fundamental barriers. The arms race, with its insatiable demands on global, financial, material and intellectual resources, must be slowed. And the appaling debt burden of developing countries, totalling more than $1,000 billion, must be alleviated.

Focus on: Greenhouse Gases and Climate

Recent climate models indicate that global mean equilibrium surface temperature is likely to rise by 1.5°C due to increases of greenhouse gases equivalent to a doubling of the atmospheric carbon dioxide concentration. A global warming in this range would lead to the seas rising by

20-140 cm; a rise in the upper portion of this range would have major direct effects on coastal areas and estuaries, with far-reaching environmental, economic and social implications for many countries. Global warming will also cause regional climatic changes and affect terrestrial ecosystems and agriculture.

Focus on: Hazardous Waste

The disposal of hazardous waste has become a difficult and controversial problem. In many cases the present disposal methods are not reliable enough to preclude any risk to humanity and the environment. Thousands of landfill sites and surface impoundments used for dumping of hazardous wastes have recently been found to be entirely unsatisfactory. Remedial actions undertaken in the United States of America, Denmark, Federal Republic of Germany and the Netherlands are costing billions of United States dollars. The recent uncovering of the dumping of hazardous wastes in some African countries, has triggered widespread concern culminating in UNEP's formulation of a global convention to control transboundary movements of hazardous wastes. The convention was adopted in March 1989.

Many technologies are available to deal with hazardous wastes. Waste prevention or reduction is the best. Reducing waste at its source, recycling it and reusing it can all cut the amount that needs treatment and disposal. More vigorous research and development is needed to develop cost-effective methods of managing hazardous wastes.

PART I
STATE OF THE ENVIRONMENT

Chapter 1
ENVIRONMENTAL QUALITY

1. Air Quality and Atmospheric Issues

A. Air Quality

1. Air pollution has long been a major environmental problem in most countries, especially in urban and industrial areas; but it has only evolved as a problem of regional and international importance in recent years—particularly since the 1970s. It affects human health, agriculture, forest growth, water resources and buildings and structures—and it is costly. Air pollution damage in France, for example, is estimated to amount to 1 per cent of the gross national product (GDP)—2 per cent of GDP in the Netherlands (1).

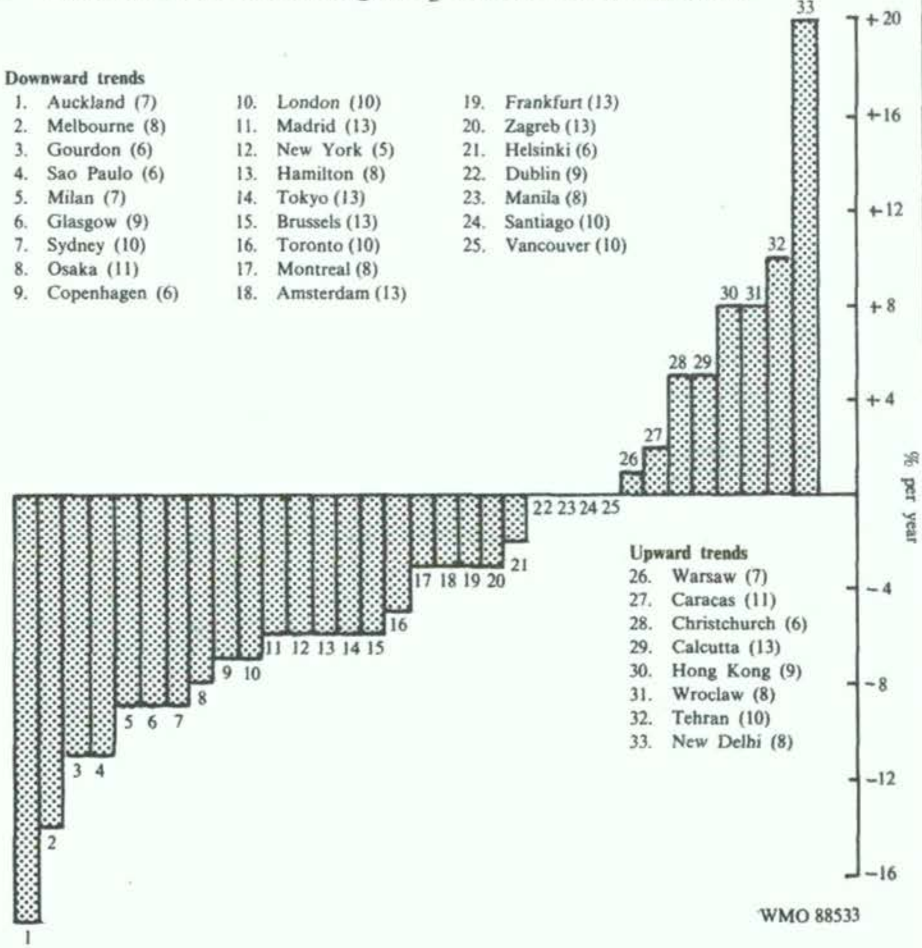
2. Concern about air pollution has triggered national and international action. Programmes have been established, especially in developed countries, to monitor and assess air quality, observe trends, and assess the relationship between pollution and human health. In 1973, WHO set up a global programme to assist countries in operational air pollution monitoring, improve the practical use of data in relation to the protection of human health, and promote the exchange of information. This air monitoring project became a part of UNEP's Global Environmental Monitoring System (GEMS) in 1976. Some 50 countries now participate in the GEMS/Air monitoring project and data are obtained at approximately 175 sites in 75 cities, 25 of them in developing countries. There are three GEMS/Air monitoring stations in most cities: one in an industrial zone, one in a commercial area and one in residential neighbourhood. The data from these stations permit a reasonable evaluation both of minimum and maximum levels, and of long-term trends of average concentrations. So far these measurements have been limited to sulphur dioxide and suspended particulate matter as indicators of pollution in urban areas. The following trends in air quality are based on the latest available information contained in the OECD Environmental Data Compendium (2) and GEMS recent assessment of urban air quality (3). The latter has been carried out for all cities in the GEMS/Air network with 5 or more years of representative annual averages between 1973 and 1985. No data are available in either the OECD Compendium or the GEMS assessment after 1985.

3. *Sulphur dioxide* (SO_2) emissions have fallen in most industrialized countries as a result of air pollution control measures. During 1970-1985, SO_2 emissions fell by 27 per cent in the United States of America, 38 per cent in France, 41 per cent in Canada, 42 per cent in the United Kingdom and 66 per cent in the Netherlands (2). In September 1987 the Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution came into force. This requires participating nations to reduce either their national sulphur emissions or their transboundary flows by 30 per cent from 1980 levels, by 1993. It is a milestone in air pollution control and will lead to further reductions in SO_2 emissions.

4. Sulphur dioxide concentrations appear to be declining—remaining stationary—in 25 out of 33 cities with 5 or more years of representative annual averages assessed by the

GEMS/Air programme (3) (Fig. 1). It is increasing in the other eight: New Delhi, Tehran, Wroclaw, Hong Kong, Calcutta, Christchurch, Caracas and Warsaw. The WHO specified of 40-60 $\mu g/m^3$ annual mean to avoid any risk of increased respiratory illnesses from long-term exposures (4). Data from GEMS/Air for 54 cities for (1980-1984) indicate that 27 of them (50 per cent)—including Auckland, Bucharest, Toronto, Bangkok, Chicago, Munich and Helsinki—have acceptable air quality with SO_2 concentrations below $40 \mu g/m^3$). Eleven cities (20 per cent)—including Dublin, Hong Kong, Shanghai, New York and London—have marginal air quality (SO_2 concentrations between 40 and $60 \mu g/m^3$. The

Fig. 1 Trends in annual average SO_2 concentration in cities



Source: (3)

other 16 (30 per cent) including Milan, Tehran, Seoul, Rio de Janeiro, Sao Paulo, Paris, Beijing, Madrid and Manila—have unacceptable air quality with SO_2 concentrations exceeding 60 µg/,³. These figures, extrapolated worldwide, suggest that some 990 million people—half the 1.98 billion living in urban areas in 1985 (5)—have to live in areas with marginal or unacceptable levels of SO_2 in the air.

5. *Emissions of suspended particulate matter (SPM)* have also fallen in most industrialized countries from 1970 to 1985 (1, 2)—particularly in recent years. There are exceptions, such as Ireland and Poland, where SPM emissions have increased (3). Monitoring data obtained through the GEMS/Air Programme indicate that out of 37 cities (with at least five years of representative annual average values between 1973 and 1985) SPM emissions fell in 19 cities (51 per cent), remained more or less stable in 12 (32 per cent), and rose in 6 (16 per cent) (Fig.2). Concentrations in Glasgow, Chicago, Houston and Madrid improved markedly. They got worse, for example in, Copenhagen, Bangkok, Santiago, Dublin and Warsaw. Data are available for 54 cities in the period 1980-1984 in the GEMS/Air network. The data show that about 60 per cent of them—including Kuwait, New Delhi, Beijing, Calcutta, Tehran, Jakarta, Shanghai and Bangkok had annual SPM averages consistently higher than 90 $\mu g/m^3$, the upper exposure level established by WHO for health effects related to long-term exposure (4, 6). 24 per cent had SPM concentrations within the WHO guideline values (60-90 $\mu g/m^3$), and only 16 per cent were below the lower exposure limit (60 $\mu g/m^3$). The cities with low concentrations are: Frankfurt, Copenhagen, Cali, Osaka, Tokyo, New York and Vancouver—though time-series data by OECD (2) indicate that Oslo, London and Stockholm also belong to this group. Although there was a marked decline of SPM in Brussells, from 1980 to 1985, concentrations are still above the upper limit of the WHO guidelines.

6. Emissions of *nitrogen oxides* NO_x have remained fairly constant over the period 1970-1985 (1, 2) in many developed countries. Time-series data given by OECD (2) show that NO_2 levels were higher in 1985 than in 1980 in London, Vienna and Wiesbaden but were lower in New York, Tokyo and Montreal. Data gathered from various sources for cities reporting at least five years of representative annual average values between 1973 and 1985 (3) show that nitrogen dioxide (NO_2) levels are rising in several of large European cities including London, Frankfurt and Amsterdam (Fig. 3). Annual average levels of NO_2 determined for 42 cities between 1980 and 1984 ranged from about 20 to 90 $\mu g/m^3$ (3). The WHO has not specified an annual mean guideline value for NO_2 because the data from studies of long-term exposure were not considered sufficient (6).

However, the United States of America and Canada have set an annual National Air Quality standard of 100 $\mu g/m^3$. All but one of the cities (Sao Paulo) for which data are available remained consistenly below this level. The WHO has recently recommended 1-hour and 24-hour guideline values of 400 $\mu g/m^3$ and 150 $\mu g/m^3$ NO_2 respectively that should not be exceeded (6). A significant number of sites in cities where NO_2 data is available showed higher levels between 1980 and 1984. Amsterdam, Munich, Jerusalem and Rotterdam were among cities that exceeded the 1-hour guideline at least once in the five years. Sydney, Santiago and Hamilton were among those that exceeded the 24-hour guideline. Tel Aviv exceeded both guidelines.

7. Total *carbon monoxide (CO)* emissions declined in some countries, including the United States of America, the Netherlands and Ireland, between 1980 and 1985 but increased in others, like the United Kingdom where emissions rose by 5.2 per cent (2). Data gathered from different sources for 15 cities between 1980 and 1984 show that all exceeded the WHO guideline (8-hour CO concentration of 10 mg/m^3) (3, 6) at some time during that period. In 8 of them—Paris, Brisbane, Sao Paulo, Los Angeles, Melbourne, New York, Chicago and

Fig. 2 Trends in annual average particulate concentrations in cities.

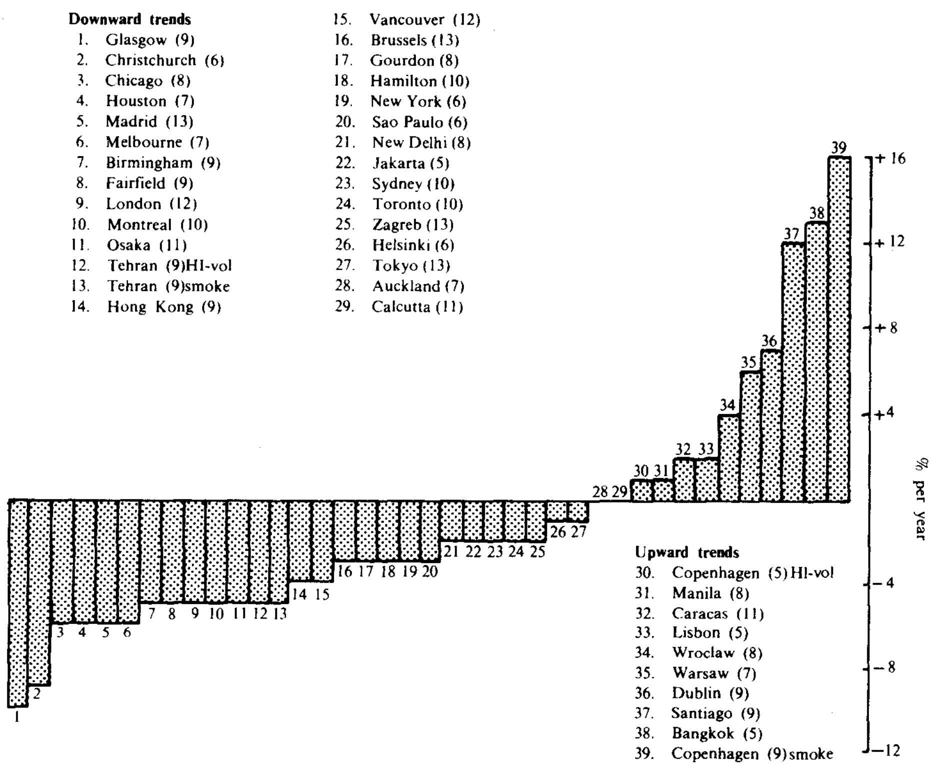


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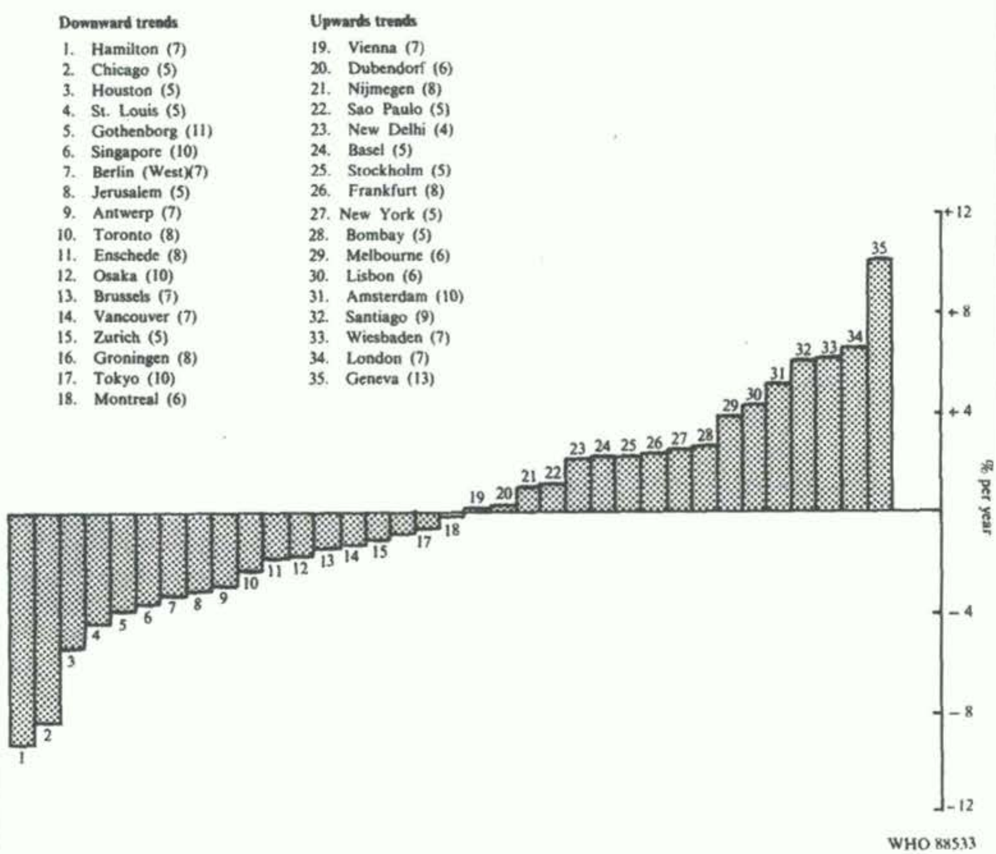
Fig. 3 Trends in annual average $N0_2$ concentrations in cities.



Toronto—the *average* 8-hour CO concentrations over the five year period exceeded the WHO guideline.

B. Acidic Deposition

8. Acidic deposition continues to be a major international environmental issue. A considerable body of evidence shows that it threatens fisheries, forestry, agriculture and wildlife (see the UNEP State of Environment-1987 for details). Recent studies show that acid fog is stronger than acidic precipitation and constitutes an important, and hitherto neglected, portion of the deposition (see UNEP/GC.15/7/Add.3).

9. The signing of the Convention on Long-range Transboundary Air Pollution in 1979 demonstrated the determination of different countries to work together to cut back sulphur and nitrogen oxide emissions (the main agents of acidic deposition) to acceptable levels. In 1987, the Protocol to the Convention,—which requires participating nations to reduce either national sulphur emissions or their transboundary flows by 30 per cent from 1980 levels by 1993—entered into force, further stressing international willingness to co-operate to control the pollution.

C. Stratospheric Ozone

10. Ozone (O_3) acts as a natural filter in the stratosphere absorbing the sun's harmful ultraviolet radiation (UV). Human activities add compounds to the atmosphere that upset the balance between the production and destruction of ozone. The most important are chlorofluorocarbons, halons, carbon tetrachloride, and methyl chloroform. All are chemically inert in the lower atmosphere, and drift up to the stratosphere. There ultraviolet radiation attacks them, releasing chlorine and bromine, which act as catalysts to destroy ozone.

11. Extensive research over the past few years, has greatly improved our understanding of the nature of stratospheric ozone and the processes that deplete it. Recent studies (7, 8) have shown that total column ozone amounts over Antarctica have decreased by 30 to 40 per cent in the springtime (September through November) over the last decade. The phenomenon is known at the Antarctic ozone hole. Current theories suggest that it is caused by man-made chemicals and previously unknown reactions associated with the cold Antarctic stratosphere. Satellite ozone data from the Total Ozone Mapping Spectrometer (TOMS) from 1979 through 1986 show that total ozone has recently decreased world-wide. Global mean total ozone fell by about 5 per cent over the eight years from 1979 to 1986.

In the tropics the trend is nearly independent of season and ranges about between -0.5 and -1.0 per cent per year. Outside them the losses generally vary seasonally, and increase with latitude, becoming greatest at the poles. A recent study (9) revealed that ozone levels had fallen since 1969 by about 2 per cent in temperate latitudes in summer. In winter the reductions in the ozone layer were much greater—around 6 per cent at latitudes between 53°N and 64°N and around 4.7 per cent between 40°N and 52°N.

12. Recent reports (10) point to the formation of another hole in the ozone layer over the Arctic. The Arctic ozone hole is half the size of its Antarctic counterpart; but it similarly occurs in late winter and early spring. Data from ozonesonde and TOMS showed it was present during the winter of 1985-1986, and TOMS images suggest it also formed in 1981-1982 and 1983-1984. In the winter of 1986-1987, however, there was no ozone hole over the Arctic. The preliminary results of the study of the Arctic ozone during the winter of 1988-1989 confirmed the occurrence of the phenomena that could lead to a one per cent destruction of the Arctic ozone for every day in which the vortex stays over the North Pole.

13. Efforts to address the possible threats of ozone depletion led to the adoption of the Vienna Convention for the Protection of the Ozone Layer in 1985. The purpose of the Convention is to promote information exchange, research and systematic observations to protect human health and the environment against adverse effects resulting or likely to result from human activities which modify or are likely to modify the ozone layer. It was followed, in September 1987, by the Montreal Protocol on Substances that Deplete the Ozone Layer—a landmark in international co-operation to protect the environment. The Protocol set limits for production and consumption of the damaging CFCs and halons, so it will curb the levels of chlorine and bromine reaching the high atmosphere and damaging the ozone layer. It came into force on 1 January 1989.

14. Measures have already been taken in some countries to reduce or ban the use of the controlled CFCs in all or some products (e.g. non-essential aerosols). The United States of America took such restrictive measures long before the adoption of the Montreal Protocol, Canada, Sweden, Norway, Switzerland and Belgium have banned or drastically restricted the use of CFCs in non-essential aerosols (11). The Federal Republic of Germany plans to reduce its production of aerosols containing CFCs to 10 per cent by 1990. The Nordic countries decided to reach the 1998 50 per cent reduction goal of the Protocol at a much earlier date. Several governments are now advocating much higher targets for reduction of the production and use of the ozone-depleting substances over the next few years. The major CFCs producers are seeking alternatives to CFCs for foam blowing, refrigeration and air conditioning, solvents and other uses.

2. Water Quality

15. For thousands of years humanity has discharged untreated or inadequately treated wastewater into rivers, lakes and seas. More recently, industrial wastewaters have created new pollution problems. Toxic chemicals have killed aquatic biota and rendered waters useless for human use and for irrigation. The runoff of nutrients from agricultural lands has caused increasing eutrophication.

16. The GEMS Water Monitoring Project, launched in 1977, currently consists of 344 stations (240 river, 43 lake, and 61 groundwater stations) in 59 countries. It collects data for about 50 different indicators of water quality, including basic measurements such as dissolved oxygen (DO), biological oxygen demand (BOD), faecal coliforms and nitrates, as well as analyses of chemical trace constituents and contaminants. The available data base covers the period from 1979 to 1981 and from 1982 to 1984 (12).

17. Biological oxygen demand (BOD) and dissolved oxygen (DO) are the most commonly reported water quality variables in the GEMS network; 72 per cent of the stations report BOD, 86 per cent report DO. The chemical oxygen demand (COD) is measured at only 48 per cent of the stations. About 10 per cent of all the rivers monitored may be described as polluted, as they have a BOD of more than 6.5 mg/1 and a COD of more than 44 mg/1 (12). The two most important nutrients, nitrogen and phosphorus, are well above natural levels in the waters measured by the network. Rivers outside Europe contain 2.5 times as much nitrates as the natural average for unpolluted rivers (100 μg/l). Levels of nitrates in the European rivers are 45 times higher than natural background. The median phosphate level in GEMS/Water rivers is 2.5 times the average for unpolluted rivers (10 μg/l).

18. The organic pollutants measured by GEMS/Water consist of organochlorine pesticides and the polychlorinated biphenyls. Data obtained from about 25 per cent of the stations in operation during the period 1979-1984 show that the concentration of these

organic compounds are generally below 10 ng/l. Markedly higher levels, ranging from 100 to 1000 ng/l, were reported from the River Trent in the United Kingdom and several monitoring stations in Japan for PCBs and from the Chinese rivers of HCH isomers. Levels above 1000 ng/l were found in the rivers Rufigi in Tanzania (dieldrin, 30 µg/l), Canca Juanchito in Colombia (DDT, 1.2 µg/l; dieldrin 3.0 ug/l), Gombak in Malaysia (dieldrin, 30.6 µg/l) and all the monitoring stations in Indonesia (PCBs from 0.4 to 6.9 µg/l).

19. OECD time-series data (2) give a mixed picture of river quality. BOD has improved in some rivers—including the Mississipi, the Rhine (Federal Republic of Germany), the Meuse (Netherlands), the Thames and Severn (United Kingdom) and the Donau (Federal Republic of Germany—and deteriorated in others, such as The Delaware-Trenton (United States of America), Meuse-Heer (Belgium) and Elbe (Federal Republic of Germany). Nitrates increased in most major rivers from 1975 to 1985: for example, the NO_3-N increased in the Mississipi from 1.04 mg/l to 1.23 mg/l; in the Rhine from 3.02 to 4.20 mg/l; and in the River Po in Italy from 1.35 to 3.28 mg/l. On the other hand, phosphate concentrations either remained stable or declined slightly during the same period. In most OECD rivers there was a marked drop in concentrations of lead, cadmium, chromium and copper between 1975 and 1985 (2).

20. Phosphorus concentrations decreased in most lakes in the OECD countries from 1975 to 1985 (2). But NO_3-N concentration has increased during the same period, except in a few lakes such as Lake Biwa in Japan, Lake Erie in Canada, and Lake Orta in Italy.

The State of Water Supply and Sanitation

21. Large numbers of people especially in rural areas of the developing countries, still have no access to safe, clean water or sanitation services. The International Drinking Water Supply and Sanitation Decade (1981-1990), launched by the United Nations in 1980, aims to provide everyone with clean water supplies and adequate sanitation facilities by 1990. By 1985, only 42 per cent of the rural population and 75 per cent of the urban population had access to clean water, and only 16 per cent of the rural population and 59 per cent of the urban population had adequate sanitation services. The actual number of people supplied with clean water and sanitation facilities increased from 1980 to 1985, but almost in all developing countries, there has been only slow progress towards achieving the Decade's goals (13). This has been attributed to several factors including population growth, the unfavourable world economic situation and the debt burden of developing countries, which has been a major obstacle to investment in infra-structure projects.

3. The Marine Environment

22. Concern about the protection and rational management of coastal areas and marine resources has increased in many countries in the past few years. Designations of coastal or marine protected areas have gained momentum. One survey in 1986 identified approximately 1,000 of them in 87 countries (14), while a 1988 IUCN survey lists 820. Their size varies from less than a square kilometre to hundreds of thousands of square kilometres, and they may include coastal areas and small islands, coral reefs, estuaries, seagrass beds, and open water. They serve as sanctuaries, where fish and other marine organisms can feed, grow and breed, thus enhancing the variety and abundance of life. They also have scientific and educational value, and attract tourism.

23. Marine pollution, especially in coastal regions remains of concern to many countries. The outbreak of algal blooms in estuaries along the North Carolina coast in 1987 and in the seas around southern Scandinavia in 1988 increasingly focussed the attention of Governments on the need for marine environment protection: blooms can develop due to

disturbances in marine ecosystems triggered by climatic factors, but some have been accelerated by pollution. (see UNEP/GC.15/7/Add.3 for more details). The incineration of chemical wastes at sea has also triggered considerable concern. Between 1981 and 1984, European countries burned about 624,000 tonnes of wastes at sea. In 1987, eight North Sea countries agreed to reduce waste incineration in the sea by at least 65 per cent by the end of 1990 and to phase it out altogether by 1994 (15). In 1988, the United States of America suspended testing of incineration technologies at sea. An international agreement to prevent ships from dumping plastic debris in the ocean took effect in December 1988. The agreement, another important step in the protection of the marine environment, has been annexed (Annex V) to the International Convention for the Prevention of Pollution from Ships (MARPOL).

4. Land and Terrestrial Biota

24. Soil erosion has been reported from almost every country in the world. It has been estimated that humanity causes the loss of about 25,400 million tonnes of topsoil from world cropland every year (16). Declines in soil fertility—or even total losses of land to agriculture—are common in many parts of the world. Salinization, for example, affects extensive land areas in many countries in North Africa, the Middle East and Asia. About half the land under irrigation is affected by secondary salinization and/or alkalinization in varying degrees. The world-wide extent of soil degradation is not accurately known, but the Global Assessment of Soil Degradation initiated by UNEP in 1987 will considerably improve knowledge. In 1988, the IUCN adopted guidelines for rehabilitating or restoring degraded lands, and efforts are underway in some countries to address soil degradation in a rational way.

25. Deforestation is the most powerful factor in accelerating the rate of soil degradation. On a global basis, the world's forests are disappearing at the rate of about 15 million hectares each year, mostly in Africa, Asia and Latin America. In the early 1980s, it is estimated 11.1 million hectares of forests were being felled each year in tropical countries (17). About 7.3 million hectares were tropical closed forests and the remaining 3.8 million hectares were open woodlands.

26. The Tropical Forestry Action Plan—initiated in 1985 to co-ordinate human needs, environmental management, and sustainable forest development—is slowly gaining recognition by concerned countries. An intergovernmental meeting convened in Bellagio, Italy in 1987 listed several steps to alleviate tropical deforestation and to promote sustainable exploitation of the world's forests. It has been suggested that nations should assess the value of their forest resources in a comprehensive way, and then reflect this into their national economic and development plans. Once the true costs of deforestation are realized, governments may follow a different path to protect forest ecosystems.

27. The International Tropical Timber Agreement which came into force in 1985 under the auspices of UNCTAD is now implemented by the International Tropical Timber Organization (ITTO) established at Yokohama in Japan in 1987. ITTO's main objectives are to improve market intelligence, to assist producing countries to develop better techniques for reforestation and forest management, to encourage increased timber processing in producing countries, and to support research and development programmes to achieve these goals. One of the most encouraging aspects of ITTO is that producing and consuming countries are working together towards sustainable management of tropical forests. Ecological considerations have now been firmly embedded in ITTO's objectives and activities largely due to the efforts of UNEP, IUCN, WWF and many environmental NGOs.

28. Animal and plant species are becoming extinct at an unprecedented rate due to the world-wide deterioration of natural environments. Nobody knows how many species live on the Earth (18). 1.4 million have been described, but there may be more than 30 million in all. More than half of all the world's species are believed to live in tropical rain forests, which cover only 7 per cent of the Earth's land surface. Their continuing destruction must be leading to the rapid extinction of thousands of species. Other species-rich biomes in danger worldwide include tropical coral reefs, geologically ancient lakes, and coastal wetlands.

29. Only a tiny fraction of species with potential economic importance have been utilized. Throughout history, for example, 7,000 kinds of plants have been grown or collected for food. Now only 20 of them supply 90 per cent of the world's food, and just three (wheat, maize, and rice) provide more than half. In most parts of the world, these few crops are grown in monocultures, which are particularly sensitive to insect attacks and disease. Yet tens of thousands of edible species—many possibly superior to those already in use,—remain unexploited. Moreover, the new field of biotechnology will undoubtedly speed up the development of available genetic resources and their use. This increases the need to maintain the richest possible pool of genes.

30. Rapid destruction of natural environments is reducing both the number of species and the amount of genetic variation within individual species. So biological diversity is declining. Most experts conclude that perhaps a quarter of the earth's total biological diversity, amounting to about a million species, is in serious risk of extinction over the next 20-30 years. On average 100 species would be lost per day. This is perhaps 1000 times greater than the historical rate of extinction. It has been estimated that if a forest is reduced to 10 per cent of its original size, the number of species that can continue to exist in it will eventually decline by half (19). Habitat reduction on this scale has already occurred in many parts of the tropics. If present levels of deforestation continue, it is projected that 12 per cent of the 700 bird species in the Amazon basin and 15 per cent of the plant species in all of South and Central America, will be lost within the coming century (20).

31. Biological diversity must be viewed as a global resource, like the atmosphere or the oceans; all nations have a common interest in it, all have a common responsibility towards it. Science is discovering new uses for it in ways that can relieve both human suffering and environmental destruction. The state of the world's biological diversity beyond 2050 will depend to a very large extent to what happens in the immediate future.

32. There is and there are a wide range of methods available on the need for conservation on international consensus. A global network of gene banks has been established to house the World Base Collection of crop germplasm; more than 100 countries are collaborating in it. Pilot data banks and conservation schemes have been developed to offer access to information on animal genetic resources and analysis of it. A global network of Microbiological Resources Centres (MIRCENs) now exercise regional responsibility for the collection, maintenance and application of microbial genetic resources. The first national parks were established more than a century ago, and many other types of protected areas have evolved in recent years. These range from scientific reserves to multiple-use areas such as biosphere reserves where some sustained utilization of natural resources is permitted. In 1920 there appear to have been 150 major protected areas in the world (2). In the following half century, 1362 protected areas were set up. In the 15 years from 1971 to 1985, another 2002 areas were established. The total of 3514 protected areas covered about 4 million square kilometres. They comprise: 526 scientific reserves, 1050 national parks, 70 national monuments, 1488 nature reserves and 380 protected landscape areas.

33. The World Conservation Strategy (WCS) published by IUCN, UNEP and WWF in 1980, the UNEP Environmental Perspective to the Year 2000 and Beyond, and the Report of

the World Commission on Environment and Development published in 1987 set three main objectives for all conservation policies and practices: to ensure the sustainable utilization of species and ecosystems; to maintain essential ecological processes and life-support systems, and, to conserve genetic diversity. The World Conservation Strategy emphasizes priorities for national action, including the formulation of national conservation strategies, but so far only about 35 countries have started to formulate them. A new revised global conservation strategy is now being prepared by UNEP, IUCN, and WWF to take into account recent developments and analyses. Known as the World Conservation Strategy for the 1990s, it is intended as an action plan for international conservation.

34. Compared with the magnitude of the problem, the action being taken by Governments and the international community to promote conservation and sustainable use of biological diversity is inadequate in the extreme. There is a pressing need for a comprehensive biodiversity strategy. This would include a global convention to provide a strong legal basis for international co-operation. The need for this has been emphasized by the Report of the World Commission on Environment and Development, by the General Assembly of IUCN in 1988 and by a UNEP *Ad Hoc* Expert Group convened in the same year. IUCN and UNEP would co-operate with other members of the Ecosystems Conservation Group in formulating such a convention for eventual adoption by Governments. A crucial issue would be how far governments are prepared to face the political and economic issues involved, such as, compensation for the conservation of genetic resources, use of part of the compensation for more active conservation, and access to this genetic resources in the field or in gene banks including those produced through biotechnology.

Chapter II

DEVELOPMENT AND ENVIRONMENT

35. The world's population continues to grow rapidly. It doubled from 2.5 to 5 billion between 1950 and 1987, and is expected to reach 6.12 billion by the year 2000 (21). The rate of population growth has been steadily falling over the last few years, both globally and in the developing countries as a whole. Nevertheless the number of people added to the human family is expected to increase from about 78 million a year at present to about 90 million annually in 2000. The world population may reach 8.2 billion by 2025 (according to the United Nations medium estimate) finally stabilising at 10.5 billion by the year 2110. About 95 per cent of the entire projected growth to the year 2110 is expected to take place in today's developing countries (22). Several developing countries will double, triple or quadruple their populations over the next 50 to 60 years.

36. While birth, death and infant mortality rates have fallen consistently, life expectancies have risen in a large number of countries. Some developed countries have already made the demographic transition to population equilibrium, with low birth and death rates and high life expectancies. Many other developed countries and a few developing countries, show definite movement toward stationary populations. However, regional differences exist. In East Asia, South-East Asia, Central America and the Caribbean, there have been marked declines in population growth rates in recent years. In Africa, by contrast, the growth rate has actually increased over the last decade, and is estimated at 3 per cent per year. In Asia, growth rates show significant differences from one sub-region to another. China, with a quarter of the world's population, has dramatically halved its population growth rate over the last decade. But China and other populous countries of the world (e.g. Brazil, India, Indonesia and Mexico) are estimated to account for 37 per cent of the total growth in the world's population between 1987 and 2007 (23).

37. Since 1980 there has been substantial progress in improving health conditions throughout the world. Infant mortality has fallen and life expectancy risen in almost every nation. Yet enormous gaps remain between the rich and the poor in developed and developing countries—and especially between the two groups of countries. Life expectancy at birth now exceeds 70 years throughout Europe, North America, Australia and New Zealand as well as in 10 Latin American nations, and 7 countries in Asia and the Near East. By contrast, average life expectancy in Africa is still below 50 years in 21 countries climbing above 60 in only 7 nations. Infant mortality rates have fallen in nearly 150 countries in the last decade. Finland, Iceland, Sweden and Japan have the lowest rates (6 per 1,000 live births). But childhood deaths remain high in developing countries, particularly in Africa and Asia. Infant mortality in 47 of the 159 countries for which data were available is still 100 or more per 1,000 live births (13). Diarrhoeal diseases, acute respiratory infections, malnutrition and the target diseases of the Expanded Programme on Immunization (diphtheria, pertussis, neonatal tetanus, poliomyelitis, measles and tuberculosis) are the principal causes of infant and child mortality and morbidity.

38. Growing numbers of people need more food, fuel, and other necessities of life. All of this must ultimately be supplied from the Earth's limited resources; this raises complex questions about the interrelations between people, resources, environment and development. World agricultural production has expanded by an average of 2.5 per cent a year over the past 25 years (24). Agricultural output grew significantly faster in developing countries as a

whole than in developed countries (3.2 per cent and 2.0 per cent a year, respectively). Between 1980 and 1985, gross world agricultural production increased by 13 per cent. The annual increase in agricultural production in developing countries was 3.9 per cent compared to 1.6 per cent in developed countries. World-wide, agricultural production outpaced population growth between 1980 and 1985, resulting in a 4 per cent increase per person. However, substantial regional differences exist. Per capita food production increased 12 per cent between 1980 and 1985 in Asia, but fell by 5 per cent in many African countries in the same period. The per capita grain production in Africa is still well below subsistence level (180 kg/person/year).

39. World-wide, average food availability rose from 2450 calories to 2660 calories per capita per day between 1971 and 1985. But there were marked differences within countries and between developed and developing countries (24). In developed countries, the average food availability rose from 3260 calories/capita/day in 1971 to 3370 in 1985; in developing countries as a whole it rose from 2110 to 2420 in the same period. But in sub-Saharan Africa, it declined from 2100 calories/capita/day to 2050. In most of the low-income countries, the very poor did not get enough food to lead a normal life. Per capita food supplies in these countries, excluding China and India, were no higher in 1985 than they had been 15 years earlier (2080 calories/capita/day). About 500 million people are estimated to have been undernourished in 1985 and the number may reach 550 million in 2000 (24). By another estimate, about 950 million people still consume too few calories each day to support an active working life (15). This situation has been created and aggravated by a combination of geographical, climatological, social, economic, environmental and political factors,—ranging from the inequitable access to resources and products to unfavourable natural conditions and primitive methods of production and processing of agricultural products in many areas.

40. The FAO estimates that world agriculture will have to increase output by about 40 per cent by the end of this century to keep pace with population growth (24). Three-quarters of this extra output will have to be produced in developing countries. There are two main approaches to raising agricultural production: increasing the area of cultivated land, and increasing yields. In most developing countries, the distribution of agricultural land reflects the distribution of wealth. Unequal distribution, combined with growing rural populations, exacerbate rural poverty. In 1987, FAO's World Conference on Agrarian Reform and Rural Development noted that the number of landless and near-landless people is growing in South-east Asia, Latin America, and Africa,—and is highest in South Asia. In addition, unused arable land is not always available to the people who need it most, while opening up new areas is expensive. Increasing the yield per unit of land by using modern agricultural technologies implies continuing intensive use of chemical fertilizers and pesticides and involves placing larger areas under monoculture and irrigation. The environment, and particularly sensitive ecosystems, will come under considerable strain. The nature and severity of the problems will vary amongst and within developing countries, but they will include deforestation, soil degradation and desertification, degradation of marginal lands, and water and soil pollution resulting from the excessive use of agrochemicals (24).

41. The industry plays a major role in the economic development of many countries. It provides employment for a large proportion of the population and supplies the material goods they consume. Industry's contribution to the gross domestic product (GDP) of low-income economies increased from 28 per cent in 1965 to 35 per cent in 1986. In middle-income economies, it grew from 33 per cent in 1965 to 36 per cent in 1986. In industrial market economies, on the other hand, the contribution of industry to GDP *decreased* from 40 per cent in 1965 to 35 per cent in 1986 (25). This can be attributed to the general downturn and stagnation in industrial output in these countries since 1979.

42. The developing countries' share of world manufacturing output remained virtually stagnant at around 12.7 per cent during the period 1980-1985, but increased slightly in 1986 and 1987 (26). Developing countries are now beset with problems—falling primary commodity prices, a rising burden of debt servicing, net capital outflows, protectionist barriers against entry into the markets of developed countries and the urgent demand to meet the rising needs of their people. All of them greatly impede industrial growth.

43. Industry includes a large number of activities involving the extraction, processing, synthesis and transportation of products. So it creates a wide range of environmental impacts. Industrial processes generate airborne emissions, water effluents, and solid wastes that can affect human health and the environment in many ways, though the composition and impacts of different industrial discharges vary considerably. Industrial accidents and their environmental consequences have become a major concern to many Governments. UNEP is in the process of consultation with governments, relevant members of the United Nations system and industry to conclude international agreements on the notification of industrial accidents and on mutual assistance when accidents occur. Concern has also recently increased over the transportation and disposal of hazardous wastes (see Chapter IV for focus on hazardous wastes).

44. The emergence of new technologies is one of the most important recent trends in industrial development. Robotics, automation, microelectronics, information technology, new materials and biotechnology, have provided the basis for and driving force behind both the development of new high technology industries and the modernization of existing production processes in traditional industries such as textiles and pulp and paper. Some of these technologies can reduce industrial discharges by using raw materials and energy more efficiently and through recycling. Advances in biotechnology for example, have led to improvements in the effectiveness and efficiency of treating industrial effluents, development in microelectronics have enabled greater control over production processes and hence increased in-plant recycling of waste streams and reduced production losses; and the development of environmental sensors has made it easier to monitor emissions in and around factories and so contributed to better protection of workers and the surrounding environment.

45. Such technological advances offer considerable potential for environmental improvement. Others—together with changes in the structure of industry and in the types of material used in production processes—are leading to the emergence of new types of pollution problems. There is a shift from traditional pollutants to more complex ones such as heavy metals, toxic air and water pollutants, and hazardous wastes. The environmental problems associated with new technologies remain to be assessed in detail. The implications of such technologies to the world economy and to the developing countries in particular is clearly of major importance.

Sustainable Development and Environmental Security

46. Economic turbulence and uncertainty persist as the 1980s draw to a close. The global economy remains fragile despite reasonable short-term growth prospects. The world economy in 1985 was characterized by modest expansion of production and disappointingly slow growth in international trade, after significant, but uneven, increases observed in 1984. Although average gross domestic product (GDP) in the industrial countries was marginally higher in 1987 than in 1986, it was well below the high levels of the 1950s and 1960s (25).

47. Inadequate external financing has been demonstrated once again since 1985. The vulnerability of many developing countries to external events increased their susceptibility while the slow-down in the growth of the developed countries was costly and untimely for all

those developing countries whose fortunes are closely tied to international trade. After some progress in 1984, these countries suffered a major set-back in 1985. The rate of increase in their exports fell significantly, their terms of trade worsened and, for many, interest rates rose sharply in real terms. The growth rate of GDP for the developing countries as a whole remains below 2.5 per cent per year. Nearly 60 per cent of the developing countries, in Africa and Latin America, have either stagnant or falling real per capita GDP.

48. Poverty is rising. Since 1980 things have gone from bad to worse in most developing countries: economic growth rates have slowed, real wages have dropped, and employment growth has faltered. Precipitous declines in commodity prices have cut rural incomes, and governments have reduced spending on social services in real terms. Comprehensive data on poverty are lacking, but scattered information from individual countries confirms a general impression of deteriorating social conditions in many developing countries (25). The number of people below the poverty line increased in several countries. There also has been a sharp and widespread reversal in the trend toward improvements in child health, nutrition and education. In 21 out of 35 low-income developing countries, the daily calorie supply per capita was lower in 1985 than in 1965. Life expectancy declined in some Sub-Saharan African countries.

49. The state of the world environment cannot be isolated from the state of the world economy. The world community is confronted by a closed cycle: economic problems cause or aggravate environmental despoliation which, in turn, makes economic and structural reform difficult to achieve. If the world continues to accept disappearing tree cover, land degradation, the expansion of deserts, the loss of plant and animal species, air and water pollution, and the changing chemistry of the atmosphere it will also have to accept economic decline and social disintegration. In a world where progress depends on a complex set of national and international economic ties, such disintegration would bring human suffering on a scale that has no precedent (27). The threat posed by continuing environmental deterioration is no longer a hypothetical: it threatens the security not only of this generation but of future ones as well.

50. The concept of sustainable development has been repeatedly emphasized since the late 1960s, at fora discussing the relationship between people, resources, environment and development. The Cocoyoc Symposium on Patterns of Resource Use, Environment and Development Strategies, which was jointly organized by UNEP and UNCTAD in Mexico in 1974, declared that "This generation should have the vision to take account of the needs of future generations and not so pre-empt the planet's limited resources, and so pollute its life supporting systems, that the future well-being of man, even his existence, was jeopardized". The World Commission on Environment and Development re-emphasized the need for sustainable development in its report published in 1987.

51. Sustainable development requires that current practices should not diminish future possibilities of maintaining or improving living standards. It does not require the preservation of the current stock of natural resources or any particular mix of human, physical and natural assets. Nor does it place artificial limits on economic growth, provided that such growth is both economically and environmentally sustainable. But it does require economic systems to be managed so as to maintain or improve the resource and environmental base so that future generations can live as well or better than we do.

52. Putting the world on the path of sustainable development will not be easy, given the environmental degradation and economic confusion that now prevail. The planning and implementation of development initiatives will have to change significantly, the global economy will have to be fundamentally restructured, and there will have to be a quantum leap in international co-operation. Unless the desire to ensure a sustainable future becomes

a central concern of national governments, the continuing deterioration of the economy's natural support systems will eventually overwhelm efforts to improve the human condition (27).

53. Two further barriers now stand in the way of ensuring that the necessary capital and political will are available. One is the profound misallocation of capital implicit in global military expenditures of about $900 billion each year. The other is the unmanageable Third World debt—now totalling about $1,000 billion. Unless these obstacles are overcome, the funds needed to ensure sustainable development will not be available.

PART II

FOCUS ON: GREENHOUSE GASES AND CLIMATE

Chapter III

GREENHOUSE GASES AND CLIMATE

54. If the world's atmosphere did not act naturally like a greenhouse, life on earth would not be possible. Without its protection against cosmic frosts, living things would wither and die on a planet with a surface temperature of minus 20°C. The atmosphere keeps us warm, like glass in a greenhouse.

55. Sunlight heats up the sea, land and vegetation. The warmed surface of the earth then radiates heat back towards space, but this outward flow of radiation is at much longer wavelengths than sunlight, in the infrared part of the spectrum. On its way out some of this infrared radiation is absorbed by trace gases. Nitrogen and oxygen, making up approximately 20 per cent and 80 per cent of the atmosphere, are transparent at infrared wavelengths and play no part in the process. But relatively tiny amounts of the trace gases—notably carbon dioxide and water vapour—play a far more important part than their low concentrations would suggest, trapping the heat that keeps the planet inhabitable.

56. The natural greenhouse effect of carbon dioxide on the climate has been known for more than a century. But it is only relatively recently that widespread attention has been given to the prospect that human activities can accentuate it and cause a global warming of the climate, with serious environmental, economic and social repercussions for the present and future generations. Human activities are artificially increasing the amount of carbon dioxide and other greenhouse gases in the atmosphere, disturbing their natural geochemical cycles. It is now generally accepted that increasing greenhouse gases in the atmosphere will make the Earth warmer. But the rate of this global warming, its regional distribution, and its impacts remain the subject of widespread discussion.

Greenhouse Gases

Carbon dioxide

57. Nature keeps carbon dioxide in balance. Natural processes produce vast amounts of the gas; terrestrial life emits about 100,000 million tonnes of carbon a year, simply by breathing, while decomposing vegetation releases another 2,000 million to 5,000 million tonnes annually (29, 30). But natural photosynthesis takes up almost the same amount as these processes release. Human activities are upsetting the balance in two ways. First they release extra carbon dioxide by burning fossil fuel. Then they upset the natural balance by the destruction of forests and other vegetation. Natural processes circulate carbon through the atmosphere, oceans and biosphere in what is known as the geochemical carbon cycle. Human activities disturb the cycle by injecting carbon dioxide into the atmosphere. It has

been estimated that between 40 per cent and 60 per cent of the carbon dioxide emitted into the atmosphere remains airborne; the rest is taken up by natural sinks, particularly the ocean.

58. Burning fossil fuels is the main source of man-made carbon dioxide emissions; it is estimated to release about 5,000 million tonnes of carbon a year (28). Deforestation is the next most important source. A recent study (31) shows that deforestation in the tropics may be responsible for the release of 310 to 1,300 million tonnes of carbon per year, while conversion of forest soil to other uses causes another 110 to 250 million tonnes to be given off. In all, man-made changes in the earth's biota—including forest destruction from deforestation and the effects of acidic deposition and the destruction of grassland and other vegetation cover through desertification—result in a net annual release of 1,600 million tonnes (30). Deforestation in Brazil, Indonesia, Columbia, Thailand, Côte d'Ivoire, Zaire, Philippines, Peru, Ecuador and Mexico accounts for three quarters of these carbon dioxide releases.

59. Estimates of how much carbon dioxide will be emitted in future vary widely with different projections for fossil fuel use and different scenarios for the fate of the earth's vegetation, particularly forests. It has been estimated that annual emissions of carbon dioxide may range between about 6,000 million and 10,000 million tonnes of carbon by the year 2000, rising to between 12,000 million and 24,000 million tonnes in 2050 (32). Releases from the destruction of vegetation may remain constant at about 1,000 million tonnes of carbon a year to the year 2000, but may increase to as much as 7,500 million tonnes in 2025 (32).

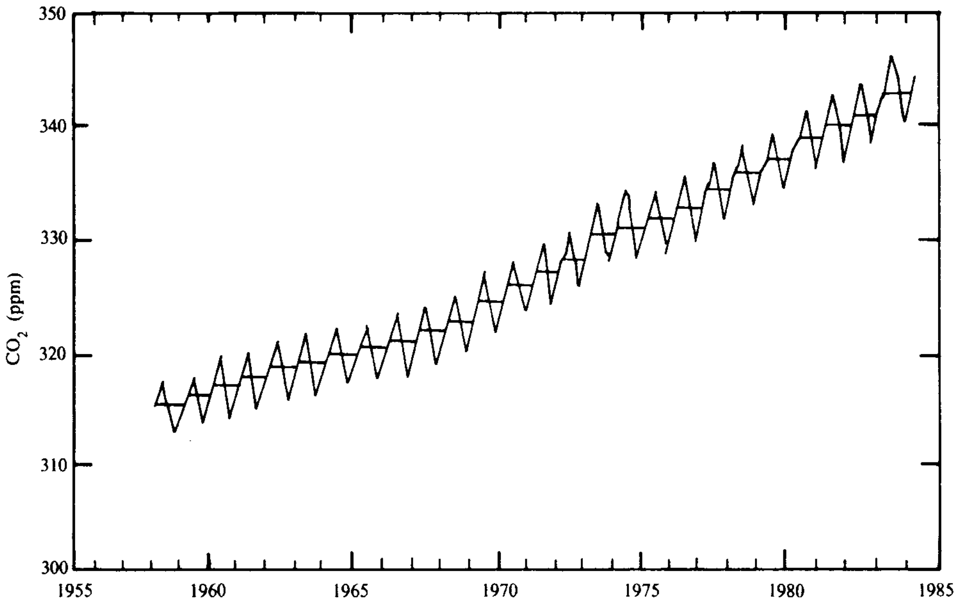
60. The concentration of carbon dioxide in the atmosphere has varied over the ages. Geological records suggest that it may have been about 200 parts per million by volume (ppmv) during the last ice age, some 18,000 years ago. Estimates of carbon dioxide concentration in the atmosphere in pre-industrial times range from 250 to 290 ppmv. Recent analyses of air trapped in glacier ice cores have revealed that the atmospheric carbon dioxide concentration around the year 1750 was 280 ppmv (33). Precise and continuous measurements of atmospheric carbon dioxide concentration have been made at Mauna Loa Observatory, Hawaii, since 1958: they clearly show that it has increased from 315 ppmv then to 345 ppmv in 1985 (34). (Fig. 4).

61. In view of the uncertainties about future fossil fuel emissions, and the biotic contribution—and about the uptake of carbon dioxide by natural sinks—several models have been developed to estimate future atmospheric carbon dioxide concentrations. The mean concentration of carbon dioxide in the atmosphere has been recently estimated to range from 494 ppmv to 627 ppmv by the year 2050 (32). The first figure corresponds to the World Resources Institute's base scenario which projects that primary energy use will continue at the present rate and reach 720 Exajoules/year in 2050. The second figure corresponds to the World Resources Institute's high emission scenario which projects that energy use will accelerate and reach 1150 Exajoules/year in 2050. There was general agreement at the Villach Conference in 1985 that the pre-industrial carbon dioxide concentration would double, reaching 600 ppmv by the end of the next century, if the present increase of emissions (an average of 1-2 per cent per year since 1973) continues over the next four decades and of the rate of increase slackens thereafter (49).

Nitrous oxide

62. Nitrous oxide emissions result naturally from microbial processes in soil and water. Human activities add to them by burning biomass and fossil fuels. The annual total emissions of nitrous oxide have been estimated at about 30 million tonnes, a quarter of this is

Fig. 4 Atmospheric concentration of carbon dioxide as measured at Mauna Loa Observatory.



anthropogenic (35). The major sink for nitrous oxide is reaction with activated oxygen in the stratosphere. The existence or importance of other sinks is uncertain, although denitrifying organisms can use nitrous oxide as a substrate. Measurements of nitrous oxide concentration in the atmosphere show that it increased from 289 part per billion by volume (ppbv) in 1970 to 304 ppbv in 1985 (34, 36), and it is rising by about 0.2-0.3 per cent a year. This comes primarily from combustion (37); it is uncertain whether the increased use of nitrogen fertilizers in agriculture or increases in deforestation and other land use changes contribute significantly (38, 39, 40). However, another study (SCOPE Report No.29, 1986) considers that applying fertilizers enhances the flux of nitrous oxide to the atmosphere. The study estimates the emissions of nitrous oxide due to fertilizers to be 600-2300 tonnes of nitrogen a year and those from increases in cultivated land to be 200-600 tonnes of nitrogen a year. By one estimate the nitrous oxide concentration in the atmosphere might reach 375 ppbv in the year 2030 (43). Another study estimates that it might range from 392 ppbv to 446 ppbv in 2050 (32).

Methane

63. Methane is produced by anaerobic bacteria found in anaerobic conditions in natural wetland ecosystems and rice paddies, in the anoxic rumen of cattle, and in the gut of termites and other wood-consuming insects. The total annual flux to the atmosphere is probably between 400 and 600 million tonnes a year (30, 35, 41). Natural wetland ecosystems represent a large source of the gas estimated annual fluxes range from 100 to 150 million tonnes a year. Methane emissions from wetlands vary depending on soil and air temperature, soil moisture, the amount and composition of organic substrate, and vegetation. The extensive, organic-rich arctic and boreal wetlands are especially important sources of the gas, and account for about half of the total worldwide emissions from natural wetlands. Human activities that alter wetlands—such as draining or flooding—also alter methane emission. Rice paddies also produce the gas; estimates range from 35-170 million tonnes a year. Altering the productivity of rice paddies or extending their area increases methane emission. A recent study (42) estimates that methane emissions may have risen from 75 million tonnes a year in 1950 to 115 million tonnes in 1980 because of increases in the extent of rice paddies. Domestic animals are estimated to produce 74 million tonnes a year and termites between 15 and 150 million tonnes (30).

64. Analyses of ice cores indicate that methane concentration in the atmosphere was about 0.7 ppmv before 1850. In 1977, the average global concentration was 1.52 ppmv, and it reached 1.7 ppmv in 1985 (30). The average global annual increase in methane concentration has been about 1.0 per cent since 1965, which means it has been rising much faster than carbon dioxide. Concentrations differ regionally. They are always 7 per cent greater in the north temperate zone than in the south temperate zone because the major methane sources are all predominantly located in the northern hemisphere (41, 43, 44, 45). It has been estimated that the methane concentration in the atmosphere might reach 2.34 ppmv globally in the year 2030 (43). Another study estimates that it may reach 3.15 ppmv to 7.45 ppmv in the year 2050 (32).

Chlorofluorocarbons

65. Chlorofluorocarbons, especially CFC-11 and CFC-12, have been emitted from industrial sources to the atmosphere for the past half century. The annual emission of each of the two main CFCs is estimated to be about 0.4 tonnes (35). Photochemical destruction, mainly in the stratosphere, and very slow uptake by the oceans are the only known significant sinks for chlorofluorocarbons. Concentrations have been rising very rapidly. In 1977 there was about 150 parts per trillion by volume (pptv) of CFC-11 in the atmosphere; this rose to about 226 pptv in 1986 (8). The concentration of CFC-12 rose from 260 pptv in

1977 to 392 pptv in 1986 (8). An average CFC-11 has been increasing by 4 per cent a year in the atmosphere: CFC-12 has been increasing even faster at 4.3 per cent, a year. It has been estimated that the concentration of CFC-11 might reach 1100 pptv by the year 2030, with CFC-12 reaching 1800 pptv (43). Another study estimates that the concentration of CFC-11 would rise to 1379-2897 pptv in the year 2050; with CFC-12 reaching 2359-3828 (32). However, the Montreal Protocol entered into force at the beginning of 1989. If it is observed, concentrations of CFC-11 and CFC-12 in the atmosphere should be about 700 pptv and 1400 pptv, respectively—if not lower.

Ozone and other gases

66. Ozone absorbs short-wave ultraviolet radiation in the stratosphere and thereby protects living organisms. When it is in the troposphere (below 12 km up) it can damage life. Hence both its breakdown in the stratosphere and its increasing concentration in the troposphere are serious environmental problems. Tropospheric ozone partly comes from the stratosphere and partly arises from photochemical production involving nitrogen oxides, methane and other hydrocarbons. The concentration of ozone in the troposphere was about 0.01-0.1 ppmv in 1985 and appears to be increasing (34).

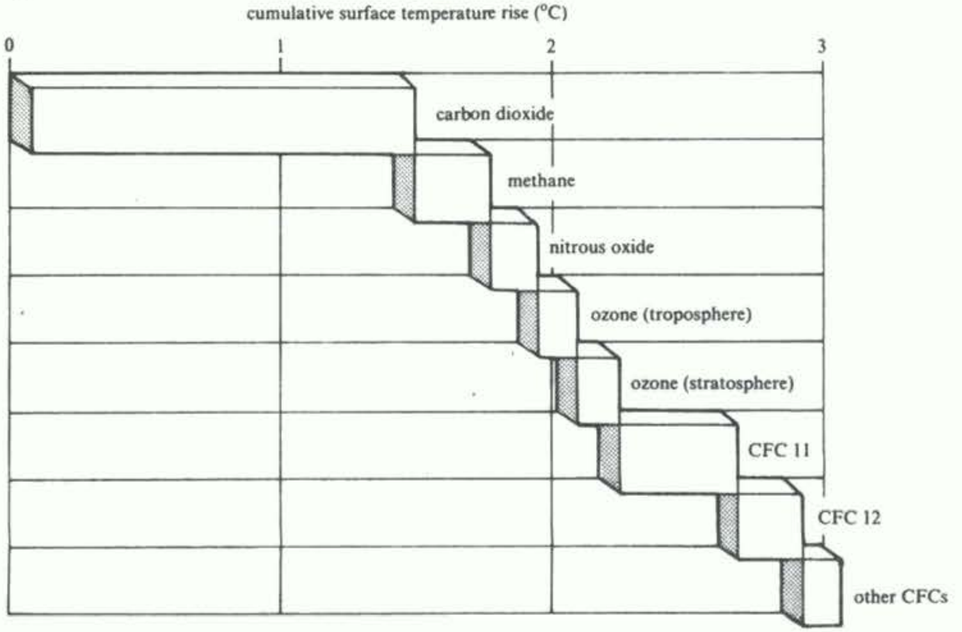
67. Ozone's contribution to the greenhouse effect is complicated by interaction with trace "reactive" gases. Many of these gases are produced biologically or by burning biomass, and the concentrations of many are currently increasing in the atmosphere. Many do not absorb infrared radiation and so are not greenhouse gases in the strict sense. But they interact in ways that cause the production or destruction of other gases, and can, therefore, indirectly influence the greenhouse effect. The most common reactive gases in the atmosphere are carbon monoxide, non-methane hydrocarbons (especially isoprene and terpenes), nitrogen oxides, ammonia, and trace sulphur compounds (especially, hydrogen sulphide, dimethyl sulphide, methyl mercaptan, carbon disulphide and carbonyl sulphide). Many of these gases interact with ozone in complex ways. Hydroxyl radical and ozone are major oxidants in the breakdown of carbon monoxide, methane, isoprene and terpenes. At low concentrations of nitric oxide, carbon monoxide oxidation is a sink for ozone. At elevated nitric oxide concentrations, however, ozone concentrations can actually be increased during carbon monoxide oxidation. This interaction may be partially responsible for increasing tropospheric ozone concentrations in developed regions (46). Further increases in nitric oxide concentrations due to fossil fuel combustion, biomass burning, or agriculture could cause more widespread increases in tropospheric ozone.

Changes in Climate

68. Obviously the effects of the buildup of carbon dioxide cannot be studied directly. So researchers have relied on global climate models—mathematical representations of the atmosphere used to simulate climate change under different scenarios. Carbon dioxide is such a minor constituent of the atmosphere, that no model can make any predictions of the changes that might result from anything less than a doubling of concentrations. Even then, estimates of temperature increase vary widely—from 0.7°C to 9.6°C. Recent studies agree, however, that doubling the carbon dioxide concentration from the pre-industrial level of 270 ppmv will probably increase global mean temperature by 1.5°C to 4.5°C (47, 48, 49)—but most likely by 2°C.

69. Since carbon dioxide is both the biggest contributor to the anthropogenic greenhouse effect and the first to be identified, experts measure the import of other trace gases in terms of their carbon dioxide equivalent. In 1980, the other greenhouse gases (methane,

Fig. 5 Predicted temperature rises caused by increasing concentrations of carbon dioxide and other greenhouse gases by the year 2030. The predicted rise is about 3°C, of which only about one-half would be caused by carbon dioxide itself.

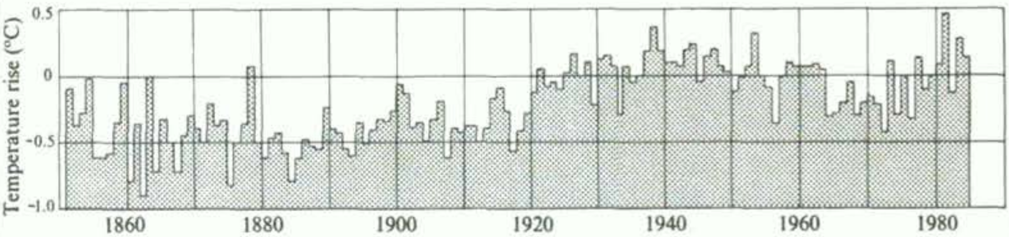


Source: UNEP/GEMS Environment Library No. 2 "The Ozone Layer", 1987.

tropospheric ozone, CFCs, extra water vapour resulting from the greenhouse warming of the oceans, and nitrous oxide) would have produced the same amount of heating as an extra 40 ppmv of carbon dioxide. By 2030, their effect is expected to be the same as an extra 140 ppmv of carbon dioxide. These gases, therefore, accelerate the warming of the earth. Carbon dioxide concentrations alone may not double until the year 2080, but the addition of other gases would lead to the same effect by about 2025, some 50 years earlier (Fig. 5).

70. Many interactions lead to the greenhouse effect and they are very complex, with many feedbacks. There is, for example, an important synergism between carbon dioxide and water. Increasing carbon dioxide raises the temperature, causing more moisture to evaporate from the ocean and land. The extra water vapour, in turn, traps more infrared radiation and amplifies the greenhouse effect. This water-greenhouse feedback has been estimated to amplify the warming of the air by a factor of about 1.5 and the warming of the earth's surface by a factor of about 3 (34). Another well-studied effect is the ice-snow albedo feedback. The greenhouse warming will lead to increased melting of the sea ice and snow cover. The underlying surface, be it water or land, is much darker than ice or snow, and so absorbs more solar radiation, thus amplifying the warming. The ice-albedo feedback increases the global warming by 10-20 per cent, but locally, near the sea-ice margins and in polar oceans, it can exceed the global warming by factors ranging from 2 to 4. Thirdly increased moisture from the warmer oceans could alter cloud distributions and characteristics. The nature of these cloud changes and how they will affect the radiative heating is unclear. The interactions between ozone and reactive gases in the atmosphere have already been referred to in paragraph 65 above.

Fig. 6 Average annual temperatures of land masses in the northern hemisphere since 1850.



Source: UNEP/GEMS Environment Library No. 2 "The Ozone Layer", 1987.

71. Analysis of surface temperature records during the past 100 years indicates that the Earth's temperature rose by 0.5°C between 1880 and 1940, fell by 0.2°C between 1940 and 1965, and has rapidly increased since 1965 (Fig. 6). These analyses suggest that global mean temperature has risen 0.3-0.7°C in the past 100 years. But a definitive association between this warming and the greenhouse effect requires further data and studies (50).

Environmental Impacts of Possible Changes in Climate

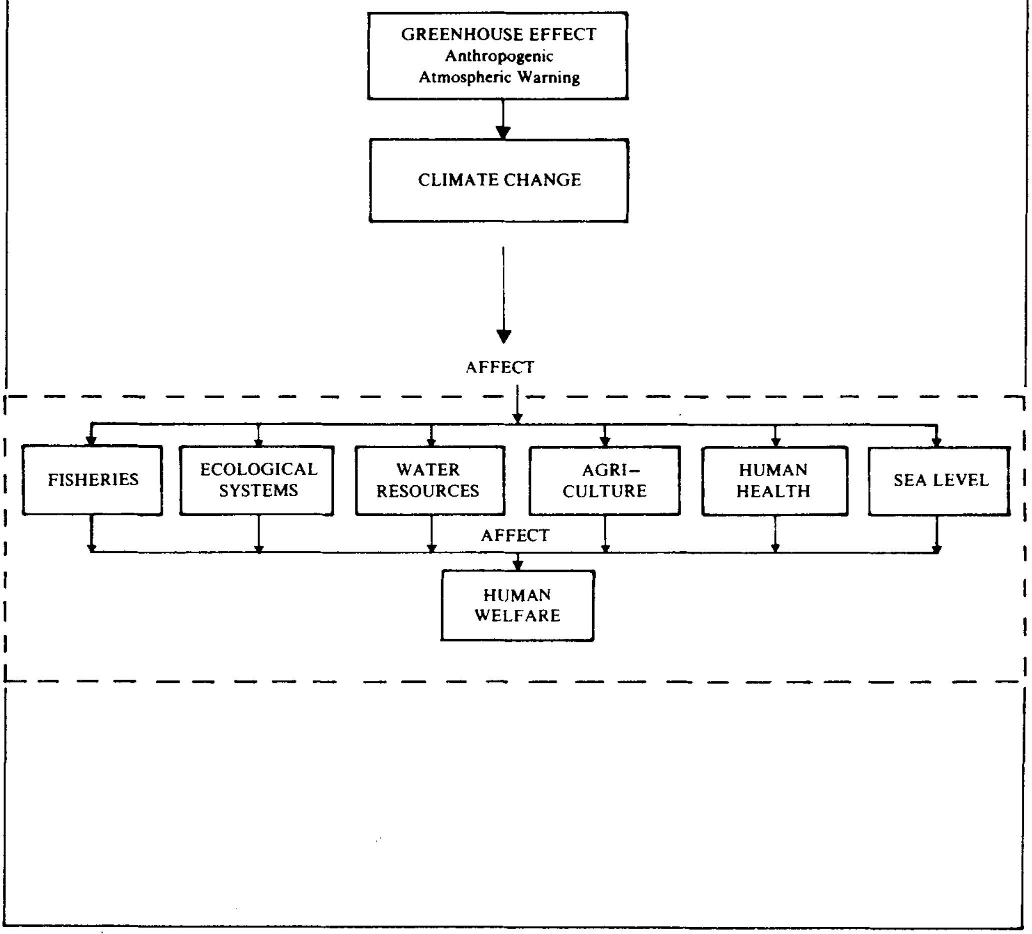
72. Changes in climate resulting from increases in atmospheric carbon dioxide and other trace gases may affect the environment in many ways. However, the question of how climate interacts with environment and society is complex (Fig. 7). In the absence of detailed and accurate predictions of future climate, it is only possible to speculate about the impact of possible changes (49).

Changes of sea level

73. In the past, climate has profoundly affected sea level. Geologists generally recognize that ice ages removed enough water from the oceans to lower the sea 100 metres below present levels. Although the glaciers that once covered much of the northern hemisphere have long retreated, the world's remaining ice cover contains enough water to raise sea level more than 75 metres.

74. It has been estimated that a global warming of 1.5°C to 4.5°C would lead to a sea level rise of 20 to 140 cm (49), mainly through the thermal expansion of ocean water. Climate warming could also melt the drifting sea ice in the Arctic Ocean and thaw the West Antarctic ice sheet. Melting the sea ice would substantially increase sea surface temperature and so shift major climatic zones 200 kilometres or more northward. There is considerable debate over the likelihood of the Antarctic ice sheet melting. Recent studies conclude that a significant melting would lead to a much larger rise in sea level, but this is not expected during the next century (49).

Fig. 7 The relationship between climate change, environment and society.



75. A sea-level rise of about one to two metres would permanently submerge wetlands and lowlands, accelerate coastal erosion, exacerbate coastal flooding, threaten coastal structures, and increase the salinity of estuaries and coastal aquifers. These would have far-reaching environmental, economic and social implications for many countries. Several developing nations are especially vulnerable.

Regional climatic changes

76. Comparisons of warm and cold years, and computer calculations, show that when the world warms, the highest latitudes heat up most and the equatorial regions warm least (Fig. 8). Such temperature changes would alter rainfall wind patterns. Some parts of the world will get wetter, some drier; reliable winds that bring monsoon rains may change course; in some regions storms may become more common. Climatic changes could prolong droughts in the semi-arid tropics by raising temperature and decreasing rainfall in one or more seasons, worsening their already critical problems. Some scientists have speculated that the recent prolonged drought in Africa may be an early manifestation of the regional impact of global warming (51). In the humid tropics rainfall may increase. Tropical storms may extend into regions where they are relatively uncommon.

Effects of terrestrial ecosystems

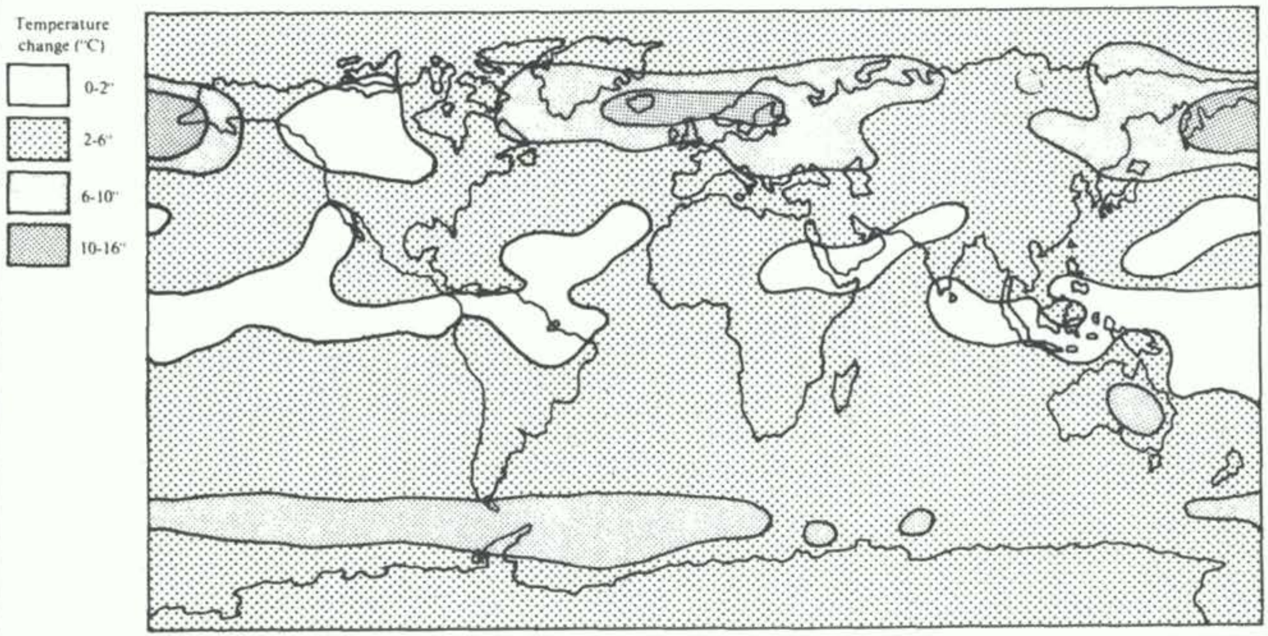
77. Examining patterns of global vegetation and climatic changes in the distant past leaves no doubt that a doubling of atmospheric carbon dioxide concentrations—could potentially have profound effects on global ecosystems.

78. In semi-arid regions, trees are vulnerable to decreases in rainfall. In wet forests, they are vulnerable to insect pests and infestations, influenced by temperature and precipitation. In the Arctic tundra warming would reduce the permafrost, and trees would grow further north. The upper layers of the tundra peat would dry out increasing the oxidation and decay of organic matter. More carbon dioxide would be released and this would, in turn, enhance the warming, creating a positive feedback (52).

79. Food production, and its distribution, could be greatly affected by climate warming. In general, increasing carbon dioxide concentrations in the atmosphere would have beneficial effects on crop yields. Laboratory experiments indicate that—if there was no climatic change—a doubling of carbon dioxide concentration would increase the growth and yield of maize, sorghum and sugar cane, by up to 10 per cent, with a 10-50 per cent increase for wheat, rice and soya bean, depending on the specific crop and growing conditions (49). Doubling the carbon dioxide concentration could reduce transpiration by 34 per cent; plants would use water twice as efficiently. But, of course, there would be changes in climate, and crops would be substantially affected. Crop impact analyses show that warmer average temperatures decrease both wheat and maize yields in the vital mid-latitude crop regions of North America and Western Europe. Given current technology and crop varieties, a sudden warming of 2°C with no change in precipitation might reduce yields by 3-17 per cent (49). Warmer and longer growing seasons induced by climatic changes could enable many insect pests to pass through an additional one to three generations. The exponential increase of some pest populations under the newly favourable conditions could increase crop losses.

80. The global warming produced by the greenhouse gases will arrive slowly. By the time average temperatures have risen by one or two degrees, agriculture should have already largely adapted. Different crops, different varieties and different farming techniques will all help to absorb the impact of the change. The world agricultural trading system can also adapt to change as different countries export and import different quantities of different

Fig. 8 Temperature changes predicted by one atmospheric model caused by a doubling of carbon dioxide. In winter, temperatures might rise by as much as 6-10°C in parts of northern Europe.



Source: UNEP/GEMS Environment Library No. 2, "The Ozone Layer", 1987 commodities. However, marginal food-producing areas may have much more difficulty in adapting. Their production is already very sensitive to climatic change, and the rate of change of their agricultural technology is very slow.

Concluding Remarks

81. The prospective global warming and the forces driving it are now broadly understood. However, its precise regional distribution and its environmental impacts are not. There are many uncertainties. The problem is global, and it will take concerted efforts by the international scientific community to clarify the inadequacies in our knowledge. Based on current scientific findings, the world community has two options. The first is to consider the issue academic and to let things go on as at present. If this happens, the world will eventually have to adapt its socio-economic structure suddenly to the changing climate, and face possibly catastrophic consequences. This is clearly unviable. The second option is to take immediate measures to slow down the buildup of greenhouse gases, and hence minimize the warming and its undesirable consequences. The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer is a step in the right direction. It calls for a 50 per cent cut in production of fully halogenated chlorofluorocarbons (CFCs), which are greenhouse gases, by 1998. Some recent studies (53) point to the necessity of amending the Montreal Protocol to ban the production of CFCs and halons altogether and to freeze the production of methyl chloroform (which is not restricted by the 1987 Protocol).

82. Other greenhouse gases that can perhaps be controlled in the near term are methane, and tropospheric ozone. Priority should be given to studies related to the sources and sinks of these gases, to their interactions in the atmosphere, and to technologies that would reduce their emissions. As for carbon dioxide, which is responsible for about 50 per cent of the greenhouse effect, priority should be given to strategies that would freeze or reduce the rate of its emission—including increased energy efficiency, and modification of technologies in ways that lead to reduction in the use of fossil fuels. The preservation of forests especially the tropical forests is probably even more practical. Each of these measures can serve more than one environmental and economic purpose. Even if the worst scenario does not come about we would benefit in other respects by taking these measures now.

PART III

FOCUS ON: HAZARDOUS WASTE

Chapter IV

HAZARDOUS WASTE

83. Virtually all industrial activity generates waste, which is discarded because it seems to have no further economic use. The draft global convention on the transboundary movement of hazardous wastes, defines wastes as "substances or objects which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national laws"

84. Certain wastes are defined as "hazardous", a term that has been used differently in different countries. In the United States of America, for example, wastes are defined as hazardous if they may cause or significantly contribute to an increase in mortality or in serious irreversible, or incapacitating reversible illness; or pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed (54). In the Federal Republic of Germany, the term "special wastes" is used. The technical definition for such wastes is that "because of their nature, composition, or quantity they are especially dangerous to health, air, or water quality, are explosive, flammable, or could promote infectious diseases, and therefore special requirements for their control are necessary" (55). The World Health Organization (WHO) has defined hazardous waste as having "physical, chemical or biological characteristics which require special handling and disposal procedures to avoid risk to health and/or other adverse environmental effects" (56).

85. One approach to the problem of adequately defining hazardous wastes is to draw up a list of known wastes that present no significant short-term handling or long-term environmental hazards,—and then to define hazardous waste as any waste not listed. This "exclusion" list approach has been used in some countries, for example the United Kingdom. However, listings of hazardous waste are more widely used for regulatory purposes—either with or without accompanying criteria. This "inclusive" list approach is currently employed in Belgium, Denmark, France, Federal Republic of Germany, the Netherlands, Sweden and the United States of America. The lists comprise wastes from certain industries, wastes containing specific components or specific waste streams identified by the processes from which they originate. The inclusive list offers a greater degree of certainty but suffers from the disadvantage that there may well be significant omissions.

86. The Cairo Guidelines and Principles for the Environmentally-Sound Management of Hazardous Wastes (57) defined hazardous wastes as "wastes other than radioactive wastes which, by reason of their chemical reactivity or toxic, explosive, corrosive or other characteristics causing danger or likely to cause danger to health or the environment,

whether alone or when coming into contact with other wastes, are legally defined as hazardous in the State in which they are generated or in which they are disposed of or through which they are transported".

87. Thus there was no internationally accepted definition of hazardous waste. This had two implications. The first was that estimates of hazardous waste generated by different industries in different countries varied widely depending on the definition adopted. The second was that regulatory procedures were complicated, especially when hazardous waste was carried within the same country, from one region to another with different regulations, or transported from one country to another. In 1988 the OECD identified a core list of wastes to be controlled and all others which are considered to be or are legally defined as hazardous wastes in Member countries.

88. Estimates of hazardous wastes generated in OECD countries vary from 300 to 800 million tonnes a year or even more. According to some estimates 88 per cent of these are generated in the United States of America (2). Federal Republic of Germany, France, United Kingdom and Italy are the main generating countries in Europe. In 1986, about 3.7 million tonnes of hazardous wastes were generated in the United Kingdom (58). In Hungary 3.5 million tonnes of hazardous wastes are generated annually (59). Data from other countries, especially developing ones are not readily available. Some developing countries are believed to generate substantial amounts. Brazil, India, South Korea and China might top the list. A 1985 survey indicated that some 700 industries along the west coast of Malaysia were generating hazardous wastes (60).

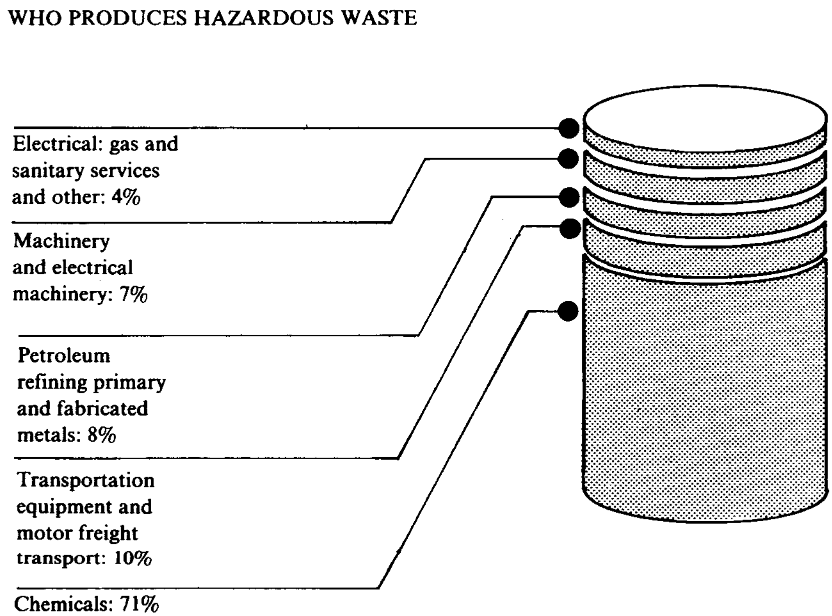
89. The composition of hazardous waste varies considerably from one industry to another (Fig. 9), and so the composition of waste generated in different countries varies with different mixes of industry. For example, in the United States of America, 71 per cent of the hazardous waste is produced by the chemical industry, 8 per cent by petroleum refining and metal industry, and the rest by other industries. In Hungary, on the other hand, 66 per cent of the hazardous waste is produced by the mineral industry, 17 per cent by the chemical industry and the rest by other industries.

Hazardous waste disposal and environment

90. The traditional low cost methods of hazardous waste disposal are landfill, storage in surface impoundments, and deep-well injection. Deep-well injection is more common in the United States of America than in Europe. Over 75 per cent of hazardous waste generated by industries in OECD countries is disposed of on land. Wastes may be disposed of in bulk or stored in drums, barrels or tanks (Fig. 10).

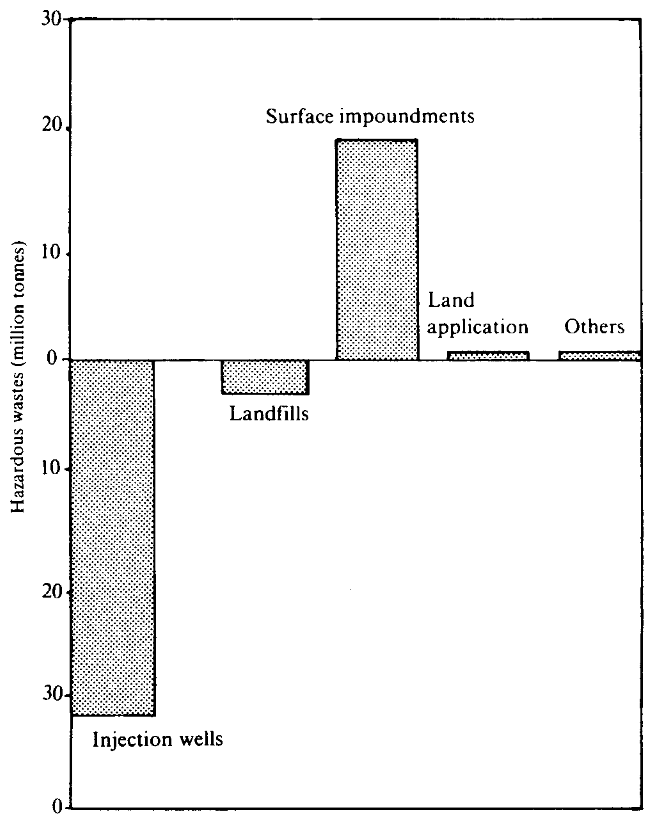
91. Thousands of landfill sites and surface impoundments used for dumping hazardous wastes have been recently found to be entirely unsatisfactory. Corrosive acids, persistent organics, and toxic metals accumulated in these sites for decades. Little thought was given to their environmental impacts. In the United States of America, about 76,000 active landfills, have been recorded most of them unlined (61). The Comprehensive Environmental Response, Compensation and Liability Act—(the Superfund Act) was passed in December 1980 to address this situation. By 1987, the United States Environment Protection Agency (US EPA) has placed 951 landfills, impoundments and other sites on its National Priority List, of sites needing urgent attention. Estimates indicate that the list may grow to 10,000 sites and that the cost of cleaning them up may range from $23 billion to as much as $100 billion (62). In Denmark 3,200 abandoned sites have been recorded; the cleanup costs may reach $1 billion. As many as 35,000 problem sites have been recorded in the Federal Republic of Germany; the expected corrective costs are at least $10 billion. In the Netherlands, there are 4,000 abandoned sites, 350 of which require immediate remedial action.

Fig. 9 Production of Hazardous Wastes in the USA



Source: 65 Piasectri, B. and J. Gravandu; The missing links, restructuring hazardous waste actuals in America. Tealm. review, October 1985, P.43

Fig. 10 Disposal of hazardous wastes in 1981 in the USA.



Source: El-Hinnawi and Hashmi "The State of the Environment". Butterworth, London, 1987.

92. There have been several hundred cases of groundwater contamination by chemicals leaking from unsatisfactory landfills and surface impoundments. In the United States of America more than 200 substances—including 175 organic chemicals have been identified in groundwater; thirty-two of the organics and five metals are known or suspected carcinogens. Several serious incidents have been reported. Wastes stored in unlined canals and ponds near Denver, Colorado, contaminated groundwater over an area of about 40 km^2. At Perham, Minnesota, some people were poisoned by arsenic that had contaminated a well (63).

93. Other unsatisfactory dumping has exposed people directly to hazardous chemicals. At Love Canal, near Niagara Falls, United States of America, homes were built on a former dump containing pesticides, chemicals used in making plastics and the sludge from the bottom of stills. The dump was sealed with clay and sold to the local community. Rainwater percolating into the ground leached the buried chemicals into a sludge that contaminated the buildings. Hundreds of families had to be evacuated from the site and the cleanup costs reached tens of millions of dollars. Researchers assessing potential health problems in children living near the site found seizures, learning problems, hyperactivity, eye irritation, skin rashes, and stomach pain all to be more prevalent than in a control population (62). At Lekkerkerk, near Rotterdam, in the Netherlands, drums of paint solvents (aromatic hydrocarbons) were included in rubble used to reclaim land. Houses were then built on it. Again hundreds of families had to be evacuated and corrective measures taken. These, and other incidents that hit the headlines are only a few of those that have actually occurred many more are likely to have gone unreported.

94. Perhaps the most notorious incident of all was the outbreak of Minamata disease in Japan in the 1950s and 1960s. Methylmercury discharged from a chemical factory into the sea, or produced in the sea from inorganic mercury discharges by marine organisms, contaminated the fish eaten by local people at the town of Minamata on Kyushu Island, Japan. As a result of this and a similar incident at Niigata on the east coast of Honshu, nearly two thousand people suffered neurological disorders; about four hundred died. Although dumping of waste at sea is controlled under international and regional conventions, several countries are still using this route for the disposal of hazardous waste. In the United Kingdom, for example, marine disposal is the second most used route—after landfill—for hazardous waste disposal. In 1986, about 579,000 tonnes of waste were dumped at sea,—half of it would be classed as hazardous (58). Following the Second International Conference on the Protection of the North Sea, held in London in November 1987, it was agreed that dumping of industrial wastes in the North Sea should be phased out by 31 December 1989. It was also agreed to cut the use of marine incineration by 65 per cent by 1 January 1991 and to phase it out altogether by 31 December 1994.

95. Underground storage of hazardous waste is practiced on a limited scale in some countries, for example, Canada, United States of America and the Netherlands. The best known example is the Herfa-Neurode facility in the Federal Republic of Germany, which has operated since 1972. About 270,000 tonnes of hazardous waste have been placed about 700m down in an abandoned part of a potash mine; annual storage is now running at 35,000 to 40,000 tonnes (64).

96. Most countries still rely on land disposal methods for their hazardous wastes. Several technologies are available for handling them. Physical, chemical and biological methods can be used to reduce the bulk or toxicity of the waste. Of all of the treatment technologies available, properly-designed incineration systems can provide the highest overall degree of destruction and control for the broadest range of hazardous waste streams. The best known system is the Kommunekemi facility in Denmark. Established in 1973 in the town of Nyborg, it destroys over 90 per cent of Denmark's hazardous waste. At the same time, it

recovers heat from its incinerators to supply Nyborg's residents with 35 per cent of their heating needs (65). In Bavaria, in the Federal Republic of Germany, integrated treatment facilities equipped with incinerators, inorganic chemical treatment plants, and secure landfills form the technological backbone of hazardous waste management. Similar incineration systems have recently been established in Finland, Sweden and South Korea.

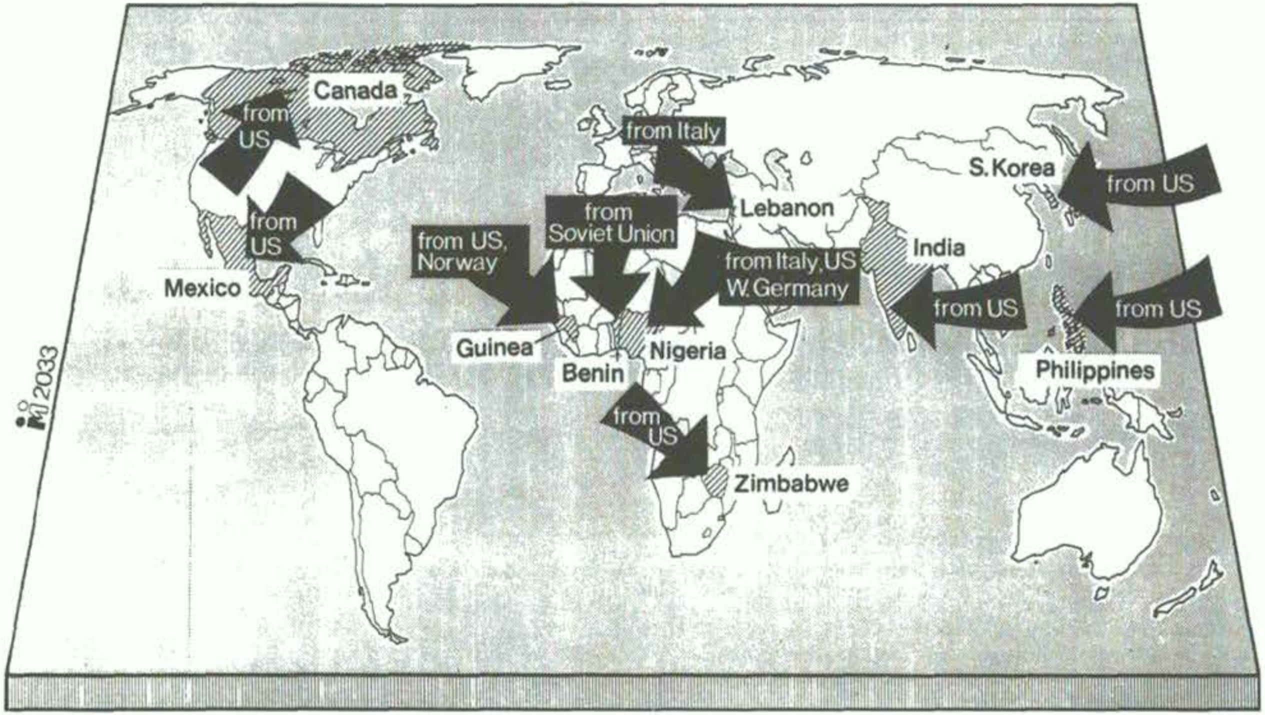
97. Ideally, incineration should produce carbon dioxide, water vapour, and inert ash. In reality, incineration involves extremely complex reactions, which are aggravated by the complex and fluctuating nature of the waste itself. The US EPA conducted a survey of the composition of hazardous waste for incineration; 237 different constituents were identified as present in one or more of the 413 hazardous waste streams reviewed in the survey (67). Incineration devices are designed to optimize the chances that these reactions will be completed, but they never completely attain the ideal. Small quantities of a multitude of other products may be formed, depending on combustion conditions and the chemical composition of the waste. These products—along with potentially untreated components of the waste—constitute the incinerator's emissions (66). Emissions from incinerators include hydrogen chloride, nitrogen oxides, sulphur oxide, trace metals and trace amounts of dioxin and furan. Studies have shown that such emissions appear to pose little increased risk to human health, but more detailed studies are needed. Incineration at sea has taken place in specially designed ships; the costs are one-third to one-fourth of the costs of land-based incineration, since emissions are not as tightly controlled (68). However, there is now a trend to limit marine incineration or ban it altogether (see paragraph 92 above). Rising costs, scarce treatment capacity, and public opposition to siting new facilities plague hazardous waste programmes virtually everywhere, despite its demonstrated destruction capabilities and the apparently low incremental risks of emissions. At Denmark's Kommunekemi facility, for example, the volume of incoming waste has mounted by about 17 per cent a year for the last few years. The incinerators are now operating at full capacity, and a new one is needed. But local opposition may prevent it from being built in Nyborg, and it may have to be constructed elsewhere which will delay bringing it on-line (62). Similar public opposition has also been encountered in the United States of America.

Transfrontier Disposal of Hazardous Waste

98. The transport of hazardous waste from one country for treatment and/or disposal in another takes place in several regions. More than a tenth of the waste generated in OECD countries is transported across national borders for disposal. In 1983 about 2.2 million tonnes of hazardous waste crossed the frontiers of OECD countries in Europe. Cross-frontier traffic in the waste involved some 20,000 to 30,000 border crossing events a year (1). This reflects the absence of disposal or treatment facilities in countries of origin and economies of scale. Since 1980, some countries have substantially increased the amounts of waste they import. United Kingdom imports of hazardous waste for treatment, for example, rose from about 5,000 tonnes in 1981 to about 53,000 tonnes in 1986/1987 (an additional 130,000 tonnes classified as non-hazardous were imported for landfill). The largest exporters to the United Kingdom were the Netherlands (55 per cent), Ireland (12.5 per cent) and Belgium (12.5 per cent). Lesser quantities arrived from Portugal, Canada, United States of America, Federal Republic of Germany, Denmark, Norway, Sweden, Spain, Italy, Australia, Singapore, Hong Kong and Switzerland (58).

99. As controls on hazardous waste disposal have been tightened up in some countries, industries have recently increasingly resorted to exporting their waste to foreign countries (Fig. 11). National monitoring systems often suffer from severe inadequacies in trading hazardous waste across frontiers. The well-publicized disappearance for several months of drums containing soil contaminated by dioxin from Seveso (Italy) during their transport

Fig. 11 Some major transfers of hazardous wastes.



Source: Development & Co-operation No. 6/1988.

through France showed that countries generally do not know enough about consignments of waste crossing their frontiers to exercise proper control. This prompted the European Community to issue a Council Directive on thė supervision and control of transfrontier shipment of hazardous wastes within the Community in 1986. Under this Directive, whenever hazardous wastes are to be shipped to another Community country the consignor must notify the competent authorities in the country of despatch, the destination country and, where appropriate, the country of transit. The wastes covered by this Directive must be accompanied by a standard Community consignment note each time they cross national frontiers.

In 1984 the OECD adopted a number of principles to facilitate the development of harmonized policies on transfrontier movements of hazardous waste. And in 1988, it established a core list of hazardous wastes and other wastes that should be controlled in transfrontier movements. The Cairo Guidelines and Principles for the Environmentally-Sound Management of Hazardous Wastes adopted by the Governing Council of UNEP in 1987 outlines a number of principles to guide the transfrontier movement and disposal of hazardous waste.

100. In recent years, developed country industries have resorted to exporting hazardous waste for disposal in Third World countries, after national regulations have been tightened up nearer home. In some cases this dumping is the result of legal contracts by Third World companies or governments accepting waste from companies in the industrialized countries in exchange for hard cash. In other cases, however, hazardous wastes have been dumped illegally. Recent examples of dumping in developing countries abound: 15,000 tonnes of industrial incinerator ash from Philadelphia, United States of America, were dumped on the Guinean island of Kassa; up to 4,000 tonnes of chemical waste from Italy were dumped in the port of Koko in Nigeria; about 2,500 tonnes of wastes from Italy were dumped in Lebanon; and hazardous wastes from United States of America, Japan, Federal Republic of Germany and Singapore were found dumped at Bangkok port in Thailand.

101. Recent exposures of the dumping of hazardous wastes in some African countries, has triggered widespread concern. The Organization of African Unity adopted a resolution in May 1988 condemning the use of African territory as a dumping ground. It called for a ban on the importation of wastes into the continent, and urged African governments which had already concluded agreements for dumping waste on their territory to end them. Several countries in Africa and other parts of the Third World started formulating regulations or tightening up existing ones—to ban or restrict imports of hazardous wastes. At the international level, the UNEP Governing Council, following the adoption of the Cairo Guidelines and Principles requested the Executive Director in 1987 to convene an *ad hoc* working group of government experts to negotiate an international treaty on the control of the transboundary movement of these wastes. The convention is scheduled to be for conclusion, adoption and signature in March 1989 in Basle, Switzerland.

Prevention is better than cure

102. Industries can avoid the costs and risks of treating, storing, transporting and disposing waste by reducing, or stopping its production. Waste prevention or reduction is the best way to protect the environment. If less waste is generated, it is cheaper to manage, and there will be fewer failures in handling it.

103. Strategies to reduce waste differ markedly from the end-of-pipe treatment to which most industries have grown accustomed. Waste can be minimized by changing the manufacturing processes, separating and concentrating waste, and reusing and recycling it. Other options include using different raw materials, and replacing hazardous products with

safer substitutes (69, 70, 71). Of course, waste minimization means different things to different industries depending upon the particular waste streams being generated, their quantity and physical form.

104. Numerous case studies demonstrating the feasibility and cost-effectiveness of waste minimization are available (62, 70). One company has successfully used pumice (a natural volcanic rock) instead of some 20 tonnes of hazardous chemicals per year to scrub flexible metal circuits. Another has developed a process that uses ultraviolet light instead of hazardous solvents to dry and set coloured paints. A third company has released a new line of non-hazardous biodegradable industrial cleaners. There are many other examples. But despite such signs of a shift toward waste minimization, very little of the potential gains have so far been achieved. The US EPA estimates that existing technologies could reduce the total amount of hazardous wastes generated in the United States by 15-30 per cent by the year 2000 (72).

105. Recycling and reuse of waste has been practiced in some countries for decades, for economic reasons. Perhaps the best known examples are the reuse of scrap metals and the reuse of glass bottles for soft drinks, etc. Recycling is now receiving increased attention in developed countries. Only about 4-5 per cent of hazardous wastes are being recycled in some OECD countries, but there is a great potential for recovering several materials, such as solvents and metals, including chromium, mercury and copper. It has been estimated that up to 80 per cent of waste solvents and 50 per cent of the metals in liquid waste streams in the United States of America can be recovered by existing technologies (62). Japan seems to have advanced the furthest of any major industrial country toward recycling and reusing its industrial waste, largely thanks to a unique cooperative relationship between industry and government. In Japan, United States of America and Western Europe, waste exchanges—operating on the simple promise that one industry's waste can be another's raw material—have succeeded to varying degrees in promoting the recycling and reuse of industrial waste. Most serve as information Clearing-houses, publishing catalogs of waste available and "waste wanted" lists to inform industries of trading opportunities. A successful trade benefits both buyer and seller, the buyer reduces its raw material costs, the seller its treatment and disposal costs.

Concluding Remarks

106. There are several technological approaches to deal with the hazardous wastes generated by industries. But more vigorous research and development in waste minimization technologies and recycling, technical and financial support to encourage investments in them, and, in some cases, a tax on waste generated could probably cut the production of hazardous wastes in many industrialized countries by a third by the year 2000.

107. Few developing countries have established the basic foundation of a hazardous waste management system. Most have no regulations, no trained manpower, and no facilities capable of adequately treating and disposing of hazardous wastes. An active exchange of information and experience between developed and developing countries could do much to advance the latter's capabilities to deal with such wastes. Special emphasis should be made on strategies of waste minimization, recycling and reuse, which would lead to vast economic and environmental gains.

108. The general obligations in the draft global convention on the transboundary movement of hazardous wastes and several of its articles dealing with exchange of information, technical assistance and control measures for the movement and disposal of hazardous waste—give a much greater impetus to minimizing the production of hazardous wastes production and the risk of dealing with them.

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