THE ENVIRONMENT IN QUESTION

ROUTLEDGE

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ETHICS AND GLOBAL ISSUES

Edited by DAVID E. COOPER & JOY A. PALMER

ROUTLEDGE

9 Air pollution – with special reference to acid rain, the greenhouse effect and ozone layer depletion

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It is an irony of air pollution that the cure for one problem may well exacerbate another. Much publicity, for example, has been given to the use of three-way catalytic converters in the exhaust systems of cars to 'reduce noxious emissions by 95%' in the words of a recent advertisement (Audi 1989) from a major vehicle manufacturer. It goes on to explain that as the 'engine exhaust gases pass through at around 300°C these convert nitrogen oxides, unburnt hydrocarbons and deadly carbon monoxide into nitrogen, water and carbon dioxide . . . the stuff that makes fizzy drinks fizzy'. What it does not say is that 'the stuff that makes fizzy drinks fizzy' is also the stuff which absorbs the heat being radiated back into space from the Earth, thus warming the atmosphere and so becoming the leading culprit in the phenomenon commonly known as the greenhouse effect. Unfortunately carbon dioxide (CO_2) is produced every time something is burnt, the combustion of fossil fuels included.

The moral must be that individual aspects of air pollution cannot be viewed in isolation, that the 'cure' of each problem needs to be evaluated against the cause and effect of another, and while it may be convenient to isolate individual problems their overall relationship one to the other must be borne in mind. The conclusion seems to be obvious to the comprehensive observer; clearly, as with most ills, prevention rather than cure has to be the prime objective. From government departments to manufacturing industries the onus on research and development departments is to make a full assessment of the polluting processes and environmental hazards of technological advance, as well as of the economics of the situation.

MAJOR PROBLEMS OF AIR POLLUTION

The air is a complex chemical mixture and the processes which occur within it may take place out of sight and reach of scientists. The atmosphere undergoes constant change which laboratory experiments and computer modelling are mostly unable to replicate. It may well be that the fundamentals of the atmopsheric cycle are understood, but the introduc-

tion into the air of laboratory-created chemicals, in addition to the products of incineration, increases the difficulty of interpretation. Insufficient environmental evaluation is carried out into the effects of new chemicals which soon become part of our daily lives. Chlorofluorocarbons (CFCs) and polychlorinated biphenyls (PCBs) are two good examples of this; both were developed with little apparent regard to their long-term environmental effects – not even the well-known cautionary tale from an earlier decade, of the adverse effects of the indiscriminate use of DDT, appears to have made a lasting impression. It took two persistent scientists (Molina and Rowland 1974) to discover the ugly side of CFC gases, which was the fact that they had the propensity to destroy ozone, a fact now accepted as the prime cause for the depletion of the ozone layer in the outer atmosphere; and they have other adverse effects, yet commercially they promised so much good.

Air pollution results from the overburdening of the atmosphere with gases and chemicals. Like the oceans of the world, whose waters are able to assimilate and 'digest' quantities of pollutants in moderation, the air around us is able to absorb and dilute reasonable amounts of extra substances although a finite measurement cannot be placed on these quantities. Common sense must suggest that adverse effects result from the constant addition to the air of exhaust fumes from the smokestack of even one coal-burning power station.

The prime source of pollutant gases is from incineration. This may be natural as with the ejections from volcanoes or the fires of forest, bush and grassland; there is little we can do to prevent this. Within our control is the burning of fuel, mostly fossil fuel, for warmth and power. Either we have personal responsibility as with our open fires and the internal combustion engine in our car or motor cycle, or we may be indirectly responsible as with the centralized burning of coal, oil or gas necessary to produce the electricity available to us at the flick of a switch. We can recognize, and control, our personal contribution to pollution as we see smoke and fumes rise from our chimney, central heating flue or car exhaust pipe. What is not so obvious is that part of the smoke rising from the power station smokestack is ours as well.

The car manufacturer accurately named the three main culprit pollutants from car exhausts, namely nitrogen oxides (NO_x), hydrocarbons and carbon monoxide (CO). Sulphur dioxide (SO_2), the other main pollutant gas, is produced primarily when industry burns coal or other fossil fuels. Hydrogen, oxygen and carbon dioxide (CO_2) are non-toxic products of combustion, the two former usually in the form of water (H_2O).

Much has been made of lead as a pollutant, with the ensuing campaign for the use of unleaded petrol in order to clean our air. Lead is a health hazard, but since it is added to petrol in the first place, in order to ensure smooth-running engines, it is not a by-product of the combustion process itself. Lead-free air is essential, but to replace the fuel we use with unleaded petrol does not in any way resolve the problem of pollutant gases – in fact it tends to lull the general public into a false sense of security in relation to the poisons of vehicle exhaust. What it does prove is that, with the proper incentives and explanation, people are prepared to alter their habits.

Other pollutants, such as the CFCs and the PCBs, are now a part of our manufacturing processes and commercial or domestic life. Few people in the USA, UK or other western-style countries can be ignorant of the fact that aerosol containers, refrigerators and foam packaging are associated with gases harmful to the air. The 'ozone friendly' labelling on innumerable products reminds them of it daily. Again, perhaps, such an approach by industry and retailers brings about a feeling of complacency with regard to atmospheric pollution. The awful conditions, in some American cities, of the long, hot, dry summer of 1988 stimulated the *New York Times* (14 August 1988) to recognize that 'the suns and seas and sins of man have combined to transfer New York life into a seemingly endless slog through simmering broth'. This simmering broth was the pollution-laden air, thick with vehicle fumes and industrial haze.

Agriculture is not free of blame. The addition of artificial fertilizers to the land contributes mainly to an excess of nitrates and phosphates in the water runoff which enters the water cycle. But a considerable contribution is also made to the atmosphere, not least of all by the enormous increase in cattle rearing (over 1,000 million worldwide – McKibben 1990) and, to a lesser extent, other livestock. The digestive system which turns green fodder into food inside every beast also produces methane gas; 73 million tonnes (McKibben 1990) of this flatulence is expelled into the air and, globally, is a most significant contribution to the increase of methane in the atmosphere, up by 435 per cent over the last 100 years. Methane also derives from the process of decay. Rotting conditions as are found naturally in swamps are ideal for the generation of methane, which is often known as marsh or swamp gas. Paddy fields for growing rice imitate such conditions and provide a major source of methane. Well over 100 million cubic tonnes of the gas rise from the paddies annually. With the increase in world population, particularly in China, there needs to be an annual increase in rice acreage. Far from a decrease, we can only anticipate more methane from this source.

Termites can digest wood with bacteria in their intestinal tracts similar to those in cattle. They, too, excrete methane – every termite mound exudes 5 litres of the gas every minute. With an estimated half-tonne of termites for every person on Earth, some research scientists claim they make a considerable contribution to the release of this greenhouse gas (McKibben 1990). The dumping and rotting of domestic and commercial waste in pits leads on to a build-up of methane, dangerous directly

because of its explosive nature and indirectly as an air pollutant. Methane is also a by-product of gas and petrol manufacture; collected from any source it is a valuable creator of power, yet only a few sporadic attempts are made to utilize it in the UK – for example, as at Packington Hall, Coventry, where waste disposal company PEEL exploits methane for electricity generation.

The interplay of natural forces provides various ways of counteracting pollution, that of air included. The process of photosynthesis is one of the most important whereby vegetation replaces carbon dioxide with oxygen. This vital link in the carbon cycle is able to provide a counterforce to the excessive production of CO_2, yet other activities of people, apart from that of direct pollution of the atmosphere, hinder this remedial action.

Timber extraction and other destruction of forested lands are a prime example, whilst the overloading of the seas with toxic materal is another. This is because the two major sources of plant material to perform the photosynthesis process grow in the tropical rain forests and on the oceans. In the former, masses of trees and other vegetation cover vast areas of land; with the latter, algal blooms extend across large expanses of the water surfaces. These are discussed in Chapter 6. It has been estimated that the CO_2 emitted from a 1,000 megawatt power station operating on 38 per cent thermal efficiency can be neutralized by the vegetation of 700 square miles of forest (McKibben 1990) (something like five days of rain forest destruction at the present rate). Environmental matters are full of contradictions – it is an ironic 'twist in the tail' of air pollution that some of the species of algae (*Phaeocystis pouchetti*, for example) are also a major source of SO_2, so that their CO_2-friendly activities are offset by their hostile contribution to acid rain.

So far my attempt has been to recognize the main pollutants and their sources, as well as to emphasize the holistic nature of the problems of air, and other, pollution. Mindful of the interrelation of these issues, let us look at the major problems individually.

The main problems associated with air pollution are:

- the contamination of the air we breathe;
- the creation of acid rain;
- global warming (the greenhouse effect);
- the depletion of the ozone layer.

CONTAMINATION OF THE AIR WE BREATHE

Clean air to breathe is an inalienable right of every person. It follows that it is equated with an individual responsibility not to foul the air. Yet the common concept of an ever improved level of living standards includes as major items:

- superior living accommodation;
- increased opportunity for travel (mainly through car ownership);
- the acquisition of goods and chattels;
- living and working in premises heated, cooled and managed by convenient services at the flick of a switch, the turn of a tap, the twist of a handle or the push of a button;
- better health facilities;
- increased opportunities to participate in leisure pursuits.

Most of these give rise, directly or indirectly, to the production of pollutant gases from the exhaust pipes of planes, trains, boats and road vehicles, the flues of factories and electricity power stations and the chimneys or extractor vents of homes, offices, shops, hospitals, leisure centres and public buildings.

The Worldwatch Institute (1990b) claims that a fifth of the world's population (about 1,000 million) is breathing air contaminated above international safety limits and concludes that tough international agreements are the only way to combat the spread of polluted air. There is some justification for the claim that

> air pollution, more than the existence of the Iron Curtain, brought about the revolution in Czechoslovakia. . . . The constant sore throats and headaches, the high incidence of lung disease and cancer, the lack of red blood corpuscles in the children, the low life expectancy were a nagging irritant – a daily, personal complaint against the old regime.
> (*Observer* 1990)

A crisis response to a recognized danger to pure air is not good enough. Long-term plans are required to eradicate the cause as opposed to short-term measures which alleviate the symptoms. This will be emphasized later, but a simple example will highlight the matter. The smog mask, commonly worn in Tokyo, Hamburg and Los Angeles, is finding favour with cyclists in Central London as individuals attempt to combat the inhalation of noxious fumes and particles of carcinogenous matter. These masks may help the wearer to avoid the worst of the evils in the air and they may help to advertise the existence of a problem, yet, at the same time, they may 'mask' the true problem as well, the problem of pollution caused by the inefficiency of the internal combustion engine and the incomplete incineration of a fossil fuel.

Encouragingly the full recognition of an air pollution problem backed by popular pressure to alleviate the cause can be effective. Smoky fog, which became known as 'smog', is one such example. It has been eradicated in Britain by the suppression of sooty particles, which poured from the chimneys of coal fires in susceptible areas. On days of temperature inversion when a layer of warm air sited itself above cooler air at ground level, the smog was trapped, and in London the 'pea-souper', as yellow as the lentils of the real soup, was created. A disastrous London smog episode in November 1952 caused the deaths of thousands of bronchitis sufferers and the complete disruption of the capital city for many days. The public uproar which followed led eventually to the Clean Air Act 1956 which set up legislation to impose smoke control zones in the UK and thus remove the smoke particles from the air in urban areas. Smokeless fuels, and a change to gas and electrical heating systems, have removed the dirt from the fumes, but not the gases. Now another 'smog' has appeared in some townscapes where nitrogen oxides from vehicle exhausts react with the sunlight to form ozone (O_3) and peroxy acetyl nitrate (PAN) in a photochemical process. Where a basin-shaped land area is host to thousands of petrol and diesel powered vehicles, the invisible spread of the gases gives rise to the photochemical smogs such as give notoriety to Los Angeles and Athens. By another ironic twist of nature, ozone, the very gas whose absence we deplore in the upper atmosphere, brings acute physical discomfort, and even more serious symptoms, to those who inhale it at ground level. PAN, the other main contaminant, apart from its minor effects, is thought to cause cancers; it also damages vegetation.

Vehicle emission reduction

Unlike the railway system, where the gross pollution of steam engines has given way to diesel oil powered locomotives and increasingly to electric trains, road vehicles remain firmly based on the petrol or oil fuelled internal combustion engine. Until a technological breakthrough occurs, such as the design of a ceramic engine to give a possible 200 miles per gallon fuel consumption, or the use of hydrogen as vehicle fuel (*Christian Science Monitor* 1990), there cannot be a fundamental improvement.

At present there are only two adaptations to the design of vehicles which can reduce, but not eliminate, pollutant emissions. The first has been mentioned already – the catalytic converter, already in general use in the USA and Japan on petrol driven vehicles. The three-way catalytic converter reduces the emission of CO, NO_x and hydrocarbons. It consists of an addition to the exhaust pipe similar in outward appearance to the silencer. Inside it contains a honeycomb structure coated with expensive metals such as platinum, palladium and rhodium. Reductions in pollutant gases of 90 per cent plus can be obtained with a conversion to nitrogen, water and CO_2. The life of a converter is limited to about 80,000 km (50,000 miles), which means it needs to be changed every three or more years depending on the use made of the vehicle. As catalysts the costly metals are not affected and can be recycled. It is essential to maintain the efficiency of the converter, which necessitates a national system of emission control, similar to the MOT testing at present. Lead damages the converter, so unleaded petrol must be readily available. It is also necessary to make certain that the engine is functioning well; this requires efficient combustion control. Even if the first owner of a car will accept the necessary restrictions it seems unlikely that subsequent owners, as the depreciation of the vehicle increases, will be so keen to pay out the necessary cost for replacement and maintenance. The other system is to use 'lean-burn' engines. As the petrol/air mixture is weakened the production of CO and hydrocarbons remains low while the NO_x falls away rapidly. Thus a lean-burn engine will not eliminate pollutants but it will reduce emissions for the whole life of the car. If a catalytic converter is used in conjunction with a lean-burn engine an even better result can be obtained. The question might be asked: if a silencer on cars is mandatory for UK vehicles, why not a pollution control converter?

There is something all drivers can do to lessen exhaust pollutants without design modifications. Slower speeds, especially if a constant level is maintained, reduce the creation of gases, and if this is coupled with the use of a fifth gear, which utilizes a slower engine revolution for the same road speed than a lower gear, then a minimum level of pollution is caused. Better still is to use a vehicle less for individual travel by making more use of public transport; this begs the question of an improved public system – available, reliable and regular.

The chemical industry

Direct pollution of the air from the chemical industry is well known through scenarios such as that of the leak of 40 tonnes of methyl isocyanate from the Union Carbide factory at Bhopal. Yet there is considerable evidence to show that the regular emission of toxic substances such as formaldehyde, hydrogen sulphide, silicon tetrafluoride and benzine has serious effects on the local population. At Abercwmboi, near Aberdare in south Wales, a smokeless fuel plant pours out those gases which would, without the prohibitions of smoke control zones, have poured from domestic chimneys elsewhere. A mere 20 miles way a Pontypool factory deals with toxic waste and denies the claim that it releases PCBs into the air. It is difficult to avoid the conclusion that the cost of remedial treatment to prevent the escape, or the complete destruction of pollutants, is only measured in financial terms and that the indirect costs to the welfare of people, animals and plants is not a consideration. Pearce, Markandya and Barbier in their *Sustainable Development, Resource Accounting and Project Appraisal: State of the Art Review* (1989), which was prepared as a report for the Department of the Environment, explore this economic aspect of environmental concern.

THE CREATION OF ACID RAIN

The term 'acid rain' has become the popular expression for any of the weather phenomena associated with excessive acidity. One of these matters is in fact the extra acidity associated with rainfall over and above that of the usual acidity of rain. Similarly, snow, hail and fog can all be over-acidic so that a better overall term is 'acid precipitation'. But acid rain does not preclude the inclusion of dry deposition of acidic particles, which in contact with dampness take on an acidic composition. Thus the preferred term for all of these acidic variations is 'acid deposition'.

Acidity is measured on the pH scale reflecting the concentration of hydrogen ions in the liquid. A pH of 7 is neutral, between 0 and 7 indicates that the substance is acidic, whilst a reading from 7 to 14 indicates an alkaline, or basic, state. The pH scale is logarithmic, so that between each point on the scale there is a tenfold difference. For rainfall which may measure 5.5 pH in normal circumstances to change to 3.5 pH may not sound alarming, but when this is interpreted to mean a 100-fold increase in acidity the magnitude of the variation becomes clear. Rainfall in the UK is normally acidic, between 5 and 6, because of the natural presence of carbon dioxide, and oxides of nitrogen and sulphur in the air. A rainfall reading of 2.4 (about the acidity of a lemon) was recorded at Pitlochry in Scotland on 20 April 1974 (Environment Canada 1982), and in late 1978 a pH of just under 2.0 was measured at Wheeling in West Virginia, USA (Eckholm 1982). Acid rain will not burn holes in cotton fabric – but even in its weak state it can destroy sensitive materials over a period of time.

The three 'common' acids of the atmosphere have been mentioned. Carbonic acid, nitric acid and sulphuric acid result from the chemical reaction of carbon gas, nitrogen gas and sulphur gas with atmospheric water. Of these the mixing of sulphur dioxide and rain leads to the most trouble unless the area affected happens to be a location where vehicular traffic is very heavy, when nitric acid, resulting from the reaction of nitrogen oxides with rain, will predominate. About 50 per cent of pollutant gases come from natural sources, but the other 50 per cent created by human activities are concentrated in fairly small areas relative to the size of the planet as a whole. This means that the major effects of acid rain are to be found in industrial concentrations such as the north-east USA, western Europe and the Far East.

Most of the pollutant gases come from the burning of fossil fuel as a power source. Natural gas, oil and coal (anthracite, steam coal, lignite or brown coal and peat) are the fossil fuels used to energize our industrial world. Their direct use is decreasing, for most are used to create electrical power. Coal in particular is sulphur rich, especially much of the coal mined in the UK. The release of this sulphur into the atmosphere as sulphur dioxide is the fundamental problem. The highest-level emitters of SO_2 in Britain are power stations – especially coal-burning ones – and refineries; next, as medium-level emitters, come other industries; low-level emitters are other non-domestic sectors (e.g. motor transport) and the domestic sector. To appreciate the immensity of the problem, observe the smoke rising from any of the thirty-eight coal-fired stations in the UK such as Ironbridge, Didcot, Fiddlers Ferry or Drax, and realize that this goes on every minute of the day and night, week after week, year after year.

The *emission* from a chimney is warmer than the air and thus rises into the atmosphere. Here the winds *transport* it away from the source, possibly across national borders, for it to react with water vapour and undergo *transformation* into an acidic mixture. This will fall as a *deposition* of acid rain on the land below, probably part of the territory of an 'innocent' nation as far as the origin of the pollutant is concerned. The speed at which this process occurs will vary according to the atmospheric and other conditions pertaining at the time.

The three main effects of acid deposition are on rivers and lakes, on trees and on buildings and other stone constructions.

Rivers and lakes

High acidity in a river or lake will lead to the death of most living things. Lakes, where the water is fairly static, are the most severely affected. The lake bed becomes covered with mosses and a few other growths which manage to exist. No algae are present to 'discolour' the water; no floating plants obscure the surface. The water is crystal clear, attractively enhanced by the reflection of sky, clouds and trees. It all looks most appealing, but the lake is dead – no fish, no invertebrates, few plants. The acidic rain leaches metals from the soil into the lake. Aluminium clogs the gills of fish, where such still exist, whilst the calcium in their skeletal structure is attacked and bones become brittle and unable to withstand the pull of muscle, resulting in deformity; eggs are infertile and what fry are produced are contorted in their shape. As the lake increases in acidity, specific creatures reach the ultimate level of their tolerance and die out. One indication, therefore, of the danger level reached is the 'suite' of plants and animals still in residence.

The time of greatest danger from acidity is in early spring when the snow is melting in the catchment areas which supply the water for the lake. Over the winter months snow will have fallen, bringing with it the acidity gained from pollutants in the upper air. As the ground cover of snow increases, the acid content will build up. Added to this there will be an evaporation of the snow surface as winter sunshine warms the top layer. Only the water will evaporate; the acid-causing chemicals will remain to increase the acidic ratio of chemical to snow. With the spring melt the water and the acidity will be released in a surge – an acid surge.

Sudden falls in pH values occur over very short periods of time; a 100-times increase in acidity over a twenty-day stretch is common (Figure 9.1). The effect on water life is devastating.

Trees

The leaching of chemicals from the soil has its deleterious effect on trees (Figure 9.2). Mineral deficiency is indicated by the premature discoloration and drop of deciduous leaves or coniferous needles. The direct attack of acid rain and acid mist adds to the harassment so that crown die-back is common and a thinning of the leaf canopy is apparent. Trees in a weakened state are more susceptible to permanent damage by attack from fungal disease and the ravages of ips, thrips and other insects. In particular trees growing on acidic soils are most sensitive to acid attack.

In high forest areas which are in close proximity to urban sprawls with dense vehicular traffic, the formation of photochemical ozone from the reaction of sunlight with nitrogenous exhausts will damage the trees. Such an area is the Black Forest of Germany and the hillsides, scarred with the defoliated trunks of dead trees, are testimony to the devastating effect of the pollutant gas.

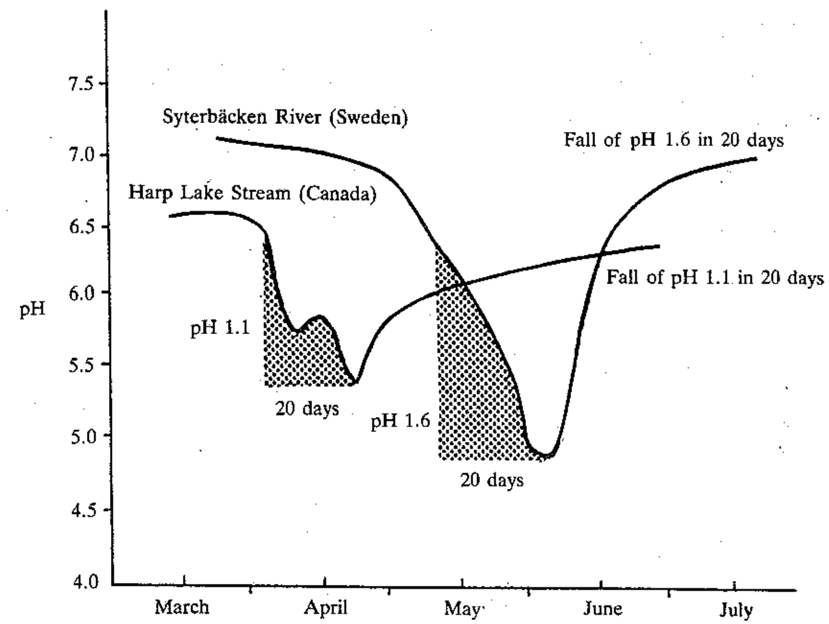

Figure 9.1 The increase in acidity in two rivers at the time of acid surge
Sources: Environment Canada; Stop Acid Rain Campaign, Sweden.

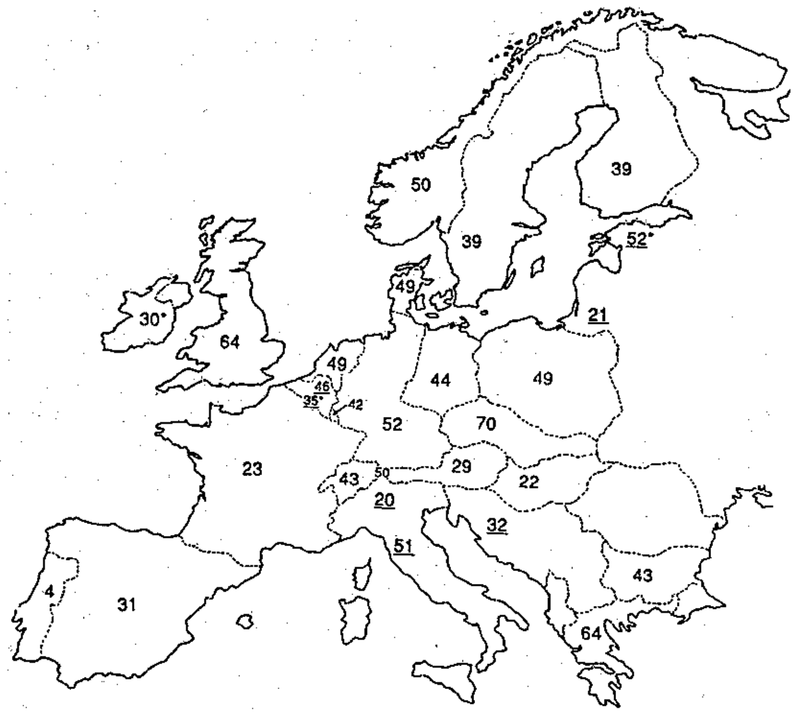

Figure 9.2 Intensity of defoliation in European countries, 1988: percentage of trees with more than 10 per cent defoliation
Sources: UN Economic Commission for Europe; International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests.
Except when underlined (regional) the figures represent nationwide surveys
* = conifers only

Buildings

Dilute acids react with the lime in natural stone and concrete structures. Flakes of materials are lifted from the surface and the weakened features of decorative statuary crumble away. The ground below is littered with particles of eroded material. Measurements of the external structure of St Paul's Cathedral indicate that an average 30 mm of stone has disappeared from the outside walls in the last 250 years, whilst in some places 22 mm of it has crumbled away in the last 50 (Dudley *et al.* 1985). Stained glass is badly affected by acidity and many of the outstanding examples of ecclesiastical glass are fading rapidly; with some it has been necessary to sandwich the original between protective glass layers to halt further acid attack.

There is only one cure for acid rain and that is the elimination of

pollutant gases at their source. It is almost certain that such is not possible in the foreseeable future as it will require a non-fossil-fuel technology as the basis for manufacturing industry and electrical power production. Even so it is possible to reduce the emissions of SO_2 from chimneys and the exhaust gases from internal combustion engines.

SO_2 removal

The sulphur is in the coal and oil before incineration. In the case of coal the sulphur content is between 0.5 and 5 per cent of its bulk, and with oil between 0.1 and 3 per cent (Parker and Trumbule 1987). Generally the soft coals in the UK have about 3 per cent sulphur content. The sulphur is contained in coal either as mineral grains of pyrites or as an integral chemical part of the fuel. It follows from this that it is relatively simple to remove the pyrites by washing the coal, allowing the heavier particles containing the sulphur to sink to the bottom. About a third of the sulphur could be removed in this way (Regens and Rycroft 1988). The removal of the chemical component is more difficult and therefore more expensive. It is hoped that commercially viable processes will come into operation in the early 1990s. One difficulty with such processes is that they create a large amount of solid waste. Compared with other forms of control the removal of sulphur before incineration is reliable and relatively inexpensive; it could be the best solution to the problem for developing countries.

The second method is to remove the gases at the burning stage. Most of the systems reduce both SO_2 and NO_x emissions, but they do require incorporation in the furnaces at the stage of factory construction, otherwise the complete change-over from one system to another is ultra-expensive. The two main methods are LIMB (lime injection in multistage burners) and FBC (fluidized bed combustion). Other systems are being developed, notably the IGCC (integrated coal gasification combined cycle). This method is used to create electric power with gas and steam turbines. Up to 99 per cent of the sulphur is removed and a great reduction in the amount of NO_x produced is made (Anderson 1987).

If fuel is used without remedial treatment and no combustion controls are made, the waste gases will be emitted from the smokestacks. Thus the only other way to deal with the pollutants is within the chimney system itself. FGD (flue gas desulphurization) employs methods which 'scrub' the exhaust gases. Again the commonest agent used is limestone in a wet or dry process. Ironically another method under development to treat the flue gases is an imitation of the acid rain process. In this E-beam (electron-beam) system both SO_2 and NO_x are removed by spraying the exhausts with water and ammonia. The resulting mixture passes through an electron-beam reactor which creates acids which in turn react with the ammonia and water to form compounds which can be used as fertilizers. Other E-beam systems are under consideration.

NO_x removal

NO_x produced in industrial technology has been considered above, for its prohibition by low-temperature incineration can be a part of the SO_2 removal system. Independent low-temperature furnaces can be installed to eradicate many of the NO_x problems from industry. But as far as acid rain is concerned the NO_x removal from vehicle exhaust is the prime consideration in the reduction of acids and ozone. This has already been described.

Liming

The cure for acid deposition has to be at source although something can be done to alleviate its effects where lakes, rivers and trees are concerned. There appears to be no economically viable technology which will prevent the reaction of acid rain with stonework, although where the object under attack is sufficiently valuable certain treatments can be employed. The introduction of lime into water can offset the effects of acidity. Putting lime on the surrounding land has the advantage of avoiding an alkaline surge – it is a more benevolent method which at the same time prevents the leaching of metals and other toxins from the soil. Liming is only palliative and not a cure; the cure has to be at source. An acid lake does not become a non-acidic lake – it becomes a lime-treated acidic lake and will revert without treatment.

As far as trees are concerned the liming process has to be evaluated over a long period of time. Unfortunately it may well be that the lime, by damaging soil organisms and leaching nitrates, actually harms tree growth. Liming the soil can at best maintain the adequate conditions until such time as acidification is reduced.

GLOBAL WARMING (THE GREENHOUSE EFFECT)[1]

The atmosphere becomes warmer as various gases absorb the long-wave radiation of heat from the Earth, in a way similar to the heating of the air in a greenhouse. The 'greenhouse effect' prevents warmth being dissipated into space and keeps the overall temperature of the Earth higher than it would be without these gases. Industrial activity over the past 150 years has increased the amount of CO_2 in the air by about a quarter and since this particular gas is the main 'greenhouse gas' it has resulted in a rise in temperature of 0.5°C. Over the next fifty years it is estimated that levels of CO_2 will rise by a further 30 per cent (Figure 9.3). There are many other greenhouse gases, notably methane, ozone,

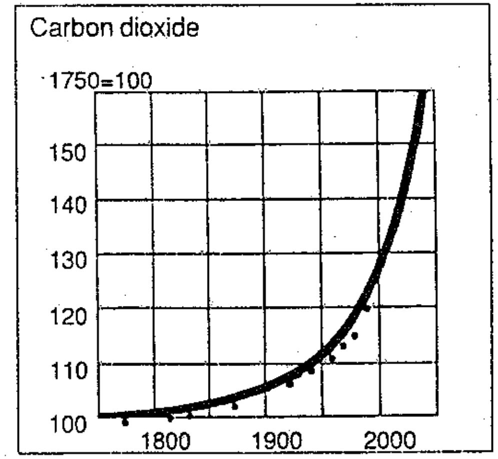

Figure 9.3 The rise in the level of CO_2 in the atmosphere over the last 250 years, taking 1750 to have a base level of 100
Source: UN Environment Programme.

nitrous oxide (laughing gas) and CFCs. Although the concentrations of these gases are much lower than that of CO_2, some of them have a greater greenhouse effect. Again over the next fifty years it is anticipated that these other gases will double the effect of CO_2. By making assumptions of the amount of each gas likely to be released into the air, computer models have predicted a potential rise in temperature of between 1.5 and 4.5°C by 2050. The oceans of the world will take longer to warm, so that the increase will be spread over a relatively long period.

These temperature rises may seem to be small and of little real significance. However, the warming will not be spread evenly, and local variations may see increases of more than 10°C at the polar regions.

What then will be the effect of this global warming? When heated, water expands and occupies more space. This will be the prime cause of higher sea levels, although increased melting of the south polar ice cap will add to this. Since many of the major towns of the world are located by the sea, the effect may be catastrophic. Certainly it is doubtful if the recently completed Thames Barrage will be high enough to cope with the spring tides rising above a higher initial base level. It is generally agreed that larger temperature changes occurring in high latitudes will affect the grain-growing areas particularly. Marginal lands will be at risk and the creation of another Dust Bowl in the USA is more than an unpleasant thought. Even if warmer temperatures speed crop growth and increase yields (extra CO_2 has a similar effect) they will also benefit pests, weeds and diseases. Increased rainfall will lower wheat production in the most northerly regions as, for example, on the Canadian prairies – some estimates say by up to a quarter.

It is likely that a change of climate in already marginal areas of farming, such as the Sahel in Africa, will lead to increased desertification, drought and erosion of the soil. In our own temperate region, winters may become warmer and wetter, with drier and hotter summers. This assessment is complicated by the effect of cloud cover, which is almost impossible to predict.

If the greenhouse effect warms the oceans and thaws the permafrost of the tundra regions it will aid the release of the 10 million million tonnes of methane estimated to be 'locked' in the muds of the continental shelves and the frozen soils. A release of a potential half-million tonnes annually would probably double the present concentration of methane in the atmosphere. A dangerous 'feedback loop' would be created: a warmer atmosphere releases more methane – more methane further warms the atmosphere (McKibben 1990).

It is perhaps too late to prevent global warming.

> A child born now will never know a natural summer, a natural autumn, winter or spring. Summer is becoming extinct, replaced by something else which will be called 'summer'. This new summer will retain some of its relative characteristics – it will be hotter than the rest of the year for instance, and will be the time of the year when crops grow but it will not be summer, just as the best prosthesis is not a leg.
>
> (McKibben 1990: 55)

Yet it is not too late to do all that can be done to minimize the greenhouse effect and to reduce its causes. The controls needed to reduce CO_2 and the other gases have been discussed already, although the present trend to improve the quality of vehicle exhaust through the use of catalytic converters does little to prevent CO_2 emissions. An overall policy which includes reduction in the incineration of fossil fuels by domestic and industrial activities, more efficient and economical use of internal combustion engines, control on the production and use of CFCs and a reduction in deforestation must be matched by a world policy of energy conservation. As the developing nations of the world anticipate a rise in living standards, it is essential that they are enabled to make technological advances which avoid the need to increase the pollution of the atmosphere – this will take massive financial aid, hopefully available from defence budgets in a 'friendlier' world.

DEPLETION OF THE OZONE LAYER

Ozone, composed of three atoms of oxygen, is concentrated in a zone between 20 and 25 km above the Earth. It has been said to protect the

planet and its people like a delicate veil protects the face beneath. Solar radiation contains ultraviolet rays and of these UV-B causes skin cancer, ageing and wrinkling, and eye malfunctions in humans, slows plant growth, destroys marine algae and fish larvae and breaks down the chemical structure of paints and plastics. At our present levels of UV-B white paints change to yellow, coloured pigments fade and fabrics rot under its influence. Any depletion in the amount of O_3 increases the UV radiation which reaches the Earth. Sun-bathing by those with light-coloured skins, already a potentially harmful activity, may become a risk to health to rank alongside smoking, drug and alcohol abuse. Estimates indicate that between 10 and 30 per cent of the sun's UV-B reaches the surface of the Earth at the present time. Were O_3 levels to fall by only 10 per cent the increase in UV-B would be 20 per cent. In the USA the National Academy of Sciences has estimated that every 3 per cent reduction in O_3 would result in 20,000 more skin cancer sufferers annually in that country alone (Watson *et al.* 1986).

The British Antarctic Survey has been at the forefront of ozone layer investigation. It was the scientists of this organization who first recognized the serious depletion of ozone in the polar region, which, during the Antarctic spring, resulted in a 'hole' in the layer. A similar depletion in the layer above the Arctic has also been recorded (Figure 9.4).

O_3 is an unstable form of oxygen, readily giving up the third atom, particularly to atoms of chlorine. CFC gases are not destroyed by the usual chemical reactions in the lower atmosphere. Instead they rise into the upper atmosphere where ultraviolet radiation causes free chlorine atoms to be released. These collect one of the oxygen atoms to form chlorine monoxide and oxygen. A further reaction releases the chlorine atom, thus again freeing it to destroy ozone in a 'chain' sequence (Figure 9.5). Nitrous oxide also plays its part in O_3 destruction and its release from high-flying aircraft is a contributory factor.

Fortunately the danger of the depletion of the ozone layer has now

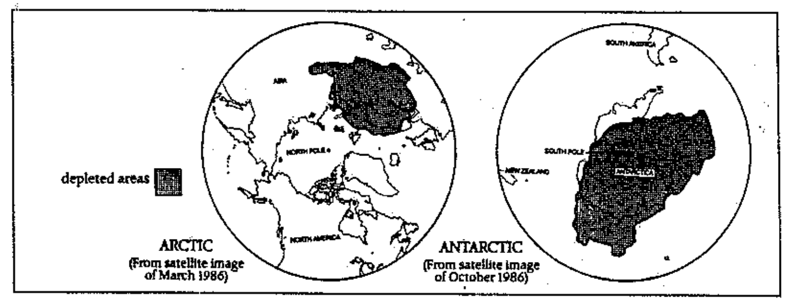

Figure 9.4 Thinning of the polar ozone layer
Source: Environment Canada.

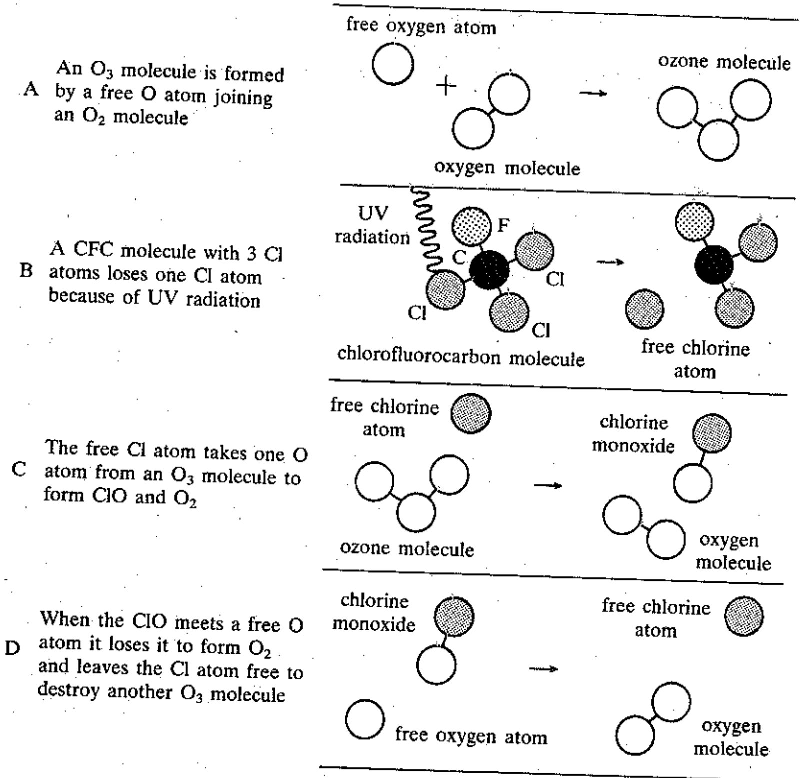

Figure 9.5 How CFCs destroy ozone
Source: UN Environment Programme.

been recognized internationally and many conferences have been held on the subject. Arguably that held in Montreal, Canada, in September 1987 was the most significant as it stimulated the debate on CFCs. A change in attitude to 'green' matters caused the British government to convene an ozone layer conference (March 1989) which brought together countries from most of the world. The Montreal Protocol demanded a 50 per cent reduction in the use of CFCs by 1999 – in the light of new evidence this was accepted as inadequate in London; Britain, for example, pledged itself to bring down its CFC emission by 85 per cent by 1990.

The use of CFCs as aerosol propellants and in refrigeration units needs to cease completely and the gas already in redundant refrigeration units must be prevented from escape into the air. Alternative foaming agents must be used. Generally it seems that HFCs (hydrofluorocarbons) may be the answer in the short term, but in due time the use of HFAs

(hydrofluoroalkanes) should be a better alternative (ICI 1990). As for the use of CFCs in the electrical industry, tighter production controls can lead to a full recycling of the gases to prevent their release into the air.

CONCLUSION

The movement of air, the wind, ensures that atmsopheric pollution cannot be considered in isolation.

> A few countries have so far accounted disproportionately for the rise in carbon dioxide but . . . the resulting climatic changes will not be allocated according to any earthly idea of justice. No nation acting alone can prevent an increase in atmospheric carbon dioxide.
> (Eckholm 1982)

If for CO_2 any of the pollutant gases is substituted the feelings expressed here are still valid. Air pollution may be seen to consist of individual problems, but they are interrelated, and preventive measures are a global problem.

Mostafa Tolba, the executive director of UNEP, speaking at the UN conference on global warming at Villach, Austria, in 1985 (World Meteorological Organization 1986), emphasized that 'In the 300 years or so that have encompassed the agricultural and industrial revolutions, man has begun to replace nature as the engine of climatic change.' It follows from this that some sort of control of this and other air pollution factors can be made if international will is positively inclined. The 'will' has to include the compliance of developed nations to underwrite the cost of the more expensive 'environmentally friendly' technology. This will enable the developing nations to exploit their natural reserves of fossil fuel or alternative sources of power production, in order to raise the living standards of their populations. The accumulation of toxic material in the air must be kept to a minimum and concentrations of solid, liquid and gaseous matter resulting from human activities must not be allowed to reach levels where they interfere with the natural cycles of a healthy atmosphere.

It is not only 'nations' which have a responsibility to change their habits and practices – it is a personal responsibility which centres primarily on energy conservation, less reliance on individual engine powered transport and a diminution of demand for manufactured goods. These need to be matched with an awareness that political pressure is necessary to bring about a true economic assessment of 'development', an assessment which places a value other than cultural on environmental loss and atmospheric pollution. Air pollution and other environmental problems require international financial intervention which will enable governments, especially of the Third World, to tackle pollution problems at source and to introduce non-polluting technology. After the Second World War the USA channelled more assistance per US citizen to the war-shattered economies of Europe than the entire world now spends on development assistance.

'I am advocating support for a meaningful international environmental fund. Not of millions, but of billions of dollars,' said Mostafa Tolba in a speech in Brussels on World Environment Day 1989 (UNEP 1989a). 'This is not a day-dream. It can be done.' To which I would add: It must be done.

NOTE

1 Statistics on the greenhouse effect show wide variations which reflect different climatic models. Those used here are provided by the United Nations Environment Programme (UNEP 1987).