

INDUSTRIALIZATION & POLLUTION

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People have been polluting air since the time they learnt to use fire, but the anthropogenic air pollution has rapidly increased since industrialization. In older days there were famine, starvation, horses and buggies fire places that spewed forth sort from burning soft coal & wood and water contaminated with micro-organisms that contributed to air pollution. But the people were so few and the land so vast that these excesses (insults) could be absorbed without serious consequences. Today, of the more than five billion (over 500 crore) people of whom many are maintaining a high standard of living using more energy and products than before - has resulted in more toxic wastes. The enormous industrial growth, a measure of development is mainly responsible for the high standard of living and this in turn is greatly exploiting the natural resources and is a major contributor to the pollution loads in the world.

Industry, Resources and Environment

Today the world produces three times the amount of minerals and manufactures even times as many goods as it did in 1970s. World wide, the use of metals have increased over the last two decades (Fig.1), though marked differences exist between different group of countries (Fig.2), and from one country to another. The developing countries account for most of the world proven reserves of important minerals such as bauxite, copper, tin and cobalt ores; and phosphates (Fig.3), but their consumption is only 12%. Most of their production is exported to developed countries. The extraction of minerals (and their concentration and initial processing) has several negative impacts on land, water and atmosphere. These impacts are especially magnified in developing countries where mining operations are greatly less

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sophisticated than those in developed countries and mostly lack environmental protection measures. For example, bauxite processing in Jamaica produces massive quantities of 'red mud' which is contaminating ground water resources. The mining of tin, copper, phosphates and iron ores has also created water and air pollution problems in some African and Asian countries. Long years of mineral extraction in some countries, for example in the U.S without due consideration for environmental impacts have created large areas of waste land and massive amount of accumulated hazardous wastes.

Industry and Waste Water

World-wide, industry consumed about 540 cubic kilometers of water in 1970 (21% of total global fresh water withdrawal), and about 973 cubic kilometers in the year 1990 (24% of total withdrawal), i.e. an increase of about 80% in two decades. This amount is expected to reach 1,280 cubic km in 2,000 A.D, constituting about 25% of total fresh water withdrawal worldwide. The modest amounts of water used in industrial sector, compared to water withdrawn for agriculture, are due to the fact that many industries reuse water several times before it is finally discharged as industrial waste-water. These waste-waters vary markedly in composition according to the industry, ranging from those with a composition similar to municipal sewage to those which are more toxic and contain a great variety of heavy metals and synthetic organic compounds. Industrial waste-water discharge into surface water without adequate treatment has created a number of serious environmental problems that have affected aquatic life. The uncontrolled discharge of industrial waste-water into municipal sewers which is being done in several countries could stress and completely destroy the microbial based system used to treat domestic wastes.

Solid Wastes

World-wide, industry generated about 2,100 million tonnes of solid wastes and 338 tonnes of hazardous wastes in 1989. Although, some industrial wastes are considered inert and are treated and disposed of like urban solid wastes, others require especial management techniques. The management of industrial solid wastes specially the hazardous wastes, remains a problem in many countries though there

are several ways to use many of the wastes in beneficial ways. For example, fly and bottom ash collected from power plants has been used for the manufacture of bricks and for road building in some East European and Asian countries.

Impact of industry on the Atmosphere

Many air contaminants are emitted by industry. The quantities and type of compounds emitted depend on many factors, in particular, the type of industry, the characteristics and quantities of raw materials used, the type and quantity of fuel, the technology applied and the environmental protection measures employed. Factors such as the size of the industrial installation, the age of the machinery, and the standard of maintenance and management are also important. In addition to common emissions, such as sulphur and nitrogen oxides, carbon dioxide, carbon monoxide, hydrocarbons and particulate matter, industry emits into the air hundreds of trace contaminants, some of which are potentially toxic.

Table - 1

ESTIMATES OF MAJOR EMISSIONS INTO THE ATMOSPHERE FROM INDUSTRY

	million t/y	% of global anthropogenic emissions
Carbon dioxide	3,500	50
Methane	84	24
Nitrous oxide	0.2	13
Ammonia	7	20
Sulphur oxides	89	90
Nitric oxide	30	44
Particulate matter	23	40
Hydrocarbons	26	50
Chlorofluorocarbons/halons	1.2	100

Includes utilities (power stations including steam generating stations). Chlorofluorocarbons and halons represent 1986 level (Chapter 2)

Source: (EI-Hinnawi-1992)

Table-1 gives the calculated estimates of the contributions of industry to global anthropogenic air emissions. From this table it is obvious that but for chlorofluorocarbons/halons and sulphur oxides, there are other strong manmade sources for the rest of the emissions but quite a few of them are directly or indirectly linked with the industry and industrial development.

The pollutants emitted into the atmosphere mostly remain confined to the area near the source of emission or to the local environment. They can travel over long distances, cross frontiers and create regional and global environmental problems. Acidic deposition, stratospheric ozone depletion, greenhouse effect are the burning issues.

The mechanism by which the emitted pollutants, mainly SO_x and NO_x are transformed into acidifying substances in both the gaseous and liquid phases are complex and incompletely understood. The concentrations and distribution of acidic deposits-wet and dry, are determined by many intricating processes, e.g. the transport and dispersal of the parent pollutants, the role of oxidizing agents such as hydrocarbon derivatives and ozone and meteorological factors. The basic physical and chemical processes involved in the washout of the soluble gases and aerosol species are not limited to sulphur and nitrogen oxides. Most atmospheric trace gases are likely to be highly soluble in precipitation. In fact, measurements have recently shown that precipitation contains hundreds of organic compounds and many trace metals. Acid fog recently reported in United States and other countries contains carbonyl compounds, alkyl sulphonate and pesticides in addition to sulphates and nitrates. Measurements of precipitation chemistry on global scale are conducted as part of work of WMO's Background Air Pollution Monitoring Network (BAPMN). First established in 1969, the BAPMN network, currently a WMO/UNEP joint effort, comprises some 196 stations, 152 of which have capability to carry out sampling for measurements of precipitation chemistry.

Impacts of Atmospheric Pollutions

Air pollution affects human health, vegetation and various materials. The notorious sulphurous smog which occurred in London in 1952 and 1962 and in New York in 1953, 1963 and 1966 clearly demonstrated the link between excessive air pollution and mortality and

morbidity. Such acute air pollution episodes occur from time to time in some urban areas. In January 1985, an air pollution episode occurred throughout western Europe. Near Amsterdam, the 34 hrs average SPM and SO_x concentrations were in range of 200-250 microgram/cubic meter (the WHO range is 60-90 mg/m³ for SPM and 40-60 mg/m³ for SO_x). During these episodes many people were affected, pulmonary functions in children were 3 to 5 % lower than normal. Athens is known for frequent occurrence of such acute air pollution episodes. But even in the absence of such episodes long term exposure to air pollution can affect several susceptible groups (children and elderly persons and those persons with respiratory and heart problems).

Air pollution can cause substantial damage to many materials. The most striking examples of such damage are illustrated by the effects of air pollutants (specially SO_x) on historical buildings and monuments. The Acropolis in Greece, the Coliseum in Italy, and Taj Mahal in India have withstood the influence of atmosphere for hundreds or even thousands of years without any great damage. Yet in the past few decades their surfaces have suffered increasing damage because of increased air pollution.

Stratospheric Ozone and its Depletion

Ozone is naturally produced and destroyed through photochemistry that occurs in the stratosphere. On purely chemical grounds, one would anticipate ozone to be most abundant in the tropics, where the photodissociation of O₃ is efficient. However, observations of stratospheric ozone reveal a very different picture. Despite the fact that ozone is produced at low latitudes, its largest column abundances actually appear at high latitudes as a result of poleward transport out of the tropical source region. Most of the atmospheric ozone is found between the altitudes of 10 and 30 km. at mid and high latitudes and between 20 and 40 km over tropics.

Abundances of ozone over mid-high latitudes are maintained by a delicate balance between production, transport and removal. A decrease in ozone could be observed at these latitudes by reduction of ozone transport from the tropics or/and an increase of the chemical ozone

removal. For example, ozone transport to polar regions could be curtailed by vortices in atmospheric circulation which appear during the spring and winter. On the other hand, the special chemical catalytic cycles involving reactive chlorine and bromine liberated at extremely low temperatures due to heterogeneous chemistry from their otherwise chemically inert reservoir species, destroy ozone. Concern about the depletion of stratospheric ozone by man's activities began in the late 1960s over emissions of nitrogen oxides (NO_x) by high flying supersonic aircrafts. The NO_x thus emitted was considered to act as a catalyst destroying ozone in the stratosphere. Later, in 1974, it was found that manmade chlorofluorocarbons (CFCs), although inert in lower atmosphere, can survive for many years and migrate into the stratosphere. There CFCs are disintegrated by UV radiation, releasing atomic chlorine which attacks stratospheric ozone, with the formation of the free radical ClO which reacts further to regenerate atomic chlorine. This chain reaction can cause the destruction of as many as 100,000 molecules of ozone per single atom of chlorine.

CFCs are compounds used as propellants and solvents in aerosol sprays, fluids in refrigeration and airconditioning equipments, foam blowing agents in plastic foam production, and solvents, mainly in the electronic industry. Although there is a range of compounds called chlorofluorocarbons CFC-11 (CCl₃F-trichlorofluoromethane) and CFC-12 (CCl₂F₂ - dichlorofluoromethane) are the most commonly used (Fig-4). Studies in 1980's have shown that emissions of bromine could also lead to a significant reduction in stratospheric ozone. Bromofluorocarbons (halons 1211 & 1311 i.e. CFC12Br & CF3Br) are widely used as fire extinguishers and ethylene dibromide and methylbromide are used as fumigants.

The concentrations of chlorine in the stratosphere is set mainly by anthropogenic sources of CFC-11, CFC-12, carbon tetrachloride and chloroform. Methyl chloride is the only natural organochlorine compound in the atmosphere. The concentrations of C1 in the atmosphere due to methyl chloride has remained unchanged perhaps since 1900. The major additions of C1 to the atmosphere have mainly occurred since 1970 and have been attributed to anthropogenic sources (Fig.5). At present the total C1 in the atmosphere due to organochlorine compounds is approaching 4.0 ppbv - an increase by a factor of 2.6 in only 20 years.

Observing changes in the chemistry of the stratosphere caused by the release of trace gases is difficult. Such changes are estimated with the help of theoretical models. The models developed in 1970's rates, if continued indefinitely, would deplete stratospheric ozone by about 15%, with an uncertainty range of 6 to 22%. Later models indicate that if production of CFCs were to continue in the future at 1980 rate, the steady-state reduction in total global ozone could be about or less than 3% over the next 70 years. There are several limitations to these theoretical models and it has been pointed out that such models might be underestimating the adverse impact of CFCs on ozone, specially at high latitudes in winter.

Worldwide ozone monitoring (ground-based total ozone monitoring) began during the International Geophysical Year in 1957, but only a very few stations have continuous records from 1957 to the present day. One of these stations is Halley Bay, Antarctica. Records from Halley Bay show that the total ozone levels above the station in 1984 were only about 60% as large as those obtained in the late 1950s and early 1960s. The changes were most pronounced in October. Recent studies have indicated an average decrease of 30 to 40% in the total column ozone in the lower stratosphere between 15-20 km above Antarctica (referred to as the ozone hole), at some altitudes ozone loss may reach as much as 100% (as observed in the Austral spring of 1993). The data indicate that the decrease in ozone occurs in spring time (September-October) and recovers in summer (January-February). Scientific evidence strongly indicates that manmade chlorinated and brominated chemicals are responsible for this massive ozone depletion. Under the special meteorological conditions of the Antarctic winter stratosphere, the polar stratospheric clouds (PSCs), composed of water ice and nitric acid trihydrate are formed around the temperatures 195 K and below. The main chemical causes of ozone destruction results from catalytic cycles involving reactive chlorine and bromine liberated from chemically inert reservoir molecules (ClONO_2 and HCl) by heterogeneous reactions at the PSC surfaces on the return of the sunlight. Recent observations suggest that catalytic ozone destruction may also take place on sulphate aerosols even at higher temperatures ($> 200 \text{ K}$) than the PSC threshold temperatures.

The discovery of the extraordinary ozone depletion during Austral springs over Antarctica in 1985 (named as ozone hole) was indeed a turning point in the field of atmospheric chemistry, generating tremendous global concern, enormous and hectic research work and modeling. Since 1985 the ozone hole has been regularly observed and monitored every year. In 1986 and 1988 the ozone destruction was not as much as in 1985 and 1987, which strengthened the then prevalent view of increased ozone loss with time modified by a two year cycle. Later on, severe ozone depletions have continuously been observed for the last 5 years (1989-1993), rendering the two-year cycle theory less credible.

Preliminary reports about the observations made by a combination of satellite, balloon and ground-based measurements indicate that during the Austral spring of 1993, an ozone hole with all time recorded depth and spread has been formed. Several measurements show the total column ozone to be 90 Dobson Units (DU) or less in place of its pre-depletion value of 275 DU. The last year's minimum value was 105 DU (100 DU is equivalent to 1 mm thickness of ozone only reduced to standard temperature and pressure). This years' data represent the lowest value of total column ozone ever measured on Earth. The atmospheric scientists were not expecting such a deep ozone hole even allowing for the effect of the increasing concentrations of chlorine and bromine in the atmosphere. Such a large ozone destruction is believed to be caused more by weather conditions than the CFC build up.

The possibility of the occurrence of a similar ozone hole over the Arctic is being contemplated since 1985. But the concern about ozone loss has recently been further intensified with the reports of significant column ozone decrease over the densely populated mid-latitudes, in all the seasons and both the hemispheres. The two Airbone Arctic Stratospheric Expedition(AASE I & II) carried out during January-February 1989 and October 1991-March 1992, and numerous other measurements indicate that Arctic vortex was as chemically perturbed as Antarctic vortex. However, at present ozone changes over the Arctic is not comparable to those over Antarctic. The degree of any future ozone depletion will depend on the particular meteorology of each Arctic winter and future atmospheric levels of chlorine and bromine.

Impact of Ozone Depletion

For nearly a billion years, ozone molecules in the atmosphere have safe guarded life on this planet. Although ozone molecules play such a vital role in the atmosphere, they are exceedingly rare, in every million molecules of air, fewer than ten are ozone. These molecules exhibit different character traits depending on where they exist in the atmosphere. About 90% of the ozone resides in a layer between 10 and 40 kilometers above the Earth's surface (i.e. in the lower stratosphere). Ozone there plays a beneficial role by absorbing dangerous solar ultraviolet radiation from 250 to 310 nm and protecting plant and animal life from the UV-B hazards. Further, since the absorbed solar energy is converted into thermal energy, it is the principal source of heat in the middle atmosphere, and is, therefore, responsible for the very existence of the stratosphere, a layer with a positive temperature gradient and a considerable static stability. The possible long term decrease in stratospheric ozone, thus will not only increase the UV-B irradiance at the Earth's surface, but is also expected to modify the thermal structure of the middle atmosphere with possible grave consequences on the general circulation and on the global climate of our planet.

Close to the Earth's surface, however, ozone displays a destructive side. Because it reacts strongly with other molecules, it can severely damage the living tissues of plants and animals. Low-lying ozone (tropospheric ozone) is a key component of the smog that hangs over many major cities across the world, and governments are attempting to decrease its levels. Tropospheric ozone is also a greenhouse gas. Although tropospheric ozone and stratospheric ozone are the same molecule, they represent separate environmental issues, controlled by different forces in the atmosphere.

It has been predicted that a 1% reduction in the amount of stratospheric ozone will lead to an increase of approximately 2% of UV-B radiation reaching the ground. Exposure to increased UV-B radiation can cause suppression of the human body's immune system, which might lead to an increase in the occurrence or severity of infectious diseases such as herpes, leishmaniasis and malaria and a possible decrease in the effectiveness of vaccination programmes. Enhanced levels of UV-B radiation can lead to increased damage to the eyes, especially cataracts. It has been estimated that each 1% decrease in

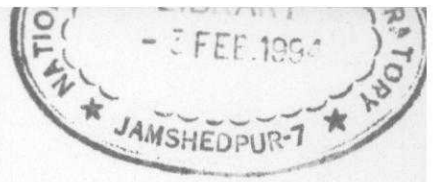
total column ozone is expected to lead to an increase of 0.6% in the incidence of cataracts (or an estimated world-wide increase of 100,000 blind persons per year due to UV-B induced cataracts). In addition, every 1% decrease in total column ozone is predicted to lead to a 3% rise of the incidence of non-melanoma skin cancer (or an estimated worldwide increase of 50,000 cases per year). There also can be concern that an increase of more dangerous cutaneous malignant melanoma. A recent study has shown that a 1% reduction in ozone will result in a 1.6% increase in male death rates and 1.01% increase in female death rates due to melanoma.

Plants vary in their sensitivity to UV-B radiation. Some crop species such as peanut and wheat prove fairly resistant, while other such as lettuce, tomato, soyabean and cotton are sensitive. UV-B radiation alters the reproduction capacity of some plants and also the quality of harvestable products.

Increased UV-B radiation has negative effects on aquatic organisms, especially the small ones such as phytoplankton, zooplankton, larval crabs and shrimp, and juvenile fish. Because many of these small organisms are at the base of the marine food web, increased UV-B exposure may have a negative effect on the productivity of fisheries. Increased levels of UV-B radiation may also modify freshwater ecosystems by destroying micro-organisms, thus, reducing the efficiency of natural water purification.

Green House Effect

The surface of our planet is heated by absorbing the radiation of wavelengths 0.4-4 μm (400-4000nm), arriving from the sun through the atmosphere. In turn, it emits IR-radiation of relatively high wavelengths of 4-100 μm , to achieve a steady state. Had there been a void around our planet, this steady state temperature would have been a few tens of degrees lower than that we find, but due to the presence of an atmosphere with relatively active trace gases like water vapour, CO_2 , methane, nitrous oxide, ozone and halocarbons, having absorption bands in the wavelength region of the Earth's thermal radiation, there is a heating of the Earth's surface and surroundings which is commonly known as the "greenhouse effect". Among the various tropospheric gases, only water, ozone and, to some extent, carbon dioxide absorb.



both solar and the earth's thermal radiation. All other trace gases are virtually transparent to the solar radiation and hence their contribution to the tropospheric heat budget is due to their absorption of the earth's thermal radiation, and as a consequence, through their own thermal emission in the range of 6-16 μm wavelengths. The most significant absorption of the thermal emission is by its hydrological cycles. Water absorbs IR-radiation of wavelengths below 8 μm and above 18 μm providing a window between 8-18 μm for the earth's thermal radiation to escape to the space. But the carbon dioxide present in the atmosphere absorbs between 12-18 μm which further masks this window for the free upward passage of the heat rays. Interestingly enough, this so called reduced atmospheric window is further masked by the strong absorption bands of trace gases like methane, ozone, nitrous oxide and various CFC's. Thus the consistently increasing concentration of these trace gases including carbon dioxide in the lower atmosphere is increasing the mean global temperature with time.

The atmospheric CO_2 concentration is now more than 335 ppmv, over 25% greater than its pre-industrial period(1750-1800) value of about 280 ppmv and is currently rising at the rate of about 0.5% per year due to anthropogenic emissions (Fig.6). The current atmospheric methane concentration is about 1.77 ppmv, more than double of pre-industrial value of 0.8 ppmv and is increasing at the rate of 0.9% per year; and presently the volume mixing ratio of nitrous oxide in the atmosphere is over 310 ppbv, about 8% greater than its preindustrial value of about 285 ppbv (Fig.6). All these have anthropogenic as well as the natural sources. The concentration of CFCs (as discussed earlier) with exception of methyl chloride, is exclusively of industrial origin.

The contributions of the aforementioned trace gases to the greenhouse effect depend on the amount of the gas released in the atmosphere, its net concentration in the atmosphere its life time, and its radiative forcing. The task of predicting the climate change in the future is extremely complex. The effects of the heat build up of greenhouse gases in the atmosphere cannot be studied directly. During the last 25 years more than 100 independent estimates through different simple and complex models, have been made. Almost all these estimates lie in the range of 1.5° to 4.5°C (Fig.7) with value near 3.0°C tending to be favoured. IPCC has recently predicted that under the "business-as-usual" scenario global warming could reach 2° to 5°C over the next century (with the best estimate around 3°C), a rate of change unprecedented in the past 10,000 years.

Detailed analysis of temperature records of the past 100 years indicate that global mean temperature has risen by 0.3 - 0.6° C (Fig.8). Much of the warming since 1900 has been concentrated in two periods, the first between about 1910 and 1940 and the other since 1975. The eight warmest years on record have all been between 1980 and 1993.

Impacts of Climate Change

Changes in climate would have an important effect on agriculture and livestock. Negative impacts could be felt at the regional level as a result of changes in weather and the arrival of pests associated with climate change, necessitating innovation in technology and agricultural management practices. There may be severe decline in production in some regions (e.g. Brazil, the Sahel region of Africa, South East Asia and the Asian region of Russia and China), but may be an increase in production in other regions because of a prolonged growing season. The effects of global warming on forests will also be mixed and will vary from one region to another.

Projected changes in temperature and precipitation suggest that climatic zones could shift several hundred kilometers towards the poles over the next 50-100 years. Ecosystems are not expected to move as a single unit, but would have a new structure as a consequence of alterations in distribution and abundance of species.

Water resources are expected to be greatly influenced due to climate change. It appears that many areas will have increased precipitation, soilmoisture and water storage, thus altering patterns of agricultural, ecosystem and other water use. Water availability will decrease in other areas, a most important factor for already marginal situations, such as the Sahelian zone in Africa.

Global warming will accelerate sea level rise (Fig.9), modify ocean circulation and change marine ecosystems with considerable socio-economic consequences. IPCC predicted that an average rate of global mean sea level rise of about 6 cm per decade could occur over the next century. The predicted rise is about 20 cm in global mean sea level by

2030, and 65 cm by the end of the next century, with significant regional variations. A sea level of this magnitude will threaten low-lying islands and coastal zones. It will render some island countries uninhabitable, displace tens of millions of people, seriously threaten low lying urban areas. In our immediate neighbourhood, Maldives may be washed off from the world map and the densely populated delta of Bangladesh may convert into a lake.

Concluding Remarks

A concerted effort is needed to save our environment from degradation. We, human beings are all selfish to some extent. and we more concerned about our own immediate surroundings and circumstances than about the rest of the world. But can we meet the challenge of the growing environmental crisis individually? This indeed is a global problem and can be tackled only by joint efforts. Fortunately global action has already been initiated.

The Vienna convention for the protection of ozone layer adopted in March 1985, the Montreal treaty of September 1987 to curb the production and consumption of CFCs, its ratification in June 1990 in London meeting and Rio Earth Summit in June 1992 in which many new countries were successfully persuaded to join and participate, are the steps in the right direction. Vigorous and sincere search for new alternatives of CFCs and pollution free alternative sources of energy and its economization; awareness for sparingly using the natural resources in a renewable manner, recognition of the population pressure, emphasis on linking the manufacture of a product from its disposal, and awareness through to protect the earth from stratospheric ozone depletion, from green house forcing and other types of environmental degradations through conference will go a long way in the betterment of mankind, animals and other living things.

These international agreements represent the critical steps towards saving our planet. But perhaps more importantly, it has taught scientists and policy makers an invaluable lesson about addressing environmental problems. Negotiations on these issues to protect the Earth for future generation, is the first step taken by various nations of the world.

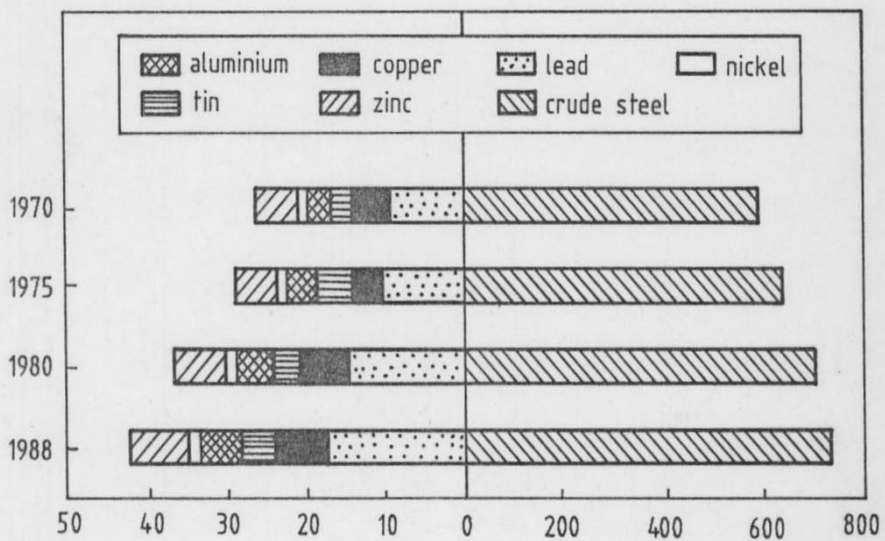
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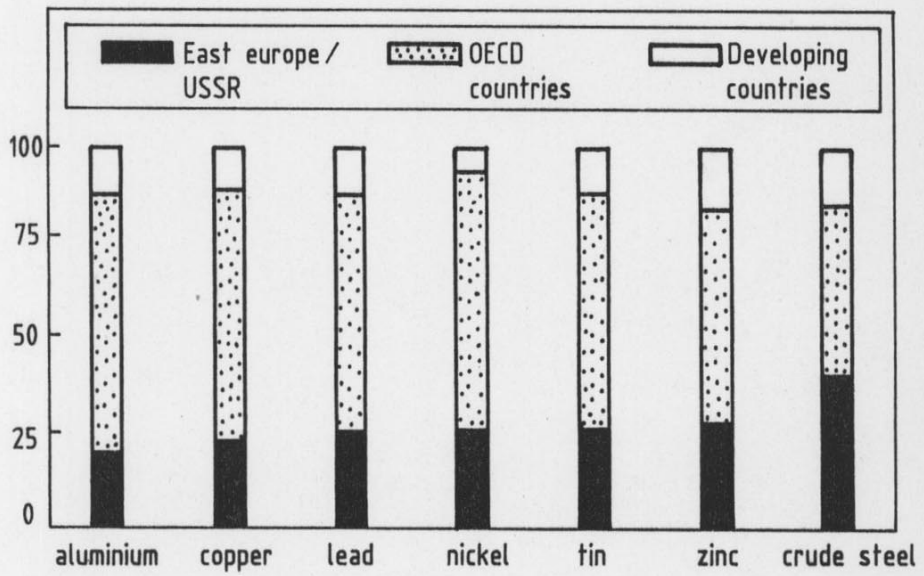
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Figure. 1. WORLD CONSUMPTION OF METALS
(million tonnes)



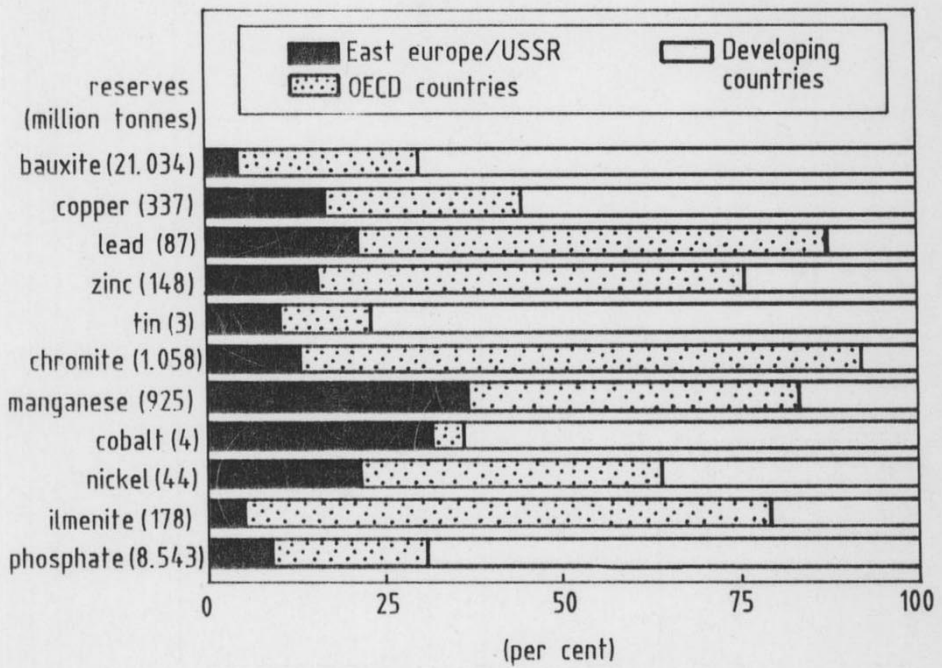
Source: (El-Hinnawi, 1992)

Figure. 2. WORLD CONSUMPTION OF METALS (BY PERCENTAGE)



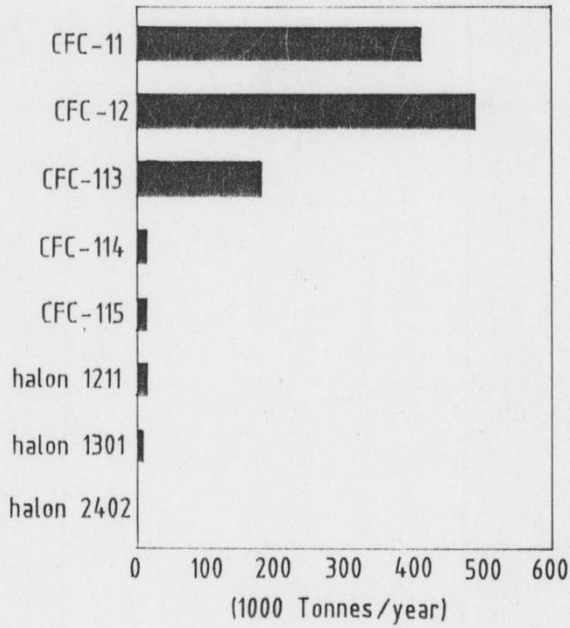
Source: (El-Hinnawi, 1992)

Figure. 3. PROVEN WORLD RESERVES OF METALS AND ORES



Source: (El-Hinnawi, 1992)

Figure. 4. ESTIMATED WORLD CONSUMPTION OF MAIN CFCs AND HALONS (1986).



WORLD USE OF MAIN CFCs AND HALONS (1986)

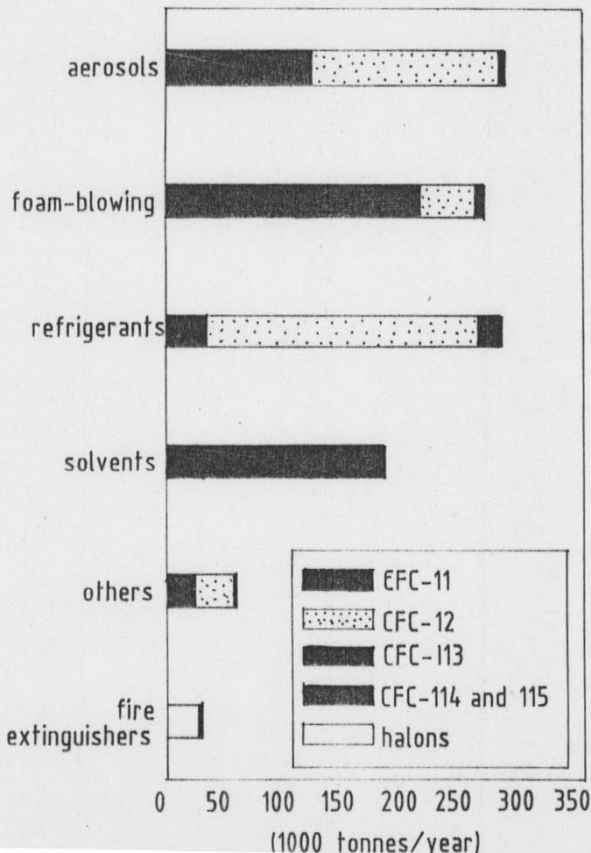
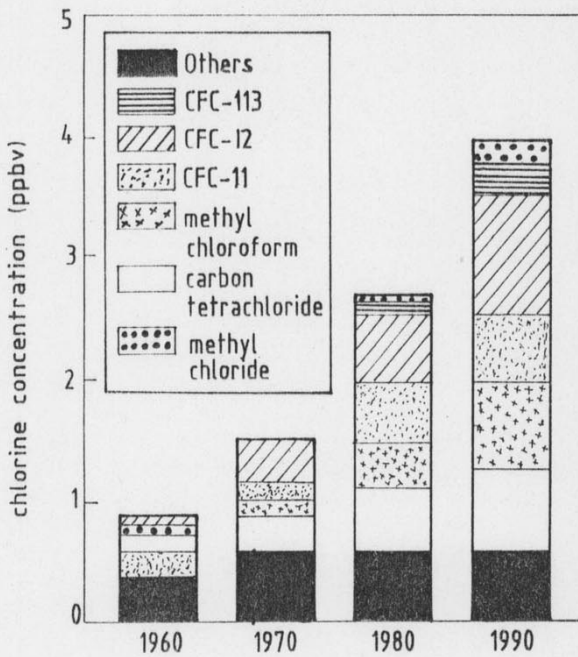
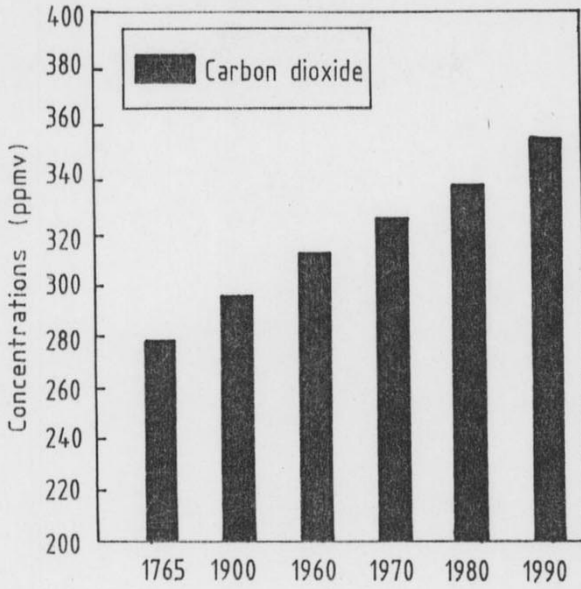


Figure 5. ORGANOCHLORINE CONCENTRATION IN THE ATMOSPHERE (ppbv Cl)

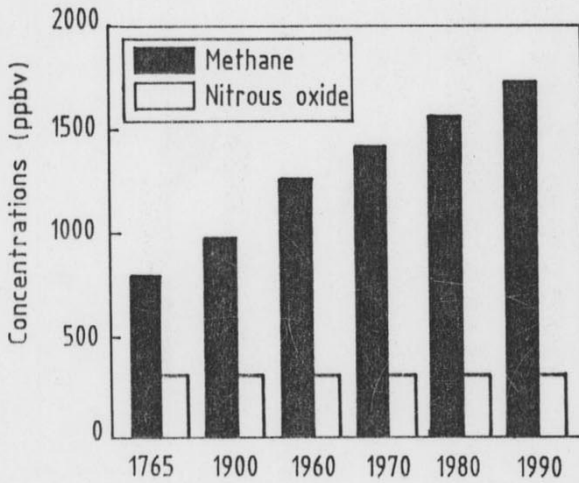


Source: Based on data from (Rowland, 1991)

Figure. 6. INCREASE OF CARBON DIOXIDE
IN THE ATMOSPHERE SINCE 1765

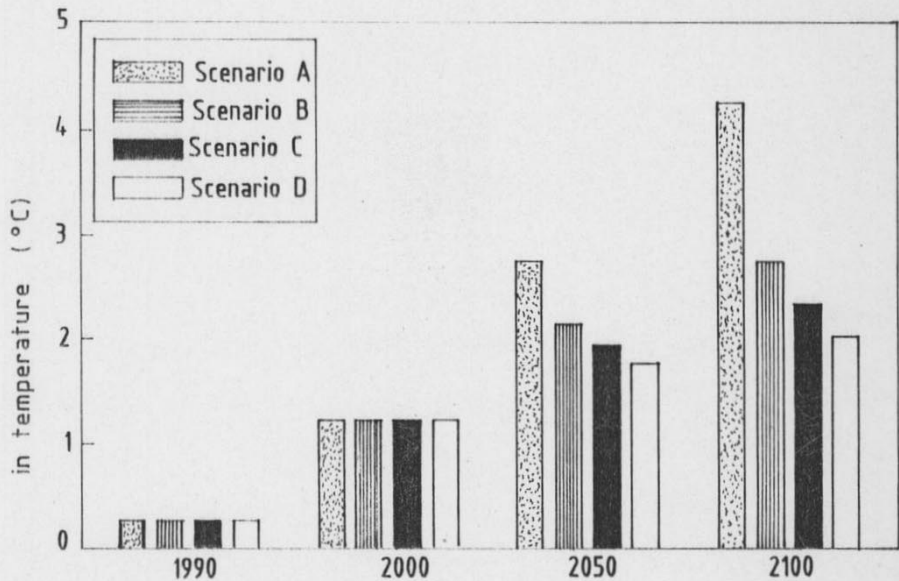


INCREASE OF METHANE AND NITROUS OXIDE
CONCENTRATION IN THE ATMOSPHERE
SINCE 1765



Source: Based on data from (IPCC-1990)

Figure. 7. PROJECTED RISE IN TEMPERATURE ABOVE PRE-INDUSTRIAL (1765)

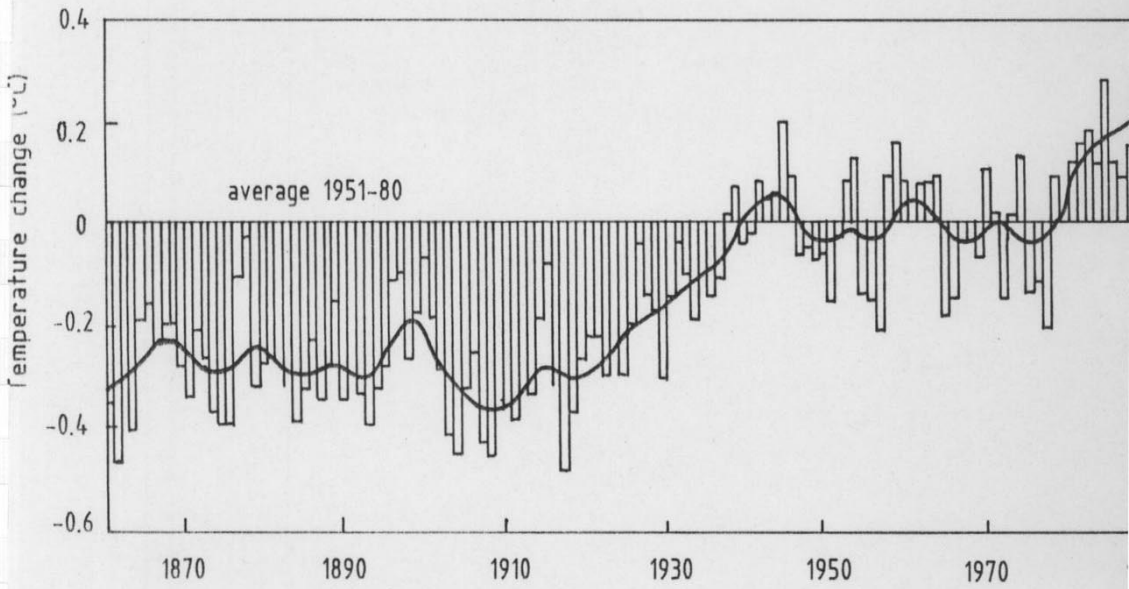


Source: Based on data from (IPCC-1990)

Scenarios as defined by IPCC

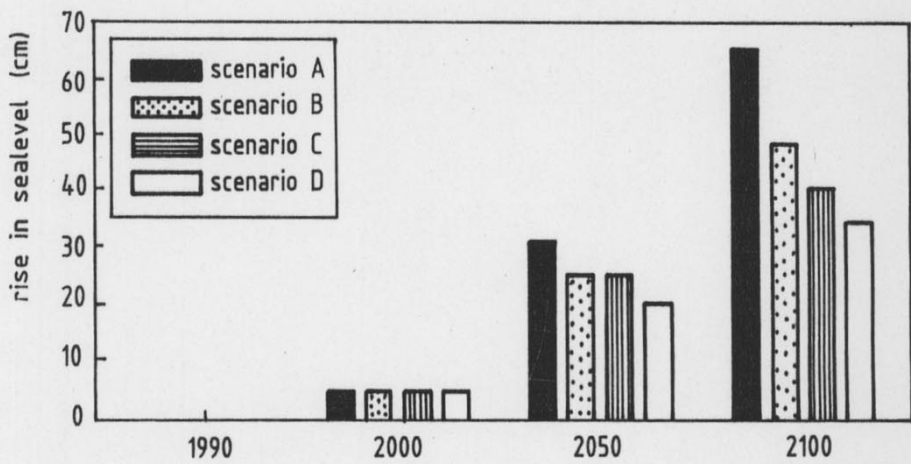
- Scenario A: Energy supply and demand continue as they are. Deforestation continues at present rate. Partial implementation of Montreal Protocol (business-as-usual)
- Scenario B: Energy supply mix shifts towards low-carbon fuels and natural gas. More energy efficiency. Deforestation reversed. Full implementation of Montreal Protocol.
- Scenario C: Shift towards renewable sources of energy and nuclear power in second half of the next century.
- Scenario D: Shift towards renewable energy and nuclear power in first half of the next century.

Figure. 8. GLOBAL CHANGE IN TEMPERATURE (1861 - 1989)



Source: Based on data from (IPCC-1990)

Figure. 9. PROJECTED SEALEVEL RISE



Source: (IPCC - 1990)