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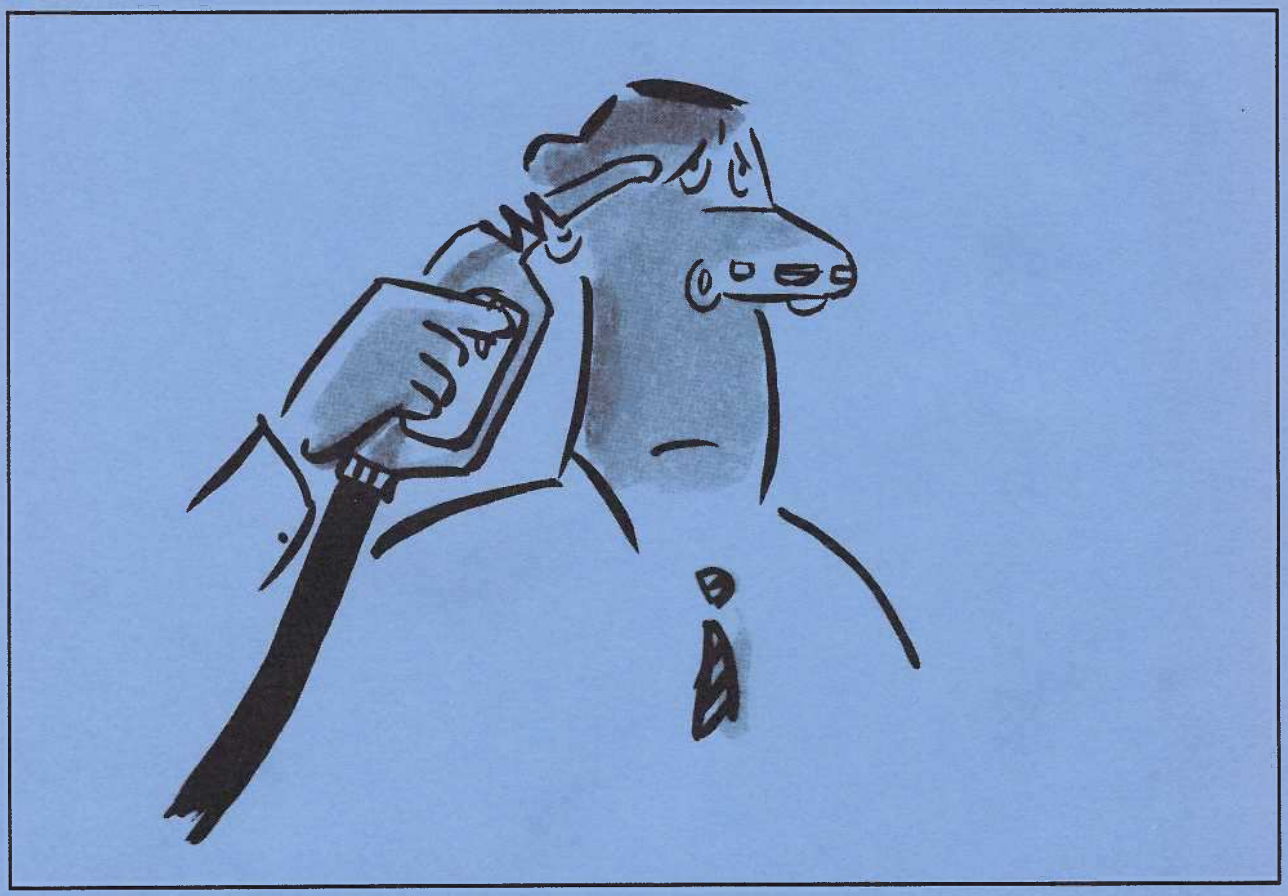
To clear the air over Europe

By Magnus Nilsson



A critical examination of the present guidelines and standards for air quality, with proposals for their revision

The Swedish
NGO Secretariat
on Acid Rain

European Federation for
Transport and Environment

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Foreword

Now that the World Health Organization and the European Union are in process of revising their guidelines and standards for air quality, it is important that environmentalist organizations should seize the opportunity to exert influence so as to bring about real improvements – all the more so as environmental quality standards will probably play an ever more prominent part in future in environmental control.

The aim of this report is, first, to provide a general introduction to the subject of air-quality standards for environmentalists, journalists, politicians, civil servants and others who may be affected. Its other aim is to set out basic information for an understanding of the subject and present proposals for standards for air quality as it is affected by those pollutants in particular that are of importance from the ecological point of view. The proposals are all put forward with the internationally recognized "precautionary principle" in mind.

A limit value should, in my opinion, indicate the concentration of the pollutant in question that will be acceptable in the long run, with medical and ecological considerations both taken into account. Levels should be set to accord with the requirements of the most sensitive individuals, species, and ecological systems. Switzerland has a system of air-quality standards that follows this principle and should be worth copying.

The proposals are my own, and are put forward as material for debate on the subject which I hope many will be able to take part in. In other words, they do not represent any official standpoint on the part of the publishers of this report.

In producing it, I have received valuable help in various ways from a number of persons. Especial thanks are due to Carl-Elis Boström of the Swedish Environmental Protection Agency, Katarina Victorin, Institute for Environmental Medicine, and Christer Ågren, the Swedish NGO Secretariat on Acid Rain. Others who have given useful information and advice include Mayed Younes and Barbara Lübkert-Alcamo of the WHO office in Bilthoven, Netherlands, Kathleen Cameron, European Commission DGXI, Wilfried Kühling, University of Dortmund, Per Kågeson, the European Federation for Transport and Environment, Per Elvingson, and Johan Bogefeldt.

Any errors or omissions in the report are my sole responsibility.

Stockholm, June 1995

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To summarize

"By 1995, all people of the Region should be effectively protected against recognized risks from air pollution"

WHO 1985: Targets for health for all.

"By the year 2000, air quality in all countries should be improved to a point at which recognized air pollutants do not pose a threat to public health"

WHO 1993: Health for All Targets – The Health Policy for Europe

The existing standards – at least as issued by the European Union and the World Health Organization – do not come up to the demands that should be made of an effective system for improving air quality.

They almost only take account of effects on health, ignoring the concomitant need to protect the environment, natural and man-made.

They are taken to represent long-term environmental objectives, whereas they should really be regarded as steps on the way towards achievement of a more reasonable state for the environment.

Even in their purely health aspects, the present standards are deficient. The increased incidence of asthma and allergies alone is a reason for tightening them, and if other aspects of poor air quality are taken into account – the effects on the natural environment, on the industrial economy, and objects of our cultural heritage – there will be found to be still more reason for bringing in stricter standards.

Despite the weakness of the present standards, today most Europeans, in west and east, are being subjected to levels of pollution that exceed both the recommendations of the World Health Organization and the European Union's directives. This is causing thousands of extra cases of illness, great economic losses to society, and enormous ecological damage.

Parts of the system for measuring air pollution also evince great deficiencies, making it difficult to determine what is really going on. In the case of airborne particles, for instance, much of the measuring is irrelevant.

One reason for failure to tighten the standards is that difficulties are being experienced in many places in meeting them as they are. It is thought that if adequate standards were introduced, the gap between the actual situation and what is aimed at would often be seen to be uncomfortably wide, and difficult to handle politically. But that is no reason to refrain from setting limits to indicate the long-term aim, resting on the premise of what is good both for humanity and the environment in the long run, or from letting the aim become fully apparent in legislation.

To improve matters, it is suggested in the first place that the term "limit value" should be reserved for actual long-term objectives. If any values are to be regarded as mere steps on the way towards such objectives, they should be clearly labelled "provisional." Alternatively a date might be attached to indicate the year by which a value is expected to be met – such as Limit Value 2000 for a short-term aim, and Limit Value 2005 or 2010 for more long-term objectives.

In some parts of Europe various possible limit values are already

being met. But it must not be assumed that this leaves the way open for an increase in atmospheric pollution in these places. They should be designated "clean-air areas," as a means of preventing deterioration of their air quality.

A limit value represents of course the highest accepted level for any pollutant, and in principle the aim in setting limit values should be a return to the natural background concentrations. If it should turn out that separate limits are desirable for protecting health and the environment, the lower of the two values should apply for both.

In the case of noxious substances that also have distinct ecological effects not directly connected with their concentrations in the air (acidification, eutrophication), an extra long-term factor should be inserted, beyond any required for dealing with the health problem or with short-term local ecological effects. Among such substances may be mentioned oxides of nitrogen, sulphur dioxide, and those that form ozone.

Substances that have mainly health effects should be permitted in concentrations no higher than 20-50 per cent of the levels that have been found to disturb especially sensitive persons.

For carcinogenic substances it is suggested that the limit value should be set according to some uniform principle – allowing, say, a highest lifetime risk of one in a million after continuous exposure.

Detailed proposals for limit values for the chief atmospheric pollutants will be found in Section 5, pages 31-33.

Air quality standards are useful instruments for the protection of human health and lessening stress on the natural environment – if only they are properly formulated. Ill-thought-out, improperly formulated standards can on the other hand be turned to advantage by those who want to delay moves towards better air quality.

1. The various aspects of air quality

Standards for air quality have been established to protect both human health and the environment, natural and man-made. The idea has been that setting uniform requirements for maximum concentrations of air pollutants will ensure a good environment for all concerned. Uniform requirements will also facilitate the handling of a number of matters associated with the environment by the appointed authorities and thus help to hasten environmental action.

The very need of standards, combined with extremely poor coordination, has led to a plethora of differing standards (see Appendix 1). Many different actors – governments, courts of justice, business corporations, and local authorities – have sensed the value of air-quality standards and in the absence of coordination created their own.

The existing standards often have quite differing aims and status. Some constitute legally binding regulations, others may be simply official guidelines issued by governments or international organizations. Then there are the various target or guide values that have been adopted by expert groups or local authorities.

It is possible to discern three main areas where the protective effect of standards is needed, resulting in somewhat differing requirements as to their formulation and stringency:

- ☐ Human health.
- ☐ The natural environment.
- ☐ Man-made environments and objects such as buildings.

The requirements will have to be of differing strictness, both as regards the air quality that is aimed at and the technical formulation of these standards, according as to which of these aspects claims priority. Hitherto the medical aspects have overwhelmingly prevailed when it has come to setting the limit values for pollutants. In the case both of the European Union and the World Health Organization, little attention has been paid to the possibility of ecological damage or the economic effects in the way of diminished output in farming and forestry or increased corrosion of materials.

The effectiveness of the standards will, in the final instance, naturally depend on the extent to which priority is given to health and the environment.

Differing problems, differing standards

When deciding on acceptable levels for the concentrations of some pollutant, it will not suffice to have agreement on the risks it entails. A number of practical and technical factors will also have to be taken into account. For example:

- ☐ Lead causes damage in the long term by becoming accumulated in the body or in the environment. The important thing is not, therefore, to prevent transient high concentrations but to ensure as low a total level as possible over a period of time – in other words, to keep the average yearly emissions as low as possible, not to cut off the peaks.
- ☐ As regards ozone, the opposite is the case (at least to some extent). Unlike lead, ozone occurs naturally in the air in relatively high concentrations. Also unlike lead it is a very unstable substance, highly reactive and unable to accumulate. Its most serious harmful effects, acute but maybe also lasting, occur during brief episodes with high concentrations in summertime. The aim of air-quality

standards should therefore be to prevent the occurrence of high concentrations during short periods (0.5-8 hours). Since even quite low concentrations will also have some effect, however, some kind of long-term limits are needed to relieve the environment.

☐ Since sulphur dioxide produces effects both in the short and the long term, two different limit values are needed: one setting the highest permissible average level for the year, and the other peak values for single days.

The same will apply for most of the other pollutants: there should be both a long-term limit (such as yearly average value) and a short-term one (average hourly value).

Other factors affecting standard formulation are custom and the kind of measuring method employed. For particulates three methods are common: the black-smoke one, and those known as TSP and PM10. They all measure different things, but pending agreement on a uniform method, continue to exist alongside each other.

The matter is further complicated by the existence of separate standards for indoor air and workplaces, which also differ from those for the outdoor environment. This may be because people are at work during less than 20 per cent of the year's hours (and exposure is in a sense voluntary). It is therefore considered not unreasonable to have less strict requirements in such cases than are necessary for the outdoor environment.

Limit values

Limit values are legally binding definitions of the maximum permissible levels for pollutants. In other words, they may *not* be exceeded. Limit values have been set by the European Union and by federal law in the United States.

The EU values are minimum ones that the member countries are obliged to incorporate in their legislation. They are however only minimum values; it is open to member countries to apply stricter standards if they wish. But the member countries are in any case bound to institute measures to ensure that the concentrations of pollutants will not overstep the EU limit values. Countries that fail to meet the standards can be brought before the European Court by the European Commission and reprimanded.

There are now EU directives that set limit values for:

☐ Sulphur dioxide in combination with suspended particulates.
☐ Nitrogen dioxide.
☐ Lead.

In cases where the EU gives no set limit values, the member countries are free to introduce and apply their own.

Because limit values are legally binding, they have to be hedged about with close definitions. The EU directives include for instance exact descriptions of the measuring methods that have to be used.

Limit values are practically never given as absolute maximum levels. The requirement is that they shall not be exceeded during a prescribed part of the time in the course of a year, which usually means 50 or 98 per cent (see below under Percentiles). The limit values may apply during various periods of time, from a maximum during one hour to an average over a year.

Guidelines, guide values and target values

Since they are various kinds of recommendation that are not legally binding, guidelines, guide values and target values are not usually so closely defined as limit values. They are mainly intended to exert an indirect influence on town planning, concessions to industries,

etc., and are usually more stringent than limit values, having the implied aim of causing limit values to be lowered in the long term.

In 1987 to World Health Organization presented its first *Air Quality Guidelines for Europe,* and a new, revised set is expected in 1995. The present list covers twenty-seven different substances, or considerably more than those for which there are EU limit values. This is possible because the WHO guidelines have no legal status.

In practice however the WHO guidelines occupy a very strong position, giving them great influence over both EU and the national regulations. It may be expected that the European Union, in the coming revision of its limit-value system, will follow to a large extent the WHO recommendations.

The EU also issues guide values alongside its legally binding limit values. Among the substances covered in this way are nitrogen oxides, sulphur dioxide, and particulates. The intention is to send out a signal to indicate that the limit values should in time be lowered so as to enable the ecological aspects, for instance, to be taken into account.

The EU guide values may thus be likened to the long-term target values that are sometimes given alongside the limit values. The target values indicate of course the long-term aim for the improvement of air quality.

Threshold values

Only a few countries have set limit values for ozone (see Appendix 1). As a temporary alternative the EU employs threshold values, the two lowest of which merely enjoin upon the member states to report at various intervals to the European Commission when the thresholds have been crossed. When the third level is exceeded, the authorities of the affected country have to warn the public (in particular asthmatics, elderly people, and others who may be sensitive) of the risk of remaining outdoors, especially if it entails great physical effort. Level four calls for a general warning to stay indoors. There is no formal insistence that the member countries should take steps to reduce emissions of ozone-forming substances, such as by closing factories or forbidding the use of motor vehicles.

Critical loads and critical levels

Attempts to define critical loads and critical levels have been made by groups of experts working within the UN ECE Convention on Long Range Transboundary Air Pollution. The resulting figures indicate for instance the amounts of acidifying and fertilizing substances or gaseous pollutants that the natural environment is considered able to withstand in the long term without suffering serious damage. Critical-load values are also being worked out in respect of the effects on building materials, for instance, and organic materials such as rubber, paint, etc.

Critical loads apply particularly in the case of sulphur and nitrogen fallouts.

Critical levels are used for gaseous air pollutants such as sulphur dioxide and ozone.

In neither case are the values set at such levels as to eliminate any risk of damage. The intention is that they shall be so low as to prevent fundamental ecological processes from being disturbed or building, etc., suffering unreasonable damage. The actual figures thus represent a compromise between the claims of the environment and the economy.

Differing soil conditions, variations in climate, precipitation, and vegetation, etc., will mean that loads and levels that are ecologically

determined will have to differ for different parts of Europe.

Percentiles

The WHO guidelines set either an absolute value or a limited range, under which pollution should be kept. Legislatures and other authorities seldom employ the concept of an absolute "pollution ceiling." Usually the national limit and guide values are set at levels that may be exceeded during a small part of the day or a certain number of days during the year. That part of the period where they may not be exceeded is expressed as a percentile.

A 98 percentile means that the value in question may only be exceeded during 2 per cent of the time, or during half the time in the case of a 50 percentile. It should be noted however that a 50 percentile represents a median, not an average value. An average value is usually an arithmetical average.

In the European Union the limit value of 200 $\mu g/m^3$ for nitrogen dioxide (NO_2) is expressed as a 98 percentile one-hour value during a year. In other words, the level of 200 $\mu g/m^3$ may be overstepped at the most during 2 per cent of the year's hours (0.02 x 8760 hours = 175 hours). Alongside the limit value are however also two guide values, the one dictated by care for health and the other for the environment. Since the aim of the health-guide limit of 135 $\mu g/m^3$ is to prevent high concentrations, it is given as a 98 percentile, while the ecological guide limit is a 50 percentile because here the aim is to contain the total long-term load.

Fixed and rolling periods

In air-quality standards eight hours does not always mean eight hours, which can have effect on the worth of the standard. In the case of ozone, for instance, the WHO recommends a highest level of 100-120 $\mu g/m^3$ (50-60 ppb) during 8-hour periods. But by 8-hour period the organization means three fixed periods in the day (00.00-07.59, 08.00-15.59, and 16.00-23.59). High concentrations during the afternoon will therefore be spread over two 8-hour periods, and extremely high levels may be partially concealed. A relatively low guide value could be met despite some occasionally very high concentrations of ozone in the air.

With rolling 8-hour periods the same guide value will in practice be very much stricter, because then the concentrations will have to be low throughout all the day's 8-hour periods. Extremely high levels will be hit if the standard is so constituted. By way of example: A limit value of 100 $\mu g/m^3$ (50 ppb) calculated as a rolling 8-hour value will correspond to 75-96 $\mu g/m^3$ (37-48 ppb) calculated as an 8-hour value according to WHO principles. (9)

Similarly the 24-hour periods may be stipulated either as fixed 24-hour periods (00.00-24.00) or as rolling 24-hour values.

Principles for standards

Non-carcinogenic substances

All the common pollutants (sulphur dioxide, particulates, nitrogen dioxide, ozone, etc.) occur naturally in higher or lower concentrations. Standards with consideration for health should therefore as a matter of principle be set so as to protect even especially sensitive individuals.

Among the especially sensitive are of course asthmatics. allergics, and those suffering from other kinds of reduced lung functioning. But there can be a great variation in sensitivity even among the

apparently healthy. The differences may be due to age, sex, or whether the individual is physically active, or even to genetic factors, or simply personal peculiarities.

The risk levels are determined by toxicological experiment and/or epidemiological research.

By controlled toxicological experiments (usually with mice or apes) the researchers try to determine the lowest level at which damage occurs (the lowest-observed-effect level, LOEL), but also the highest level at which there can be proved to be no damage (no observed-effect level, NOEL).

Health standards are usually set by dividing the LOEL value by 2 to 5, stopping at a concentration of 20-50 per cent of that at which experiment has shown effects on humans. It is estimated that if the standards are met, by far the greater part (although not all) of the individuals in the especially sensitive group will be protected.

The extra margin of safety is allowed as a protection against combined effects, the chances of the harmfulness becoming increased if the substance occurs in combination with others.

The aim of epidemiological studies is to try and find a relation between pollution levels and the incidence of disease as well as other health problems. Since it is not possible through such studies to show that a certain pollutant has caused so or so many cases of disease or mortality, but only to point out a relation, the findings are not normally used for setting limit values.

Carcinogenic substances

Other criteria than those used for the common pollutants are applied to some extent in the case of these substances. The starting points are that there are no harmless concentrations, and that the risk is in direct proportion to the degree of exposure (i.e. concentration level x exposure time). Although it may be uncertain whether this is so in many cases, it is considered a useful hypothesis for determining standards.

The International Agency for Research on Cancer (IARC) classifies all chemicals according to their carcinogenic properties as follows:

Group 1. Substances that have been proved to cause cancer in humans.

Group 2. Substances that can be assumed to cause cancer in humans. These substances range from anything that is almost certain to cause cancer to others with only a slight connection. They are therefore usually separated into Groups 2A and 2B. Further research often leads to re-classification.

Group 3. Unclassified chemicals.

In regard to air-quality standards Group 2A should, in the view of the cancer research agency, be also treated as carcinogenic. The IARC intends eventually to have a special category for substances that are considered definitely non-carcinogenic.

In these circumstances air-quality standards become a matter of the number of sick and dead that is considered acceptable. It is often said that a risk of $1x10^{-5}$ to $1x10^{-6}$ with lifelong exposure would be acceptable. The risk of anyone suffering cancer at some time during his life in account of such exposure would be one in 100,000 or one in a million.

Exposure

The effects of various air pollutants on health depends to a very large extent on the degree of exposure.

In the case of individuals doing hard physical work outdoors, who also spend much of their leisure time in the open air, the quality of the outdoor air is of great importance for health. This also applies to small children, for instance, who spend a lot of time outdoors and are very active.

The quality of the outdoor air is of less importance, on the other hand, for persons who are less physically active and remain mostly indoors.

There are also the geographical aspects. In warm southern Europe the windows and doors are often left open, so that the indoor and outdoor air are more or less the same. There is a much greater difference in northern Europe, where the climate is colder and people spend more of their time indoors.

2. How air pollutants affect health

When considering the effects of air pollutants on health, attention has focused primarily on these four: sulphur dioxide, particulates (including lead), nitrogen dioxide, and ozone. It might be possible to add certain hydrocarbons, but for the fact that too little is known about their effects, coming from inhalation. But they also contribute to the formation of ozone and aerosols, which consist of extremely small particles.

The World Health Organization has singled out four typical air-pollution problems:

1. Summer smog, characterized by elevated concentrations of ozone and nitrogen dioxide.
2. Winter smog, with high levels of sulphur dioxide and particulates.
3. Persistent high concentrations in urban areas of sulphur dioxide, nitrogen dioxide, and particulates.
4. Long exposures to other airborne pollutants, such as heavy metals, including lead.

Sulphur dioxide and particulates

Sulphur dioxide and particulates often occur simultaneously in high concentrations. The sources of emission are mostly the same: coal-fired power plants and small boilers. For those making health studies it is difficult however to separate the effects of each. Both

Guide values for sulphur dioxide/particulates WHO (1987) ($\mu g/m^3$)

Time period	Sulphur dioxide	Black smoke	TSP	PM_{10}
10-minute value	500			
1-hour average value	350			
24-hour average value (health)	125	125	120	70
24-hour average value (ecology)	100			
Yearly average (health)	50	50		
Yearly average (ecology)	30			

Reference (38)

Limit values for sulphur dioxide in combination with particulates in EU (1980/89) ($\mu g/m^3$)

Time period	Sulphur dioxide	Black smoke	TSP
24-hour average value during year (98 percentile)	250	>150	>350
24-hour average value during year (98 percentile)	350	<150	<350
24-hour average value during winter half-year (50 percentile)	130	>60	>200
24-hour average value during winter half-year (50 percentile)	180	<60	<200
24-hour average value during year (50 percentile)	80	>40	>150
24-hour average value during year (50 percentile)	120	<40	<150

Reference (23)

Limit and guide values for particulates (black smoke) in EU (1980)

Time period	($\mu g/m^3$)	Type
24-hour average value during year (98 percentile)	250	Limit value
24-hour average value	100-150	Guide value
24-hour average value during winter half-year (50 percentile)	130	Limit value
24-hour average value during year (50 percentile)	80	Limit value
Arithmetical average value of the yearly 24-hour average value	40-60	Guide value

Reference (23)

Guide values for sulphur dioxide in EU (1980)

Time period	($\mu g/m^3$)
24-hour average value	100-150
Arithmetical average value of the yearly 24-hour average value	40-60

Reference (23)

pollutants tend moreover to intensify each other's effect. Both the EU and WHO therefore set combined values (see tables).

When inhaled, sulphur dioxide and particulates affect the mucous membranes in the respiratory system, causing irritation and coughing. Damage to the membranes may lead to inflammation and the growth of tumours. Numerous studies have shown a connection between elevated concentrations of sulphur dioxide and/or particulates and an increase in the need for medical attention and even in mortality. It has been calculated as a result of the great London smog episode in 1952, some 4000 people had died within a short time as a result of air pollution. Cases of death and serious pulmonary diseases occur continually in places where there are high concentrations of these pollutants.

The exact connection between pollutants and disease has yet to be determined. Although it is obvious that high concentrations lead to an increase in sickness and death rates, the pathological processes are largely unknown territory.

One reason for this uncertainty is the composition of the group of particles. Scientists are agreed that from the point of view of health the larger particles (>10 μm in so-called aerodynamic diameter) are of little account. They get caught up in the nasal and oral cavities, or in the upper part of the windpipe and so fail to reach the lungs. Dangerous from the point of view of health are the very small particles, measuring less than 2-3 μm, which can penetrate the alveoli of the lungs and even get into the bloodstream. Among them are aerosols, which may consist either of salts (formed from hydrocarbons, sulphur dioxide, nitrogen oxides, etc.) or of sulphuric and nitric acid. Little attempt has been made to determine the exact proportion of small particles. The measuring methods that are still most common are adapted to a situation in which the pollution consists mostly of smoke from coal burning, and say little about the size of particles. The information they give is thus of no interest when it comes to judging the health effects.

The most used methods are those called TSP (Total Suspended Particulates) and Black Smoke (BS, with variants British Smoke, or simply soot).

The TSP method gives the total weight of all the particles in the air with aerodynamic diameters up to 180 μm. In other words it also

reports particles that do not penetrate deep into the respiratory system. The results do not distinguish between particles that are large, and relatively harmless from the point of view of health, and those that are smaller and probably so much the more dangerous. Since the aim is to obtain background values, the measurements are moreover taken at roof height, far above the level where most people abide.

Black smoke is an optical method, which measures the blackness of a filter through which air has been passed (it is sometimes called reflectance assessment). By using a standard method the results can then be converted to a measure of the concentration, usually expressed as $\mu g/m^3$. The values so obtained are not readily comparable with those from the TSP method. Being intended for measuring the pollution from burning coal and oil, the BS method is naturally ineffective in regard to the kind of pollution that comes from vehicle exhausts and emissions of hydrocarbons ("white smoke"), which abounds in modern city environments. It is however considered better than TSP for measuring small particles, and probably gives a fairly good picture of the degree of pollution in ordinary smog, caused by burning coal.

Now more used in the United States and some European countries is the so-called PM_{10} method, which is more or less a development of the TSP. It is sometimes called the thoracic particles method. Just like TSP it measures the aggregate particle weight, but only takes account of those of less than 10 μm in diameter. But even that is of doubtful value, since the particles that are probably most harmful to health are still smaller – often less than 2 μm or even as little as 0.1 μm in diameter. (According to a theory that is often put forward, the effect of the particles on health is very much a matter of their total surface area, i.e. ten particles each of 1 μm would do more damage than one with a diameter of 10 μm but weighing much more. If that can be proved, it is the particles total surface area that ought to be measured, or at least their total number, rather than their total weight.)

The present trend is in general to consider changing over from measuring by the TSP and BS methods to using PM_{10} or $PM_{2.5}$.

Sulphur dioxide (SO_2)

Sulphur dioxide, being easily soluble, becomes quickly converted on inhalation to other substances, such as sulphuric acid. Therefore even if the amounts of SO_2 are very small, they reach down into the lower, more sensitive parts of the lungs. When the concentrations are very high, there will be contraction and inflammation of the respiratory organs, causing coughing. Sensitivity varies greatly, however, from individual to individual.

Especially when the air is damp can sulphur dioxide easily become converted into other compounds such as sulphuric acid and ammonium bisulphate, forming very small particles (0.3-0.6 μm in diameter) or aerosols, which can easily penetrate to the respiratory organs. As they are often acid, they also react easily and damage the mucous membranes.

There has been evidence of late from epidemiological studies that the effects of sulphur dioxide have been underestimated. No matter what the general quality of the air is like, elevated concentrations of sulphur dioxide will lead to an increase in cases of sickness, and sometimes even to markedly increased mortality.

☐ In Cracow it was found that the daily number of adult patients increased by 10 per cent for every rise of 100 $\mu g/m^3$ of sulphur dioxide in the city's air. (40)

☐ Likewise in Barcelona there was an increase of 17 per cent in cases

of acute sickness among persons suffering from chronic lung trouble when the sulphur-dioxide level rose by 100 μg/m^3. Although in fact concentrations never exceeded 160 μg/m^3, a clear connection could be seen between an increase in concentrations and a rise in cases of acute sickness. (40)

Increases in mortality as a result of raised concentrations of SO_2 have come to light through other studies too:

☐ In Athens mortality increased by 4 per cent when concentrations rose above 150 μg/m^3. The numbers of dead from sicknesses connected with the respiratory organs rose by 11 per cent. The mortality rate was greatest among persons over seventy-five years of age. (40)

☐ In Lyon and Marseille the number of persons over 65 dying from respiratory diseases rose by 9-11 per cent at each increase of 100 μg/m^3 in the concentrations of sulphur dioxide (calculated as an average during the ten days preceding death).

It has appeared from another French study that people living in areas where the average level of SO_2 in the air was 100 μg/m^3 had lung functions that were on average 4-7 per cent worse than those of people in places where the average concentration was 50 μg/m^3. (40)

Particulates

Estimates of the health effects of particulates have also undergone revision during the last few years, as a result both of toxicological and epidemiological research.

☐ A German study, carried out at a time when 90 per cent of the TSP values lay under 118 μg/m^3 (i.e. less than 120 μg/m^3, the EU and WHO guide value), showed a definite connection between increases in particulates in the air and visits to doctors and hospitals of patients with acute respiratory troubles. The numbers increased by 37 per cent when the TSP values rose by 10-70 μg/m^3. (40)

☐ According to a Swiss study the number of cases with respiratory-like symptoms rose by 10 per cent the day after the TSP value had climbed by 22 μg/m^3. On most of the days while the study was going on the TSP values were under 100 μg/m^3, or considerably less than the present guide values. (40)

☐ In Utah Valley, USA, changes in hospitalization were studied between 1985 and 1988, during which period a steelworks that emitted huge quantities of particulate matter had been closed down for a year. Again there was a distinct connection between particle concentrations – especially in PM_{10} values – and the number of hospital admissions, children being the most affected. During months when the average 24-hour PM_{10} value exceeded 150 μg/m^3, the number of children admitted was trebled. The number of adults increased by 44 per cent. When the monthly average value went up more than 50 μg/m^3, the number of hospitalized children was almost double what it was when the value lay under 50 μg/m^3. Then the adult increase was 47 per cent. (5) Cases of cough increased by 80 per cent, and slight respiratory troubles by 45 per cent when the PM_{10} value increased by 100 μg/m^3. For asthmatic children the effects were still more evident, even if days with extreme rises to 150 μg/m^3 were excluded. A general weakening of lung functioning by 2-4 per cent was observed when the PM_{10} value rose by 100 μg/m^3. The connection between hospital admissions and particle concentrations was more evident when measurements were made by the PM_{10} method than it was with TSP. (40)

☐ Schoolchildren and asthmatics were made the subject of another Utah Valley study. In the case of schoolchildren the connection between PM_{10} values and achievement ability was clear: achievement dropped when particle concentrations were high. For asthmatics on

the other hand it was not so clear – probably because asthma sufferers increased their intake of medicine sixfold on days when particulate concentrations were high. The connection that could be seen was between particulates and the consumption of medicine.

☐ An analysis made in Pennsylvania, USA, revealed an average increase in mortality of 7 per cent at each rise in the TSP value for particulates of 100 $\mu g/m^3$. In the case of individuals over 65 years of age the increase was 10 per cent, and for younger persons 3 per cent. For those with chronic lung trouble the rate was markedly higher (19 per cent), and with cardiac and vascular diseases 10 per cent. No connection with sulphur dioxide could be seen. In some cities the SO_2 levels were in fact very low, and no threshold values could be noted. (5)

☐ In a continuation of this last research program, adults were studied during 14-16 years, the aim being to compare disease patterns against the concentrations of very small particles as measured by the $PM_{2.5}$ method. It turned out that the rate of mortality from cardiac and vascular disease was 37 per cent higher in the most polluted city than in the cleanest one.

☐ From a Californian study extending over 10 years it appeared that the risk of contracting obstruent pulmonary disease was increased by 36 per cent for every 1000 hours that the TSP values exceeded 200 $\mu g/m^3$. The asthma risk increased by 74 per cent. No connection was found with sulphur dioxide, the average concentrations having lain under 25 $\mu g/m^3$. (40)

Combined effects of sulphur dioxide and particulates

Winter smog, with greatly elevated concentrations both of sulphur dioxide and particulates during short periods, is still a very serious problem in many places in Europe.

☐ Two Dutch studies made in the 1980s concluded that lung function was on an average worsened by 5 per cent after a smog episode with 24-hour concentrations close on 300 $\mu g/m^3$, both of particulates and sulphur dioxide. (40)

☐ As a result of a similar episode in Germany in 1985, when the 24-hour average concentrations of sulphur dioxide and particulates reached 830 and 600 $\mu g/m^3$, hospital admissions were 12 per cent higher than they were in a comparable area where they were 320 and 190 $\mu g/m^3$. In the former there occurred a 6 per cent increase in mortality during this period. (40)

☐ As regards long-term effects, there are statistics from Cracow, Poland, where the average black smoke and SO_2 values have remained for years in excess of 150 and 104 $\mu g/m^3$. It has been found that the risk of getting lung cancer was 46 per cent higher for men who had lived there for more than thirty years than it was for a corresponding group in a relatively unpolluted region.

☐ The risk of premature death among infants in the Czech Republic living in surroundings where the TSP and SO_2 values exceeded 85 and 58 $\mu g/m^3$ was found to be 20-30 per cent higher than it was for those in another part of the country where the values were 54 and 13 $\mu g/m^3$ respectively. Here is yet another case of harmful effects taking place at concentrations that are below the levels promulgated by WHO and the European Union.

Small particles and aerosols

Both sulphur dioxide and nitrogen oxides are easily transformed in the air to secondary compounds such as sulphuric acid (H_2SO_4) and ammonium bisulphate (NH_4HSO_4), or to nitric acid (HNO_3). All according to the humidity of the air and their chemical characteristics,

these secondary substances can form either infinitely small droplets or small crystals (<1 μm). The chief aerosols are sulphuric acid and ammonium bisulphate. As previously mentioned, these particles probably have much to do with the effects of air pollution on health (as well as direct damage to such things as buildings, machinery, and vegetation). They can also enhance allergy and asthma problems.

These small particles, or "white smoke" as they are sometimes called, are not like those that come out directly from chimneys or diesel vehicles, but are formed through chemical reactions between different gases. The resulting molecules coagulate into droplets or solid particles. Several kinds of air pollutant can assist in these transformations, as ammonia does in the formation of ammonium bisulphate. High concentrations of ozone intensify the formation of aerosols.

Statistics recently presented by British scientists indicate a connection between the quantities of these small particles and increases in mortality and pulmonary and cardiac troubles, especially among the elderly. (29) This may provide better evidence of the connection than experience from the London smog has done.

Earlier measurements of the air pollution that caused thousands of deaths in London in 1952 showed that half of the weighed particles were small light ones of less than 1 μm in diameter. After a count, every other particle turned out to be less than 0.1 μm. Most of the particles were moreover acid, with a pH value of less than 2.

It was found from a count of particles in non-urban air in Britain that there were normally between 5000 and 10,000 per millilitre of air – figures that were notably raised by road traffic, amounting to 25,000-30,000 particles/ml in the vicinity of busy roads. The levels counted in urban air are 1000-50,000 particles/ml, with peaks of 100,000 to 150,000 particles.

While large particles become relatively quickly cleaned out of the air by precipitation, aerosols can remain floating around for several weeks. Their effect, both on the environment and health, is consequently greater, because:

a) they eventually make their way into buildings of all kinds;
b) by remaining around, can be inhaled for a long time;
c) can be borne across countries and regions.

Moreover they can, unlike large particles, penetrate into the lungs. Experiments with rats whose lungs were exposed to equal amounts of titanium dioxide particles of different sizes (0.25 and 0.02 μm diameter) showed that the smallest particles got into the finest tissue of the respiratory organs much more than the big ones. In other words, the smaller the particles, the more dangerous they are. (29)

The highest recorded concentrations of aerosols are from London in 1962, when a sulphuric acid level of 680 $\mu g/m^3$ was measured. (38) Experiments with rats exposed to particles of 0.03 μm diameter in concentrations of 200 $\mu g/m^3$ brought on acute poisoning – at levels that are far below the present EU limit values for TSP (350 $\mu g/m^3$). (29) In experiments with humans, acute effects were recorded in adult asthmatics when the concentration of sulphuric acid in the air was 350 $\mu g/m^3$. (40)

Although knowledge of the effects on health of aerosols is at present limited, it is still sufficient to cause uneasiness. Neither the World Health Organization nor the European Union has yet issued any separate guidelines or limit values for aerosols.

Nitrogen dioxide (NO_2)

Nitrogen dioxide is formed in all kinds of combustion. In the first stage nitrogen oxide (NO) is formed (this accounts for 85-90 per cent

WHO guidelines for nitrogen dioxide (1987)

Time period	($\mu g/m^3$)	Aim
1-hour average value	400	Health
4-hour average value	95	Protecting vegetation with SO_2 max 30 $\mu g/m^3$ and O_3 max 60 $\mu g/m^3$
24-hour average value	150	Health
Yearly average value of 24-hour average value	30	Protecting vegetation with SO_2 max 30 $\mu g/m^3$ and O_3 max 60 $\mu g/m^3$

Reference (38)

Limit and guide values for nitrogen dioxide in EU (1985)

Time period	($\mu g/m^3$)	Type
98-percentile 1-hour average	200	Limit value
98-percentile 1-hour average	135	Guide value
50-percentile 1-hour average	50	Guide value

Reference (23)

of the formation of NOx) and the NO is subsequently oxidized in the air to NO_2.

The main source of emissions of NO_2 is road traffic. In homes with gas stoves and/or gas water heaters the indoor concentrations of NO_2 will often be higher than those outside.

Besides affecting health directly, NO_2 contributes to the formation of other, secondary compounds of great significance both for health and the environment in general.

☐ Nitrogen dioxide contributes to the formation of ozone and other components of photochemical smog. The NO_2 molecule becomes broken up under the influence of sunlight and warmth into NO + O, and the oxygen atom then reacts with an oxygen molecule (O_2) to form ozone (O_3). High levels of hydrocarbons in the air will hinder the breakdown of ozone and cause its concentrations to rise.

☐ In the air nitrogen dioxide reacts with water to form nitric acid (HNO_3), which is very acid and forms aerosols. Among the acidifying effects are leaching of nutrients from the soil, liberation of heavy metals, biological changes in surface waters, and deterioration in the quality of drinking water.

☐ All kinds of nitrogen emissions contribute to the eutrophication of soil and coastal waters.

Nitrogen dioxide is also relatively insoluble, so that when inhaled it is carried almost unchanged deep into the lungs. It can react with the lung tissue and thus diminish bodily immunity to viruses and bacteria.

Elevated levels of NO_2 will hardly have any acute effects on individuals with normal lung functioning. Most at risk are children and asthmatics.

☐ It appeared from a German study that the cases of lung trouble among children increased by 30-50 per cent on those days when NO_2 levels exceeded 150 $\mu g/m^3$. (28) Asthmatics (constituting 5-10 per cent of the population) showed in a test diminished lung function at 190 $\mu g/m^3$. (4) Only at three times that level (560 $\mu g/m^3$) did corresponding trouble occur in persons with normal lung function. (4)

With long-term exposure the effects show up at much lower levels, and then also in children and asthmatics, although even normal adults may be affected, too.

☐ A number of studies have revealed a 20-per-cent higher occurrence of disease in the lower part of the respiratory system among children in homes with gas-fired appliances than among others where there were no such appliances. The concentrations of nitrogen dioxide in homes with gas appliances have been estimated to be about 30 $\mu g/m^3$

ηιγηερ τηαν τηοσε ιν τηε ουτσιδε αιρ. (4)
☐ A clear connection between NO_2 levels in the open air and breathing troubles among pre-school children (coughing or other throat irritation, running noses, etc.) has been demonstrated in a Swiss study. The symptoms already started to increase when the average six-week concentrations were above 30 $\mu g/m^3$. The main source of the pollution was road traffic. (4)
☐ So-called hyperreactivity in the tracheae was observed in another Swiss study among non-asthmatic children living in urban surroundings (with an average NO_2 concentration of 36 $\mu g/m^3$) compared with others living in the country where the average concentration was 26 $\mu g/m^3$. (4)
☐ An increase in hoarse catarrh was noted among young girls in Stockholm at an average winter-time level of 27 $\mu g/m^3$ (actually 70 $\mu g/m^3$ expressed as a 99 percentile of 1-hour values). (4)
☐ In Oslo, Norway, 162 children and adults were kept under observation for two weeks, and the occurrence noted of a variety of symptoms (such as fatigue, sneezing, throat irritation, etc.). The chances of suffering from one or the other were found to increase by 17-145 per cent when NO_2 concentrations rose from 10 to 100 $\mu g/m^3$. (4)
☐ In an American study, based on data from sixty cities, lung capacity was shown to decline by 2-5 per cent when the average NO_2 concentration was 60 $\mu g/m^3$. (26)

All this shows that there will be effects on health even when the concentrations of NO_2 are around or under the official limit values and guide values, and that those most at risk are asthmatics and children. Exact interpretation is made difficult on the one hand because of uncertainty as to the extent to which other air pollutants affect and disturb the processes, and on the other as to how much importance shall be assigned to high peak values as against long-term averages.

Genotoxicity
Experiments have shown nitrogen dioxide to have a slight genotoxic effect (meaning it can affect the hereditary material and/or cause cancer). More worth noting is that it easily reacts with various other substances and so can contribute to the formation of new, extremely genotoxic compounds.

Among the genotoxic substances that can be formed with the aid of nitrogen dioxide are:
☐ Nitric acid, formed by the reaction of NO_2 with water.
☐ Nitroarenes, formed by the reaction of NO_2 with polyaromatic hydrocarbons. Nitroarenes are found in vehicle exhausts, especially from diesels. Among those that have been shown to be highly mutagenic (affecting hereditary material) are dinitropyrenes. Mice that have had injections of pyrene, a non-mutagenic arene, developed mutagenic nitropyrenes when exposed to high levels of NO_2.
☐ Compounds formed when NO_2 reacts, under the influence of sunlight, with propylene and vinyl chloride.
☐ Alkyl nitrites such as methyl and ethyl nitrite that are formed when the exhaust gases from vehicles driven wholly or partly by alcohols (ethanol or methanol) react with NO_2. (36)

Ozone (O_3)

Ozone is a very unstable molecule which easily reacts with other substances. Because of its instability, the ozone molecule with its three oxygen atoms tends to react with other substances by releasing one of its three oxygen atoms (oxidizing) to form the more stable, normal oxygen molecule O_2.

WHO guide values for ozone (1987)

Time period	($\mu g/m^3$)	Aim
1-hour average value	200	Vegetation
1-hour average value	150-200	Health
8-hour average value	100-120	Health
24-hour average value	65	Vegetation
Growing period (100 days)	60	Vegetation

Reference (38)

Threshold values for ozone in EU (1992)

Time period	($\mu g/m^3$)	Explanation
8-hour average value	110	Danger to health
1-hour average value	200	Risk for damage to vegetation
24-hour average value	65	Risk for damage to vegetation
1-hour average value	180	Public must be informed
1-hour average value	360	Public must be warned

Reference (24)

Ozone, a strong oxidant, is part of a group of substances with similar characteristics which are all naturally formed through the influence of ultraviolet radiation from the sun. Because of their characteristics and the way they are formed, they are called photochemical oxidants. The group includes peroxyacetyl nitrite (PAN), nitric acid, and hydrogen peroxide. Substances that are not so strongly oxidizing are also formed in the photochemical processes, such as formaldehyde, formic acid, and various small, solid particles. Ozone is however the absolutely predominant substance in photochemical smog.

The instability of ozone – its strong tendency to react with other substances – explains why it can damage plants, materials, and human tissue. Proteins, such as enzymes on the surface and in the interior of cells, as well as unsaturated fats, are attacked in the living tissue. Ozone's ability to damage tissue is so strong that it can even be used to disinfect water. (35)

Ozone probably does not spread in the body after having been inhaled. Being so strongly reactive it can, however, start a series of processes in respiratory organs and so disrupt the barrier between the lungs and the circulating blood. Substances from the lungs can then force their way out into the bloodstream, and white blood corpuscles and various proteins, for instance, work back into the lungs and lung tissue.

Ozone can, together with the substances that have thus entered the lung or become formed there through reaction with ozone, cause disturbances that can lead to inflammation. The various immune processes that are then set going can both tone down the damage and intensify possible new noxious processes. One such process is when the body tries to defend itself by strengthening the barrier between the lung and the bloodstream. This weakens the exchange of oxygen between the lungs and the circulating blood, thus reducing vitality.

Among the observed symptoms have been coughing, dryness in the mouth, and pains in the chest.

Experiments in the laboratory have shown that ozone's products of reaction can invade the body and cause damage in various parts: in the white and red blood corpuscles, in the circulatory system, the liver, the endocrine glands, and also the central nervous system.

The effects of ozone on health may depend on the concentration in the air, the length of exposure, and the intensity of inhalation. The

most important factor seems to be the concentration. Extremely high peak levels are more harmful than lower average excesses.

Children and young people are more sensitive to high levels of ozone than older persons. Especially at risk are asthma sufferers. (34)

Mild effects (irritation of the eye, nose, and mouth; headache; pains in the chest) have been related to concentrations as low as 200 $\mu g/m^3$. (38)

There have been clearly evident effects on children and young people when the 1-hour values were 160-300 $\mu g/m^3$ (38). An increase in onsets of the disease and difficultly in breathing have been noted in asthmatics at similar levels.

Exposure for 1-3 hours at concentrations of 320-370 $\mu g/m^3$ caused an average deterioration of 5 per cent in the lung function of very active (high ventilation), healthy children and young persons – although with great individual variations, some showing as much as a 15-per-cent deterioration.

When the exposure was somewhat longer (3-6 hours), similar effects were observed even at 160 $\mu g/m^3$. Exposure of 5-6 hours at a concentration of 240 $\mu g/m^3$ led to an average decline of 10 per cent in lung capacity, and very much more in the case of some individuals.

It seems that asthmatics in general are no more susceptible than non-asthmatics, but as their lung function is poorer to begin with, they start to show symptoms at lower levels than non-asthmatics.

Healthy individuals can experience a slight difficulty in breathing after exposure of six hours to concentrations of 160 $\mu g/m^3$. Coughing occurs when they rise to 240 $\mu g/m^3$, and more serious symptoms such as pain in the whole respiratory tract and severe irritation of the trachea at 320-360 $\mu g/m^3$.

Checks of protein for instance in the pulmonary fluid have revealed damage to the barrier between the lung and the blood stream after 1-3 hours exposure to a concentration of 400 $\mu g/m^3$, and after 6.6 hours at 160 $\mu g/m^3$.

It has been found that when ozone occurs in combination with other air pollutants, the various substances accentuate each other's harmful effects, be it with SO_2, NO_2, sulphuric acid, nitric acid or carbon monoxide. It seems however that if the ozone level is high, it is the ozone that determines the effects on health. But ozone also contributes to the formation of aerosols, small airborne particles which themselves have adverse effects. Among the aerosols of which the concentrations vary in accordance with those of ozone in the air are sulphuric acid, nitric acid, and various sulphates and nitrates.

There is a clear connection between heightened ozone levels and increased mortality from respiratory diseases, slight difficulty in breathing, and asthma symptoms. It seems particularly marked in asthmatic children.

Repeated collation of the number of hospital records for respiratory trouble with the concentrations of ozone in the air have revealed an increase of 1-3 visits to the doctor per million inhabitants every time that concentrations rose by 200 $\mu g/m^3$. (34) It has also been shown from studies in Los Angeles and New York that there is a clear connection between the number of deaths and the occurrence of 1-hour values for ozone of more than 400 ug/m^3.

It seems nevertheless that the body is able to accommodate itself to elevated levels of ozone. The most marked effects during a five-day period occur on the second day. The action of ozone on the lungs and the corresponding reaction cause some of the cells in the lung tissue to be replaced by other types that are better able to withstand the direct and indirect attacks of ozone. A relatively quick reversion (24-48 hours) to a normal state occurs when the ozone level falls back again.

Lengthy exposure to elevated concentrations causes permanent changes in the lung tissue, the especially sensitive cells being re-

Why are ozone concentrations increasing?

Ozone occurs naturally in the air in low concentrations. It is formed when nitrogen dioxide is exposed to ultraviolet radiation from the sun. With energy thus added, the nitrogen dioxide molecule divides into a nitrogen oxide molecule (NO) and a free oxygen atom (O). The oxygen atom then reacts with an oxygen molecule to form ozone (O_3):

1. NO_2 + light → NO + O
2. O + O_2 → O_3

The ozone thus formed is unstable and reacts easily with the nitrogen oxide (NO) formed in reaction 1.

3. O_3 + NO → NO_2 + O_2

Reactions 1 and 2 occur mainly during the daylight hours, reaction 3 when it is darker and cooler.

Certain substances, in particular some hydrocarbons but also carbon monoxide, for instance, react easily with NO and can block reaction 3 by "slipping in" before the ozone. These ozone precursors take the place of ozone in reaction 3 and in that way hinder the break-up of ozone. Examples of hydrocarbons that thus contribute naturally to the formation of ozone are certain terpenes that evaporate from coniferous trees.

In unpolluted air the processes that form and break down ozone are in equilibrium. On clear, warm summer days the ozone-forming processes dominate, while in the dark hours and during winter the breaking-down ones are at work. In this way the concentrations vary naturally over a 24-hour period and from season to season. In the long term the opposing processes cancel each other out.

The concentrations at ground level may however be affected by inflows of ozone from the stratospheric layer (10-50 kilometres above the earth's surface). In the stratosphere an independent production is taking place as a result of high-energy radiation striking the oxygen. In certain weather situations ozone from the stratosphere can descend to ground level and augment concentrations there.

The greatly increased concentrations of low-level ozone that are now occurring are due to a combination of increased emissions, on the one hand of nitrogen oxides, and on the other of ozone precursors:

a) Increased emissions of nitrogen oxides lead to an increased production of ozone (processes 1 and 2), and

b) Increased emissions of ozone precursors hinder the breaking down of ozone.

The formation and breaking down are both relatively slow processes. While they are taking place the ozone-forming pollutants as well as the ozone itself can become transported far from the source of the emissions. This explains why the highest concentration occur, not in the big cities where the emissions are greatest, but out in the countryside.

The chief reason for the concentrations being relatively low in city centres is however that there are high levels of nitrogen oxide (NO) just there (85-90 per cent of the nitrogen pollutants from motor-vehicle exhausts consists of nitrogen oxide). Nitrogen dioxide (NO_2) is formed in a second stage when the nitrogen oxide reacts with oxygen (is oxidized) or with ozone, in other words reaction 3. As long as the increment of nitrogen oxide from motor vehicles in city centres is greater than the formation of nitrogen dioxide, vehicle exhausts help to suppress the formation of ozone just there. (31)

placed by others that are more resistent. (34)

The genotoxic effects of ozone (its ability to cause cancer or damage to the hereditary material) are to some extent disputed. Ever more specialists are however coming to the conclusion that it is carcinogenic.

Hydrocarbons

Hydrocarbons with adverse effects on health and the environment are present in the open air in a variety of forms. Here only one particular substance will be considered: benzene, which is highly carcinogenic and occurs in petrol. Then follows a look at those hydrocarbons that are most prominent in the formation of ozone.

Benzene

Petrol usually contains 3-5 per cent of this substance. It occurs naturally in crude oil, but the proportion increases during refining. It can generally be said that the higher the octane number, the higher will be the proportion. Benzene can also be formed in the process of combustion. Evaporation from storage tanks and filling stations accounts for most of the additions to the atmosphere. The emissions are by and large proportionate to the benzene content of petrol. Benzene can also come from the burning of wood.

Benzene can, when inhaled, penetrate various parts of the body (via the lung tissue) and there react and become transformed – a process that takes place primarily in the liver, but also in the bone marrow and the placenta.

Besides having direct noxious effects, benzene can also affect the hereditary material and cause cancer – as has been proved in a variety of studies. The connection is clearest as regards leukemia, although lung and skin cancer are also among the effects. The International Agency for Research on Cancer puts it in Group 1, among substances that are definitely carcinogenic to humans.

Several of the most important studies showing the risks of benzene have been carried out on individuals that are especially exposed, by reason of their work, to benzene, including workers in shoe factories, rubber manufacturing, and the petroleum sector (such as filling-station attendants). A distinctly increased cancer risk was noted.

From these studies it is possible to calculate the risk as 3.4×10^{-6} to 2.7×10^{-5} per ppb, or one in 100,000 and one in 1,000,000 respectively, after lifelong exposures of 0.37 ppb (1.2 $\mu g/m^3$) and 0.037 ppb (0.12 $\mu g/m^3$). (10)

Such levels occur regularly in areas of heavy traffic – that is to say, in towns and along busy highways. From a British survey it appeared that they could reach 10 to 65 $\mu g/m^3$ within 20 metres on either side of such roads. (8) In the centre of Stockholm the average value in 1992 was 30 $\mu g/m^3$. (10)

According to the British Department of Transport, 98 per cent of the benzene in the air comes from petrol-driven vehicles, refineries, and the distribution of petrol. The European Union has set the maximum permitted benzene content of petrol at 5 per cent. High octane, unleaded petrol has the highest content. In so-called alkyl petrol the benzene content can be practically eliminated. (8)

Neither the World Health Organization nor the European Union has issued guidelines or limit values for benzene in the air.

Ozone forming substances

The extent of ozone formation depends on three factors: the levels of nitrogen oxides and hydrocarbons, the intensity of light, and the temperature. Also important, however, are the kind of hydrocarbons that are present in the air, since there are differences in their

The different ozone-forming abilities of hydrocarbons

	Estimated share of the emissions of hydrocarbons to the air over Sweden (%)	Relative ozone-forming potential at high concentrations of NOx
Alkanes		
Methane	5.95	–
Ethane	2.02	0.13
n-butane	5.51	0.48
i-butane	2.74	0.39
n-pentane	9.55	0.39
n-hexane	3.41	0.50
2-methyl pentane	4.13	0.56
3-methyl pentane	2.92	0.46
n-heptane	1.52	0.59
Cyclohexane	1.34	0.39
Alkenes		
Ethene	4.34	1.00
Propylene	1.89	1.06
Acetylene	3.83	0.29
Aromatics		
Benzene	2.23	0.32
Toluene	6.05	0.57
m-xylene	1.99	0.88
o-xylene	1.99	0.60
p-xylene	1.73	0.80
1,2,4-trimethyl benzene	2.2	0.87
1,3,5-trimethyl benzene	1.02	0.94
Alcohols		
Ethanol	7.99	0.32
Butanol	1.23	0.40
Dimethyl ester	2.68	0.05
Dimethyl ether	1.49	0.29

Reference (2)

ozone-forming effect. It is therefore especially desirable, in order to reduce the production of low-level ozone in general, to bring down the concentrations of those hydrocarbons that are most easily able to form ozone. In a study of the ozone-forming ability of seventy-five substances during a 96-hour period, it was found that ethene and acrolein were most effective, followed by higher alkenes, aromatic substances, alkanes, and ethers. Chlorinated substances, alcohols, and ketones were less effective.

The table shows which hydrocarbons are emitted in the greatest amounts from human activities in Sweden (>1 per cent of total hydrocarbon emissions), and which of them are best able to form ozone. A non-hydrocarbon that is prominent in ozone formation is carbon monoxide (CO), and there is every reason to lower the levels of this pollutant to a greater extent than its direct effects on health alone would require. (2)

Asthma and allergies

The number of asthma and allergy sufferers has increased markedly during the last few decades, and the increase seems to be greatest in the well-off western nations.

In the United States the number of deaths involving asthmatic symptoms increased by 42 per cent between 1982 and 1991. Of all

asthma sufferers 63 per cent lived in areas where the federal air-quality standards were not being attained. (21)

☐ The number of deaths from asthma among persons aged 5-34 rose in the eighties by 30-60 per cent in Australia, England and Wales, France, Canada, and the United States. (25)

☐ In Great Britain the number of asthma cases increased fourfold 1975-85. (5)

The evidence is becoming ever clearer that outdoor air pollution really does lead to an increased frequency of asthma and allergies. While the exact relationships and the medical aspects remain for the most part to be determined, as regards ozone and particulates they are already clear. Although there appears to be a connection with SO_2 and NO_2, it is not quite so evident.

Although air pollutants do not in themselves trigger allergic reactions, they can affect the respiratory tract in various ways so as to awaken a latent sensitivity to allergy-causing substances, so-called allergens. This does not necessarily lead to immediate allergic reaction – that may not come until later when the individual comes into contact with those particular allergens, for instance by inhaling pollen or mites. (5)

The relationship between allergies and levels of air pollution has also been shown in epidemiological studies. It is known, for instance, that allergies are commoner among town dwellers than among country people. But it is also evident that there are other factors involved, besides outdoor-air quality. Among them are smoking, indoor ventilation, and eating habits.

☐ In Japan the frequency of allergic hay fever was almost three times higher among people living beside a motorway (13.2%) than it was among others in a forested area (5.1%). The pollen levels were about equal. (5)

☐ A study in Seattle, USA, showed a clear relationship between the PM_{10} values and asthma frequency among children. (5)

☐ From a French study it appeared that a rise in NO_2 concentrations of 100 $\mu g/m^3$ led to a 63-per-cent increase in doctors' asthma patients. The number of persons admitted to hospitals for the same reasons rose by 17 per cent. (20)

☐ It was found from a test in Canada that asthmatics exposed to ozone levels of 120 ppb during one hour suffered attacks at half the concentration of allergens that was needed to bring them on in a corresponding group inhaling background air. (7)

3. The WHO guidelines vs reality

In its latest review of the health situation in Europe (40), the European office of the World Health Organization reported that the guidelines issued by the organization in 1987 (*Air Quality Guidelines for Europe*) were being regularly breached in large parts of the region.

The office noted that although the levels of sulphur dioxide and lead in the air had fallen, and probably also of particulates in northwestern Europe, otherwise no favourable trends were discernable.

Since the measuring stations for air quality are very irregularly spread over the continent, the available data has to be reconstituted and approximations made if a complete picture is to be obtained.

All the data is from the end of the eighties and the beginning of the nineties. Subsequently there has been a fall in industrial activity in the former Soviet Union and many parts of central and eastern Europe, which may have had the effect of reducing total emissions.

Sulphur dioxide

It is estimated that all told 65 million Europeans live in places where the concentrations of sulphur dioxide in the course of the year exceed the average value (50 $\mu g/m^3$) recommended by WHO. Of those dwelling in towns of more than 50,000 population, 20 per cent are so affected. Three per cent, or 3 million people, are estimated to live in towns where the yearly average level of sulphur dioxide exceeds 100 $\mu g/m^3$, twice as high as the WHO recommendation. The highest average concentration, 200 $\mu g/m^3$, was recorded in Leipzig, Germany.

It is still more usual for the short-term values to be exceeded. Almost every other European town dweller (45 per cent) is living in a town where the highest recommended 24-hour average (125 $\mu g/m^3$) is exceeded at various times during the year. Worst affected is the Black Triangle, comprising parts of southern Poland, eastern Germany, and the north of the Czech Republic, with high concentrations all over the countryside as well as in the towns. On the days when the recommended values are exceeded in Russia and central and eastern Europe, the concentrations are often more than 200 $\mu g/m^3$. Altogether 241 million people are estimated to be exposed at some time or other during the year to 24-hour concentrations in excess of the WHO guide value. (40)

Consequences

Exceeding the WHO 24-hour guide value for SO_2 (125 $\mu g/m^3$) is estimated to lead to:

- Between 6000 and 13,000 extra deaths among the over sixty-fives.
- Between 89,000 and 203,000 cases of aggravated chronic breathing difficulty.

Long-lasting concentrations of more than 100 $\mu g/m^3$ of sulphur dioxide are, in addition, estimated to give rise to a 5-per-cent lowering of lung capacity among 9.7 million people, mostly in eastern Europe. (19)

Particulates

World Health Organization has recommendations for particulates measured both by the BS (Black Smoke) and the TSP (Total Sus-

pended Particulates) methods. Measurements are however only available for 29 per cent of the European town-dwelling population. The situation has been much better mapped for western Europe than for Russia and eastern and central Europe. It has been estimated that the guideline, as measured by the BS method, is being exceeded in the case of 23 per cent of the total town population, the highest average concentration (100 $\mu g/m^3$) having been reported from Tammerfors in Finland. Where the long-term values are exceeded, episodes occur with very high figures. In towns where that has happened, the guide value (125 $\mu g/m^3$) has been exceeded on at least twenty-two days per year when the concentrations averaged 200 $\mu g/m^3$.

The TSP method shows 61 per cent of the town populations being subjected to concentrations above the level at which a worsening of the lung function occurs. The highest average values (60 $\mu g/m^3$) have been reported from Sofia and Ruse in Bulgaria and from some places in Lithuania. There are also reports of average values of 100-165 $\mu g/m^3$ from a number of Italian and Spanish towns.

In towns where the TSP method has been used, as much as 95 per cent of the population has been subjected at some time during the year to concentrations in excess of the 24-hour guide value (120 $\mu g/m^3$). In the case of 18 per cent that figure was exceeded on more than 200 days of the year. The worst oversteppings have taken place in Kaunas and Shuaylay in Lithuania, Sofia and Ruse in Bulgaria, Barcelona in Spain, and Turin in Italy.

Simulations also indicate that the yearly average value (50 $\mu g/m^3$) recommended by WHO is being exceeded in the open country in the Donetsk region in Ukraine as well as in the Black Triangle. (40)

Consequences

The statistical material is considered far too limited to allow presentation of any reliable figures for sickness and mortality.

Nitrogen dioxide

About 20 per cent of the Europeans in towns, or 50 million people, are estimated to be exposed to concentrations of this pollutant that are above the WHO 24-hour guide value (150 $\mu g/m^3$). That value is more often exceeded in western than in central and eastern Europe. A similar number are exposed to average yearly concentrations of more than 60 $\mu g/m^3$, a level harmful to the respiratory organs. The highest figures have been recorded in Athens, Madrid, and Belgrade. In the first two the 24-hour guide value was exceeded on about thirty days of the year, and in Belgrade on eighty-eight days. The average yearly NO_2 level recorded in Belgrade was over 100 $\mu g/m^3$. (40)

Consequences

Exceeding the 24-hour WHO guide value (150 $\mu g/m^3$) is estimated to cause between 58,000 and 99,000 extra cases of disease of the lower respiratory tract in children.

Every year in Europe 60 million people are likely to have their lung function worsened by between two and five per cent as a result of the average concentrations of NO_2 in the air exceeding 60 $\mu g/m^3$. (19)

Ozone

The pollution pattern for ozone varies over wide areas. Marked differences may be discernable even short distances apart, and the number of those affected varies accordingly. High concentrations (>200 $\mu g/m^3$) are hardly ever recorded in city centres in northern and western Europe – any ozone that may be formed being quickly

broken down by the large amounts of nitrogen oxide that are emitted in such places.

It is downwind of the big cities that high concentrations can be measured in those parts of Europe. People in the suburbs and out in the countryside will thus be exposed to considerably higher concentrations than the inhabitants of the cities will ever be.

Because of the higher temperatures in southern Europe, ozone formation takes place more quickly there than in the north, and there are not the same differences between the city centres and the rest of the country.

According to WHO calculations, concentrations above the lower WHO 1-hour guide value of 150 $\mu g/m^3$ occur over practically the whole of Europe.

Exposures vary however from year to year, depending on the weather situation. During the hot summer of 1989, when a lot of ozone was formed, some 367 million people were, according to estimates, exposed to levels higher than the upper WHO guide value of 200 $\mu g/m^3$. Omitting the city centres in northern and western Europe leads to the result that 38 per cent of the Europeans were in areas where the 200 $\mu g/m^3$ level was at some time exceeded. The greatest deviations occurred in southern England, the Benelux countries, northern France, Germany, and Switzerland. The highest local values were recorded in the south of England and around Lisbon.

The occurrence of ozone was much less in 1985, when the summer was cool. Nevertheless, 16-22 per cent of the whole European population, although more in the south, were estimated to have been exposed to 1-hour values of more than 200 $\mu g/m^3$.

There is much less difference in the average concentrations. In 1989 the inhabitants of the continent were exposed, according to estimate, to an average level of 139 $\mu g/m^3$. In 1985 it was 130 $\mu g/m^3$. Taking the figure of 90 $\mu g/m^3$ – the level at which long-term exposure will cause reduction of the lung function – 431 million persons, or 65 per cent of Europe's population, were living in places where that level was exceeded even in the cold year of 1985.

Practically the whole population of southern Europe (95 per cent) were subject to average concentrations in their environment of more

Number of Europeans living in places where WHO guidelines were being overstepped in the early 1990s. Source: (40).

Pollutant	Time period	Guide-line ($\mu g/m^3$)	Numbers exposed according to statistics (millions)	(%)	Total number exposed (calculated) (%)
Sulphur dioxide	24 h	125[a]	144[d]	46	34
	1 year	50[a]	22	20	9
Nitrogen dioxide[e]	24 h	150[a]	21	23	8
Ozone	1 h	150[b]	105-367[d]	63-93	63-93
	1 h	200[c]	105-367[d]	16-56	16-56
	1 year	90	431[d]	65	
TSP[f]	24 h	120[a]	29	95	
	1 year	60	18	61	
Black smoke[f]	24 h	125[a]	14	23	
	1 year	50[a]	14	23	

[a] WHO guidelines.
[b] Lower guideline.
[c] Upper guideline.
[d] According to model calculations.
[e] Exceeded only in urban areas.
[f] Data insufficient for calculating total exposure.

than 90 $\mu g/m^3$ in that year too. In northern Europe 63 per cent of the population outside the big towns were estimated to have been so exposed in 1985, and 93 per cent in 1989. (40)

Consequences

Depending on the weather, an increase of 220,000 to 1.9 million cases of cough and eye irritation among children can be expected in a single year as a result of short episodes with high concentrations of ozone. Children living in the southern parts of the Benelux countries and adjoining parts of Germany and France are likely to be the most affected. (19)

4. The economic damage from air pollution

It is generally agreed that air pollution ought to be reduced, but the great argument against doing anything about it is the cost. And anyone can see that new cleaning equipment, cleaner fuels, and economizing on the use of energy will cost a good deal of money. Yet it is evident that the present concentrations of air pollutants are having adverse effects on our civilization. Damage to the environment is costing us something too.

Putting things to right will certainly be expensive, but refraining will cost still more.

Although it is not one of the main objects of this report to try and estimate the costs of air pollution, some examples will be given here of attempts to do so. The difficulties must however be emphasized. For one thing it is almost impossible in some cases to translate the damage into terms of money. Also the connection between emissions and their effect is often extremely complicated.

Health

☐ In a study carried out for the Los Angeles region an attempt has been made to calculate the direct economic consequences of the effects on health traceable to elevated concentrations of ozone and particles (PM_{10}) in the air. In respect of ozone the effects were only measured for concentrations of more than 80 ppb (=160 $\mu g/m^3$), a relatively high level. No threshold value was taken for particulates, it being assumed that the number of cases of sickness would be proportionate to the time of exposure. The conclusion was that the amounts of illness and abnormal deaths among the 12 million inhabitants of the region due simply to PM_{10} and ozone levels above 80 ppb yearly were costing the community $10 billion a year. If the US air-quality standards were maintained (and they are not especially strict), some 1600 deaths would be avoided every year.

☐ From a Swedish study using the CVM method (see box, p. 27), it was concluded that the damage from inhaling various pollutants could be assessed thus:

Nitrogen dioxide	$0.50 per milligram
Volatile organic compounds (VOCs)	$0.50 per milligram
Particulates	$5.00 per milligram

From interviews it appeared that people put a higher price on the pollution in city centres than they did on that in the outskirts or the countryside, and the higher the concentrations, the more value they were inclined to put on a reduction. The price put on emissions of NO_x and VOCs in Göteborg was $6.00 per kilogram. In the city centre, where exposure is greatest, it was ten times higher: $60 per kg. The local effects of air pollutants (some 80 per cent of which can be traced to vehicle exhausts) can be estimated, according to this study, to be "worth" $1.3 billion for the whole of Sweden. That is what would be worth paying to curb the pollution. (17)

Corrosion

A number of estimates have been made of the cost of the increased corrosion, due to air pollution, of buildings, roads, bridges, machinery,

etc. The pollutants that have most to answer for in this connection are sulphur dioxide, nitrogen oxides, and ozone.

☐ The estimates made in various studies of the total costs swing from $3.40 to $26.00 per inhabitant a year (in 1991 money value). For Europe that would mean an annual cost for corrosion alone of $2.4-18.2 billion. (The total population of Europe is about 700 million.) (6)

☐ Corrosion of air pollution of the railway bridges and power pylons in the former West Germany is estimated to have cost $4.6 and $2.6 billion respectively in 1990 alone. (1)

☐ In an attempt to evaluate the economic effect of the second Sulphur Protocol of the UN ECE Convention on Long Range Transboundary Air Pollution, it was concluded that the expected reduction of sulphur emissions from 37 to 18 million tons a year would lessen the European costs for corrosion by $9.5 billion a year. That would be equivalent of $2.00 per kilogram of sulphur dioxide or $4.00 of sulphur. (6)

☐ According to a calculation made for Sweden, the corrosion that can be associated with depositions of sulphur costs at least $365 million a year. Depositions are estimated to be 200,000 tons a year, which would put the corrosion cost at $2.00 per kilogram of sulphur, or $1.00 per kg of emitted sulphur dioxide. Not taken into account were the (potentially very high) costs for structures in the ground or stoppages due to corrosion of electrical contact material. Two-thirds of the corrosion related to acidification is reckoned to come from sulphur, and one third from emissions of nitrogen. The total cost to Sweden of this kind of corrosion could thus be put at $600 million per annum at the very least.

☐ Looking at the matter in another way, the Austrian-based IIASA institute has come to the conclusion that a 50-per-cent reduction of sulphur emissions could be achieved by imposing a charge on sulphur of $3000 per ton. By way of comparison, the Swedish tax on sulphur in fuels would correspond to $2000 per ton sulphur. (16)

The damage from corrosion naturally depends very much on the level of the concentrations of acidifying pollutants in the air, and as the concentrations are highest in the vicinity of the emission sources, it is inevitably those areas that are most polluted. In other words, the countries where the emissions occur are those that suffer most, economically. Contrariwise it is just those countries that would have the greatest economic gain if corrosion were to become reduced as a result of stricter standards for air quality.

Farming

☐ The effects on the country's harvests of the concentrations of ozone in 1986-88 have been studied in Sweden. The calculations were based on the losses for various crops that were noted from experiments in controlled conditions with varying concentrations of atmospheric ozone. It is estimated that on an average ozone in elevated concentrations causes harvest losses of 9 per cent in Sweden. The total economic loss for Swedish agriculture is put at $200 million a year. Worst affected are the more leafy plants such as potatoes, although the greatest annual loss, $100 million, is for fodder crops. On an average the harvest losses suffered by Swedish farmers every year on account of ozone amount to $75 per hectare. (14)

☐ The changes in the atmosphere are causing farmers to adapt themselves, switching from crops that are sensitive to ozone to less sensitive ones. Swiss researchers who have studied this process and calculated the economic consequences, have found fodder crops to be radically reduced as a result of high ozone levels. There are also less potatoes. While switching to barley is the most marked trend, the

growing of maize and wheat is also increasing. An unwelcome development from the point of view of the environment is an increased application of machinery and chemicals. Seen economically, farmers' incomes are estimated to drop by 4 per cent for every 10-per-cent increase in ozone concentrations. With present levels of ozone in Switzerland, the losses to argiculture are accounted at least $400 per hectare. (22)

Putting a price on environmental damage

Some of the costs arising from air pollution are fairly easy to calculate. There can be little doubt, for instance, about corrosion damage to structures: buildings, roads, bridges, etc. There is a market value to them, and in any case the cost of repairs can be calculated. It is likewise possible to assess the financial loss of effects on harvests or on forest growth – although in these cases uncertainties are beginning to enter in the form of controlled prices for food and subsidies to agriculture.

It is also possible to calculate to some extent the financial costs of the effects of air pollution on human health. Increased costs to the health service and reduced industrial output due to increased absenteeism because of sickness are also examples of a fairly evident cost.

A majority of the costs for air pollution concern however things for which there is normally no market. How much is the Acropolis, for instance, worth in terms of money, and how does one assess the damage brought about by air pollution on that and other edifices of cultural value? The increased incidence of asthma among children: what is that worth? What price can be put on the acidification of a lake and changes in the flora as a result of air pollution?

All that is certain is that the cost is not zero.

In principle there are three methods of assessment:

1. The simplest: singling out the extra costs or losses that can be translated directly into economic terms. This is applicable in the case of damage from corrosion, loss of income in agriculture and forestry, or a falloff in production as a result of sickness (human capital cost). But the method only takes in a fraction of the real costs to society of atmospheric pollution – the top of the iceberg, so to speak. It does not, for instance, take account of the mortality rate.
2. Translating political measures for the environment into economic terms and assuming that to be society's valuing, say, of some kind of emission. This is what is called "collective willingness to pay." Lowering emissions of nitrogen oxides by making catalytic converters compulsory is calculated to cost for instance $4.00 per kilogram of avoided NO_x emissions (1995 money value), which is accounted to be society's idea of what NO_x emissions are worth. Various environmental charges and taxes can likewise be said to reflect society's pricing of an emission. A variant would be to start from a defined political objective (say, a 50-per-cent reduction of some emission) and then try to determine the marginal cost of such a measure.
3. The method of assessment that economists are more and more inclined to prefer is polling of people's willingness to pay for various environmental improvements. Known as CVM (Contingent Valuation Method), this method is thought to give the most complete picture of the costs of environmental damage, at least as regards the local effects, especially on health. (17)

Forest industry

□ An attempt has been made in Sweden to calculate the loss arising from the effects of sulphur deposition on tree growth. Because of the long turnover time in forestry, the economic consequences of the depositions occur long after the emissions have taken place. It is estimated that sulphur depositions have already cost the Swedish forest industry $10-15 billion, and that a further cost of $150-300 million is being piled on every year. The study in question has only calculated the damage that be ascribed directly to depositions of sulphur. Ozone and nitrogen as well as combinations of pollutants can also affect forest growth. (30)

5. What should be done

If they are properly formulated and applied, air-quality standards can be useful instruments in the process of working towards a reduction of the effects of pollutants on health and the environment. Badly formulated standards can on the other hand hinder this process by making it possible to take advantage of them to delay measures. The way standards are formulated is therefore of exceptional importance.

Unfortunately the existing standards (or at least those issued from the European Union and the World Health Organization), are far from meeting the requirements of an effective system.

1. They are said to take into account the requirements both of health and the environment, but in fact only health is considered. Naming of the ecological aspects seems to be mainly decoration.

2. The present limit values and guide values often tend to be regarded as an expression of long-term environmental objectives, whereas in fact they should be considered as no more than a step towards the achievement of a reasonable state of the environment. The technical phrasing and terminology easily give rise to misinterpretation, and by thus leading off on the wrong track, the standards can be used to hold back instead of hastening on desireable measures.

3. Even in their purely health aspects, the present standards are, in the light of the latest knowledge, altogether too weak. Even if the situation should not be re-judged, the current increases in the incidence of asthma and allergies should be reason enough for making them stricter. And if other aspects are taken into account, such as ecological, the industrial-economic, and cultural historical, it makes still less sense not to make the standards stricter.

4. Even with the present low levels for compliance, millions of people in the whole European region, east as well as west, are exposed to concentrations that exceed the recommended values, both of the WHO guidelines and of the various EU limit, guide, and threshold values.

5. The EU guide values, which are supposed to indicate the course and serve to hasten the adoption of compulsory measures, do not seem to be having the desired effect. Nor do the EU threshold values, although they may be useful in spreading awareness of the problems.

6. The arrangements for measuring the pollution are highly deficient, making it difficult to estimate developments. In the case of particulates, much of the measuring that is being done is probably irrelevant.

One reason for the standards not being tightened is the difficulty that is already being experienced in complying with them as they are. If they were to be made reasonably strict, the gap between the actual and the desired state of affairs would often turn out to be very wide – causing, it is thought, political problems. Such an attitude is of course unacceptable. A gap between standards and what is actually happening is no reason for not defining, via proper limit values, the long-term aim which should rest on what humans and the environment can stand over a long period of time. That aim should moreover be firmly anchored in legislation.

No devaluing of terms

The present system gives a false sense of security, giving the appearance of providing protection when it does not really do so.

The aim of limit values is said to be to provide protection against serious effects on health and the environment, but not to entirely prevent damage. The permissible levels of pollution are however to a greater or lesser extent the result of a compromise between care for health and the environment on the one hand, and on the other economic considerations. This applies to some extent to the WHO recommendations, but more to the various kinds of EU standards.

Instead of being conceived as temporary arrangements on the way towards an achievement of an acceptable state of the environment, as they should be, limit values are often taken to be final targets. All that matters is to meet these particular values, while ignoring the long-term aim, which is to provide full protection for humans and the environment.

Misinterpreted in this way, limit values actually counteract their real aim, and slow down progress towards a better environment. One way to prevent this would be to take care in the employment of terms, using "limit value" in particular in its stricter sense of a long-term aim.

Limit values, provisional limit values, and clean-air areas

As mentioned in Section 3, regarding WHO recommendations, pollution is now present at levels that lie far above the prescribed limits, which are in any case far too lenient. Bringing pollution down to desirable levels will thus often take a considerable time.

In order to maintain the pace in the short term, yet without losing sight of the long-term aim, it will be necessary to work on two levels, with one short-term limit value to guide procedures in the next few years, and another, long-term value to indicate the final target. In the following the expression used to this end will be "provisional limit value" and "limit value." Such an arrangement is already being employed in Switzerland.

In some parts of Europe a number of possible limit values for air quality are already being met. It should not however be assumed from this that increases in pollution levels will be allowable in such places. The introduction of limit values must not be taken to mean that pollution levels can creep up to them. Special air-quality standards may therefore be needed for such "clean-air areas."

Principles for the setting of limits

a) What should be striven for in principle is a reversion to natural background levels. An example is ozone, which is thought to be slightly carcinogenic, but in fact occurs naturally in the air.

b) Should it turn out that health and the environment would require separate limit values, the lower limit should always be the one that applies. In principle there is no reason to have differing limit values for town and country. In places where the pollution levels are already well under the proposed limit values, no deterioration of air quality should be allowed (see above).

c) When setting limit values to substances that are harmful to health, but can also have considerable effects on the environment that are not directly due to their concentrations in the air (such as acidification and eutrophication), an extra factor, other than any dictated for reasons of health, should be incorporated. The important value here is the arithmetical long-term value, which should be set so as to bring down the total emissions of the substance, be it an oxide of nitrogen, sulphur dioxide, or some ozone-forming substance.

d) Substances that do not have any evident ecological effects should be judged not only from the viewpoint of health, but also from the likelihood of their damage to buildings, cultural objects, etc. The

limit value should in principle be made to suit the most sensitive part of the population – at 20-50 per cent of the level as which effects starts to occur in that group (see p. 4, Principles for standards).

e) The limit values for carcinogenic substances should be set according to a uniform principle, say, according to the highest lifetime risk of one in a million at continual exposure (see again Principles for standards).

Boundary-crossing pollutants

Limit values are applicable at the national level. Pollutants can often be transported over long distances and across several countries, which may make it difficult for some countries to meet the limit values, although their own emissions may be quite low. E.g. large-scale formations of ozone over Europe.

In general however the quality of the air and the environment is most affected in that country where the emissions have their source. But with common minimum limit values strictly applied everywhere, the conflict between limit values and transboundary pollution can be held down.

Proposal for limit values/provisional limit values

The following proposals should be regarded as material for discussion while revised and new limit values are being developed within the European Union during the next few years. To the extent that further knowledge and information become available, as for example through revised recommendations from WHO, the proposals themselves should also be revised.

In the division between provisional and final limit values, the provisional ones should become obligatory as from 2000, and the limit values proper somewhere between 2005 and 2010.

To make matters clear, it should be possible to add the year at which the limit values are to become obligatory. Thus the provisional ones could be designated Limit Value 2000, and the final values Limit Value 2005 or Limit Value 2010.

Sulphur dioxide

Time period	Provisional limit value $\mu g/m^3$	Limit value $\mu g/m^3$
24-hour average value (98 percentile)		80[1]
Arithmetical yearly average value of the 24-hour average value	20[2]	10[3]

[1] Proposal for a guide value taking account of effects on health, from the Netherlands Ministry of Environment 1987. (15)

[2] "Critical level" for damage to forest ecosystems and natural vegetation according to UN ECE 1993. (33) Limit value in Switzerland. (15) Ecological guide value, WHO 1987. (38)

[3] "Critical level" for damage to certain species of mosses and lichens according to UN ECE 1993. (33) The International Union of Forest Research Organizations recommends 25 $\mu g/m^3$. (15) The guide value for suburban and rural areas in Finland is also 25 $\mu g/m^3$. (18)

Particles

The present systems for measuring particles (TSP and BS) are largely irrelevant. In order to take account of particles of various sizes and with somewhat differing effects on health, a system with two limit values should be introduced: one according to PM_{10}, which measures the total amounts of inhalable particles, the other according to $PM_{2.5}$, measuring the smallest particles, which apparently have the chief effects on health.

In cases where the carcinogenic effects of particles, and their ability to attach to themselves dangerous hydrocarbons call for stricter rules, re-evaluations are taking place. Until measuring according to PM_{10} and $PM_{2.5}$ becomes more general, the following provisional values should be employed:

Time period	Black smoke $\mu g/m^3$	TSP $\mu g/m^3$	PM_{10} $\mu g/m^3$	$PM_{2.5}$ $\mu g/m^3$
24-hour average value (98 percentile)	60[1,2]	100[4,5]	70[7]	
Arithmetical half-year average value	15[1,3]	50[6]	20[5]	

[1] Present limit value in Sweden BS 90 resp. 40 $\mu g/m^3$. (15)
[2] Present limit value in the Netherlands 90 $\mu g/m^3$. (15)
[3] Lower guide value in EU 40 $\mu g/m^3$. (23)
[4] Present limit value in Japan. (15)
[5] Proposed by the Institute of Environmental Medicine, Sweden, 1992. (5)
[6] Present limit value in Sweden. (15)
[7] WHO guideline with at the most 125 μg SO_2/m^3. (38)

Nitrogen dioxide

Time period	Provisional limit value $\mu g/m^3$	Limit value $\mu g/m^3$
1-hour average value (98 percentile)	90[1]	60[2]
Arithmetical yearly average value of the 24-hour average value	30[3]	20[4]

[1] Corresponds to 99 percentile 100 $\mu g/m^3$, proposed by the Institute for Environmental Medicine 1992. (4)
[2] Guide value with a view to health proposed by the Netherlands Ministry of Environment 80 $\mu g/m^3$. (15) Effects found in children's health at 70 $\mu g/m^3$. (4)
[3] Limit value in Switzerland. (15) "Critical level" for damage to sensitive plants in combination with SO_2 and ozone according to UN ECE 1993. (33) Ecological guideline WHO 1987. (38)
[4] Effects on children noted at corresponding concentration of 27 $\mu g/m^3$. (4)

Ozone

Most scientists agree that the ecological effects of ozone depends primarily on how much the concentrations exceed a certain threshold value during how long time. In UN ECE 1994 40 ppb (80 $\mu g/m^3$) is proposed as a "base level." Limit values with 98 percentiles permit, for instance, odd periods with very high concentrations. During such episodes a very high aggregate load, calculated for instance according to AOT40, can arise.

It seems however that the proposed AOT40 system may be difficult to apply in practice. Limit values resting on 50 or 98 percentiles, or

arithmetical average values, represent a well established solution.

In order to arrive at a reasonably simple system that still "hauls in" the various answers to ozone, it is proposed that three limit values should be employed:

☐ A 1-hour value with a 98 percentile to eliminate too many peak values.

☐ A rolling 8-hour value (also representing a 98 percentile) to counteract excessive loads during short periods.

☐ An arithmetical average value to prevent the aggregate loads from becoming too great.

It should be noted that all three will be needed to meet the aims as regards loads during short. medium, and long periods. One value alone will not give the proper results. Should a system with 98 percentiles for 1-hour and 8-hour values be deemed to permit altogether too many episodes with high values, a 99 percentile could be substituted.

Time period	Provisional limit value $\mu g/m^3$	Limit value $\mu g/m^3$
1-hour average value 9-18 hrs Apr-Sept (98 percentile)		100[1]
8-hour rolling average value Apr-Sept (98 percentile)	75[2]	40[4]
24-hour average value Apr-Sept (98 percentile)	60[3]	30[4]

[1] The natural 1-hour maximum background concentration of O_3 is 30-50 ppb = 60-100 $\mu g/m^3$. Sporadic values of 120 $\mu g/m^3$ at the surface of the sea and at 3000 metres height found in Germany. (34) Limit value in Switzerland (98 percentile half-hour value counted monthly). (15)

[2] "Critical level" according to UN ECE is 40 ppb = 80 $\mu g/m^3$, with the proviso that the total load above that level is what counts more. A special kind of limit value is therefore recommended – AOT40, which takes account of the number of hours over a period of time with values above 40 ppb. For every hour with a value over 40 ppb an AOT40 value is calculated, measured in ppbh. Three-day periods with a highest AOT40 value of 700 ppbh is proposed for farm crops, and 10,000 ppbh during a whole growing season for forest trees. The thesis rests on the idea that a certain amount of damage to vegetation should be accepted. (12)

[3] Guideline for vegetation, growing period. WHO 1987. (38)

[4] The average background concentration measured at the end of the last century in France was 15-25 $\mu g/m^3$. Measurements taken at Arcona, on the south coast of the Baltic Sea, in the early fifties revealed concentrations of around 30 $\mu g/m^3$. (31) In UN ECE 1988 50 $\mu g/m^3$ is accounted the "critical level." (15)

Benzene

Assuming a risk of one in a million for cancer, with lifelong exposure, to be acceptable, a limit value of 0.13 $\mu g/m^3$, calculated as a year's average, is recommended. As a provisional limit value, 1.3 $\mu g/m^3$ is proposed. The risk in that case would be one in 100,000, also with a lifelong exposure. (10)

Appendix 1.

Air-quality standards for sulphur dioxide/particulates, nitrogen dioxide, and ozone

References: 3, 4, 5, 10, 11, 15, 23, 24, 33, 38.

Sulphur dioxide and particulates

The effects of sulphur dioxide on health are thought to be at least partly dependent on the simultaneous presence of particulates and vice versa. These pollutants in any case often occur together, especially in ordinary smog, brought about by the burning of coal. Both the EU limit values and the WHO guide values therefore relate to a combination of the two.

Several methods, each differing in principle, have been developed for measuring particulates. The two most usually employed are:

BLACK SMOKE (BS), being an optical method, this does not measure either the weight or the number of particles, only the density of colour. Air is sucked through a filter and the amount of particulates judged by the blackness of the filter. The measure may sometimes be labelled soot or reflectance assessment. BS values are generally given as $\mu g/m^3$.

TOTAL SUSPENDED PARTICULATES (TSP) is a gravimetric method, measuring the weight of all the particles up to 180 μm in diameter. This means that particles are included which, because of their size, may often be harmless to health, since they cannot penetrate deeply into the respiratory organs. The measurements are taken at roof height, which means that the air actually measured may differ somewhat from that at street level where health can be affected.

Now other methods are gradually gaining acceptance, foremost among them being the PM_{10} method which only measures particles up to a diameter of 10 μm. Being a measure of the amount of inhalable particles it is sometimes known as the "thoracic particles method." The TSP and PM_{10} methods are sometimes lumped together under the designation SPM (Suspended Particulate Matter).

Limit values for sulphur dioxide in combination with particulates in EU (1980/89) ($\mu g/m^3$)

Time period	Sulphur dioxide	Black smoke	TSP
24-hour average value during year (98 percentile)	250	>150	>350
24-hour average value during year (98 percentile)	350	<150	<350
24-hour average value during winter half-year (50 percentile)	130	>60	>200
24-hour average value during winter half-year (50 percentile)	180	<60	<200
24-hour average value during year (50 percentile)	80	>40	>150
24-hour average value during year (50 percentile)	120	<40	<150

Guide values for sulphur dioxide/particulates WHO (1987) ($\mu g/m^3$)

	Sulphur dioxide	Black smoke	TSP	PM_{10}
10-minute value	500			
1-hour average value	350			
24-hour average value (health)	125	125	120	70
24-hour average value (ecology)	100			
Yearly average (health)	50	50		
Yearly average (ecology)	30			

Limit and guide values for particulates (black smoke) in EU (1980)

Time period	($\mu g/m^3$)	Type
24-hour average value during year (98 percentile)	250	Limit value
24-hour average value	100-150	Guide value
24-hour average value during winter half-year (50 percentile)	130	Limit value
24-hour average value during year (50 percentile)	80	Limit value
Arithmetical average value of the yearly 24-hour average value	40-60	Guide value

Guide values for sulphur dioxide in EU (1980)

Time period	($\mu g/m^3$)
24-hour average value	100-150
Arithmetical average value of the yearly 24-hour average value	40-60

Sulphur dioxide

Period	$\mu g/m^3$	Type	Country/origin/date	Explanation
10-minute value	500	Guideline	WHO 1987	
1-hour average value	350	Guideline	WHO 1987	
24-hour average (98-percentile)	350	Limit value	EU 1980	With particulate values BS max 150 $\mu g/m^3$
24-hour value (98-percentile)	250	Proposal	Netherlands 1987	Limit value
24-hour value (98-percentile)	250	Limit value	EU 1980	With particulate values BS >150 $\mu g/m^3$
24-hour value (98-percentile)	80	Proposal	Netherlands 1987	Guide value
½-hour value (95-percentile)	100	Limit value	Switzerland	
24-hour average value	70	Critical level	UN ECE 1988	Protection of crops
24-hour average value	125	Guideline	WHO 1987	In combination with particulate value
24-hour average value	100	Guideline	WHO 1987	Ecological guideline
24-hour average value	100	Limit value	Switzerland	
24-hour average value	100-150	Guideline	EU 1980	
24-hour average value	365	Limit value	USA	
24-hour average value during year (50-percentile)	30	Proposal	Netherlands 1987	Guide value
24-hour average value during year (50-percentile)	75	Proposal	Netherlands1987	Limit value
24-hour average value during winter half-year (50-percentile)	180	Limit value	EU 1980	With particulate value BS max 60 $\mu g/m^3$
24-hour average value during winter-half year (50-percentile)	130	Limit value	EU 1980	With particulate value BS >60 $\mu g/m^3$
24-hour average value during year (50-percentile)	80	Limit value	EU 1980	With particulate value BS >40 $\mu g/m^3$
24-hour average value during year (50-percentile)	120	Limit value	EU 1980	With particulate value BS max 40 $\mu g/m^3$
Yearly average value	10	Critical level	UN ECE 1993	Protection of lichens
Yearly average value and average value October-March	20	Critical level	UN ECE 1993	Protection of forest ecosystem and natural vegetation
Yearly average value	25	Guideline	IUFRO 1979	Protection of trees in exposed locations
Yearly average value	30	Limit value	Switzerland	
Yearly average value and average value October-March	30	Critical level	UN ECE 1993	Protection of crops
Yearly average value	30	Guide value	WHO 1987	Ecological guideline
Yearly average value	40-60	Guide value	EU 1980	
Yearly average value	50	Guideline	IUFRO 1979	Protection of growing forest
Yearly average value	50	Guideline	WHO 1987	With particulate value BS max 50 $\mu g/m^3$
Yearly average value	80	Limit value	USA	

Particulates

Measured as TSP (Total Suspended Particulates)

Period	µg/m³	Type	Country/origin/date	Explanation
1-hour average value	200	Limit value	Japan	
24-hour average value	70	Guideline	WHO 1987	PM_{10} at most 125 µg/m³ SO_2
24-hour average value	100	Limit value	Japan	
24-hour average value	100	Proposal	Institute of Environmental Medicine (Sweden) 1992	PM_{10}
24-hour average value	110	Limit value	Sweden	TSP/PM_{10}
24-hour average value	120	Guideline	WHO 1987	TSP at most 125 µg/m³ SO_2
24-hour average value	150	Limit value	USA	PM_{10}
24-hour average value during year (95-percentile)	150	Limit value	Switzerland	
Average value for winter half-year	20	Proposal	Institute of Environmental Medicine (Sweden) 1992	PM_{10}
Half-year average value	50	Limit value	Sweden	TSP/PM_{10}
Yearly average value	50	Limit value	USA	PM_{10}
Yearly average value	70	Limit value	Switzerland	

Particulates

Measured by Black Smoke method

Period	µg/m³	Type	Country/origin/date	Explanation
24-hour average value during year (98-percentile)	90	Limit value	Netherlands 1987	
24-hour average value during year (98-percentile)	90	Limit value	Sweden	
24-hour average value during year (98-percentile)	250	Limit value	EU 1980	
24-hour average value during year (95-percentile)	75	Limit value	Netherlands 1987	
24-hour average value	100-150	Guide value	EU 1980	
24-hour average value	125	Guideline	WHO 1987	At most 125 µg/m³ SO_2
24-hour average value	150	Limit value	Netherlands 1987	
Winter half-year average of 24-hour average value	40	Limit value	Sweden	
24-hour avgerage value for winter half-year (50-percentile)	130	Limit value	EU 1980	
24-hour avgerage value (50-percentile)	30	Limit value	Netherlands 1987	
Yearly average value of 24-hour average value	40-60	Guide value	EU 1980	
Yearly average value of 24-hour average value	50	Guideline	WHO 1987	At most 50 µg/m³ SO_2
24-hour average values during year (50-percentile)	80	Limit value	EU 1980	

WHO guidelines for nitrogen dioxide (1987)

Time period	($\mu g/m^3$)	Aim
1-hour average value	400	Health
4-hour average value	95	Protecting vegetation with SO_2 max 30 $\mu g/m^3$ and O_3 max 60 $\mu g/m^3$
24-hour average value	150	Health
Yearly average value of 24-hour average value	30	Protecting vegetation with SO_2 max 30 $\mu g/m^3$ and O_3 max 60 $\mu g/m^3$

Limit and guide values for nitrogen dioxide in EU (1985)

Time period	($\mu g/m^3$)	Type
98-percentile 1-hour average	200	Limit value
98-percentile 1-hour average	135	Guide value
50-percentile 1-hour average	50	Guide value

Nitrogen dioxide

Period	µg/m3	Type	Country/origin/date	Explanation
1-hour average value (99,5-percentile)	175	Proposal	Netherlands 1987	Limit value
1-hour average value during winter half- year (99-percentile)	100	Proposal	Institute of Environmental Medicine (Sweden) 1993	
1-hour average value (98-percentile)	80	Proposal	Netherlands 1987	Guide value
1-hour average value during winter half- year (98-percentile)	110	Limit value	Sweden	
1-hour average value (98-percentile)	135	Proposal	Netherlands 1987	Limit value
1-hour average value (98-percentile)	135	Guide value	EU 1985	
1-hour average value (98-percentile)	200	Limit value	Germany	
½-hour average value (95-percentile)	100	Limit value	Switzerland	
1-hour average value	400	Guideline	WHO 1987	
4-hour average value	95	Guideline	WHO 1987	Protection of vegetation at SO_2 max 30 µg/m3 and O_3 max 60 µg/m3
4-hour average value	95	Critical level	UN ECE 1993	Vegetation
24-hour average value during winter half-year (98-percentile)	75	Limit value	Sweden	
24-hour average value	80	Limit value	Switzerland	
24-hour average value	150	Guideline	WHO 1987	
1-hour average value (50-percentile)	25	Proposal	Netherlands 1987	Guide value
1-hour average value (50-percentile)	50	Guide value	EU 1985	
Half-year average value	40	Corresponding value	Institute of Environmental Medicine (Sweden) 1993	
Average value for winter half-year	50	Limit value	Sweden	
Yearly average value of 24-hour average value	30	Guideline	WHO 1987	Protection of vegetation at SO_2 max 30 µg/m3 and O_3 max 60 µg/m3
Yearly average value	30	Critical level	UN ECE 1993	Vegetation
Yearly average value	30	Limit value	Switzerland	
Yearly average value	80	Limit value	Germany	
Yearly average value	100	Limit value	USA	

WHO guide values for ozone (1987)

Time period	(µg/m^3)	Aim
1-hour average value	200	Vegetation
1-hour average value	150-200	Health
8-hour average value	100-120	Health
24-hour average value	65	Vegetation
Growing period (100 days)	60	Vegetation

Threshold values for ozone in EU (1992)

Time period	(µg/m^3)	Explanation
8-hour average value	110	Danger to health
1-hour average value	200	Risk for damage to vegetation
24-hour average value	65	Risk for damage to vegetation
1-hour average value	180	Public must be informed
1-hour average value	360	Public must be warned

Ozone

Period	µg/m3	Type	Country/origin/date	Explanation
½-hour average value, calculated monthly (98-percentile)	100	Limit value	Switzerland	
1-hour average value	80	Critical level	UN ECE 1994	Crops, forests
1-hour average value	120	Limit value	Switzerland	
1-hour average value	120	Guide value	Sweden	
1-hour average value	120	Limit value	Japan	
1-hour average value	120	Proposal	Netherlands	Guide value
1-hour average value	150-200	Guide value	WHO 1987	
1-hour average value	180	Threshold value	EU 1992	Information
1-hour average value	200	Threshold value	EU 1992	Vegetation
1-hour average value	200	Guideline	WHO 1987	
1-hour average value	235	Limit value	USA	
1-hour average value	360	Threshold value	EU 1992	Warning
7-hour average value 09-16 hrs	50	Critical level	UN ECE 1988	Growing period
7-hour average value 09-16 hrs	50	Guide value	Sweden	April-September
8-hour average value	100	Proposal	Great Britain 1994	
8-hour average value	110	Guide value	EU 1992	
8-hour average value	100-120	Guideline	WHO 1987	
24-hour average value	65	Guideline	WHO 1987	
24-hour average value	65	Threshold value	EU 1992	Vegetation
Growing period	60	Guideline	WHO 1987	100 days

Benzene

Period	µg/m³	Type	Country/origin/date
Yearly average value	1	Guide value	Netherlands 1993
Yearly average value	1.3	Proposal	Institute of Environmental Medicine (Sweden) 1994
Yearly average value	10	Limit value (from 1998)	Germany
Yearly average value	10	Limit value	Netherlands 1993
Yearly average value	16	Proposed limit value	Great Britain 1994

Appendix 2.

Conversion table

Benzene (C_6H_6)
1 ppb = 3.24 µg/m^3
1 µg/m^3 = 0.31 ppb

Nitrogen dioxide (NO_2)
1 ppb = 1.880 µg/m^3
1 µg/m^3= 0.532 ppb

Ozone (O_3)
1 ppb = 2 µg/m^3
1 µg/m^3 = 0.5 ppb

Sulphur dioxide (SO_2)
1 ppb = 2.860 µg/m^3
1 µg/m^3 = 0.35 ppb

Appendix 3.

References

1. Andersson, B. (1994): **Korrosionsskadekostnaden orsakad av SO_2-emissioner**. Bilaga till Svenska miljöräkenskaper (Swedish Economic and Environmental Accounts), Konjunkturinstitutet/SCB.
2. Andersson-Sköld, Y., Calander, K. & Grennfelt, P-I. (1991): **Photochemical ozone creation potentials – a study of different concepts.** IVL report. Swedish Environmental Research Institute.
3. Ashmore, M. R. & Wilson, R.B. (Eds.) (1994): **Critical levels of Air Pollutants for Europe.** A UN ECE report from a workshop held in Egham, England, March 23-26, 1992. Department of Environment, London.
4. Berglund, M., Boström, C-E., Bylin, G., Ewertz, L., Gustafsson, L., Moldéus, P., Norberg, S., Pershagen, G. & Victorin, K. (1993): **Health risk evaluation of nitrogen oxides.** Scandinavian Journal of Work, Environment & Health, Vol. 19, Suppl. 2, 1993.
5. Bylin, G. & Boström, C-E. (1994): **Luften vi andas utomhus.** Utomhusluftens betydelse för allergi och annan överkänslighet.

Folkhälsoinstitutet. ISBN 91-88564-16-9.
6. Cowell, D. & Apsimon, H. (1994): **Estimating the cost of damage to buildings by acidifying atmospheric pollution in Europe.** Imperial College Centre for Environmental Technology. (Manuscript)
7. ENDS Report 206 (1992): **Government put on the spot on ozone and health.**
8. ENDS Report 239 (1994): **Ministers reassurance on benzene undermined by air monitoring data.**
9. Expert Panel on Air Quality Standards (1994): **Ozone.** Department on the Environment, Great Britain. HMSO. ISBN 0-11-752-873-0
10. Fransson-Steen R., Ljungquist S. & Victorin K. (1994): **Uppdaterad hälsoriskbedömning av bensen.** IMM-rapport 3/94, Institutet för Miljömedicin. ISSN 1101-2803. (English summary)
11. Friends of the Earth/UK (1995): **House of Commons environment committee inquiry into volatile organic compounds. Evidence from Friends of the Earth.**
12. Fuhrer J. & Achermann (Ed.) (1994): **Critical levels for ozone** – a UN ECE report from a workshop held in Bern, Switzerland, November 1-4, 1993. Swiss Federal Research Station for Agricultural Chemistry and Environmental Hygiene, Liebefeld, Switzerland. ISSN 1013-154X.
13. Hall, J., Winer, A., Kleinman, M., Lurmann, F., Brajer, V. & Colome, S. (1992): **Valuing the Health Benefits of Clean Air.** Science 255, pp. 812-817.
14. Hasund, K.P., Hedvåg, L. & Pleijel, H. (1990)**: Ekonomiska konsekvenser av det marknära ozonets påverkan på jordbruksgrödor.** Statens Naturvårdsverk rapport 3862. ISBN 91-620-3862-1.
15. Kühling, W. & Peters, H-J. (1994): Die Bewertung der Luftqualität bei der Umweltverträglichkeitsprüfung, Bewertungsmaßstäbe und standards zur Konkretisierung einer wirksamen Umweltvorsorge. UVP-Spezial 10, Dortmund. Dortmunder Vertrieb für Bau- und Planungsliteratur.
16. Kågeson, P. (1993): Miljö och ekonomi i samspel. Naturskyddsföreningens förlag. ISBN 91-558-0161-7.
17. Leksell, I. & Löfgren, L. (1995): Värdering av lokala luftföroreningseffekter – hur värdera bilavgasernas hälsoeffekter i tätorter? Institutionen för tillämpad miljövetenskap, Göteborgs Universitet. Kommunikationsforskningsberedningen, KFB-rapport 1995:5.
18. Lumme, E. (1991): Short resume from Finland. Workshop on Air Quality Guidelines for Air Pollution Control Strategies in western and northern Europe. Paris, July 2-5, 1991. Paper.
19. Lübkert-Alcamo, B. & Krzyzanowski, M. (preliminary assessments)
20. New Scientist (1994): **Killer smog stalks the boulevards.** October 15, 1994.
21. New Scientist (1995): **Asthma alert.** January 14, 1995.
22. Näf, W. & Fuhrer, J. (1993): **Modelling economic effects of ozone – a case study in Switzerland.** In Jäger, E.J., Unsworth, M., De Temmerman, L. & Mathy, P. (Eds.) (1993): **Effects of Air Pollution on Agricultural Crops in Europe.** CEC Air Pollution research report No. 46, pp. 297-306 (1993). ISBN 2-87263-103-8.
23. Office for Official Publications of the European Communities (1992): **European Community Environment Legislation, Volume 2 Air.** ISBN 92-826-4086-8.
24. Official Journal if the European Communities: **Council directive 92/72/EEC of 21 september 1992 on air pollution by ozone.**
25. Read, C. (1991): **Air pollution and child health.** Greenpeace UK.

26. Read, C. (Ed.) (1994): **How vehicle pollution affects our health.** Report from symposium held in London, England, May 20, 1994. Ashden Trust.
27. Schwartz, J. (1989): **Lung function and chronic exposure to air pollution: A cross-sectional analysis of NHANES II.** Environmental research, 50, pp. 309-321.
28. Schwartz, J., Spix, C., Wichman, H.E. & Malin, E. (1991): **Air pollution and acute respiratory illness in five German communities.** Environmental Research, 56, pp. 1-14.
29. Seaton, A., MacNee, W., Donaldson, K. & Godden, D. (1995): **Particulates air pollution and acute health effects.** Lancet, Vol. 345, pp. 176-178.
30. Skånberg, K. (1994): **En beräkning av skogsförsurningens skadekostnader.** Bilaga till Svenska miljöräkenskaper (Swedish Economic and Environmental Accounts), Konjunkturinstitutet/SCB.
31. Swedish Environmental Protection Agency (1993): **Ground-level ozone and other photochemical oxidants in the environment.** Report 4243. ISBN 91-620-4133-9.
32. Swedish Environmental Protection Agency (1994): **Gränsvärden för luftkvalitet. Faktablad 9597.**
33. Umweltbundesamt (1993): **Manual on methodologies and criteria for mapping critical levels/loads and geographical areas where they are exceeded.** UN ECE CLRTAP Task force on Mapping. Umweltbundesamt, Berlin, Tyskland.
34. United States Environmental Protection Agency (1994): **Air Quality Criteria for Ozone and related Photochemical Oxidants.** (Draft February 1994)
35. Victorin, K. (1992): **Review of the genotoxicity of ozone.** Mutation Research, 227, pp. 221-238. Elsevier Science Publishers B.V.
36. Victorin, K. (1994): **Review of the genotoxicity of nitrogen oxides.** Mutation Research, 317, pp. 43-55. Elsevier Science B.V.
37. WHO (1985): **Targets for health for all.** WHO Regional Office for Europe.
38. WHO (1987): **Air Quality guidelines for Europe.** WHO regional publications, European series No. 23, World Health Organisation. ISBN 92-890-1114-9.
39. WHO (1993): **Health for All Targets – The Health Policy for Europe.** Updated edition September 1991. European Health for All series, No. 4. World Health Organisation.
40. WHO (1995): **Concern for Europes Tomorrow.** WHO/Wissenschaftliche Verlagsgesellschaft mbH. ISBN 3-8047-1406-4.

The Swedish NGO Secretariat on Acid Rain

The Swedish NGO Secretariat on Acid Rain was formed in 1982 with a board now comprising one representative from each of the following organizations:

- Friends of the Earth Sweden
- The Swedish Anglers' National Association
- The Swedish Society for Nature Conservation
- The Swedish Youth Association for Environmental Studies and Conservation
- The World Wide Fund for Nature Sweden.

The essential aim of the secretariat is to promote awareness of the problems associated with air pollution, and thus, in part as a result of public pressure, to bring about the required reduction of the emissions of air pollutants. The eventual aim is to have those emissions brought down to levels – the so-called critical loads – that the environment can tolerate without suffering damage.

In furtherance of these aims, the secretariat operates as follows, by

☐ Keeping under observation political trends and scientific developments.

☐ Acting as an information centre, primarily for European environmentalist organizations, but also for the media, authorities, and researchers.

☐ Publishing a magazine, Acid News, which is issued five times a year and is distributed free of charge to some 5000 selected recipients.

☐ Producing and distributing information material.

☐ Supporting environmentalist bodies in other countries by various means, both financial and other, in their work towards common ends.

☐ Acting as coordinator of the international activities, including lobbying, of European environmentalist organizations, as for instance in connection with the meetings of the bodies responsible for international conventions, such as the United Nations Convention on Long Range Transboundary Air Pollution.

☐ Acting as an observer at the proceedings involving international agreements for reducing the emissions of greenhouse gases.

European Federation for Transport and Environment

The European Federation for Transport and Environment (T&E) is Europe's primary non-governmental organization campaigning on a Europe-wide level for an environmentally responsible approach to transport. The federation was founded in 1989 as a European umbrella for organizations working in this field. At present T&E has twenty-five member organizations in sixteen countries. The members ar mostly national organizations, including public transport user groups, environmental organizations and the European environmental transport associations ("Verkehrsclubs"). These organizations in all have several million individual members. Several transnational organizations are associated members.

T&E closely monitors developments in European transport policy and submits responses on all major papers and proposals from the European Commission. T&E frequently publishes reports on important issues in the field of transport and the environment, and also carries out research projects.

T&E member organizations are:

Aksjon Naermiljö og Traffikk (Norway)
Associació per la Promoció del Transport Públic (Spain)
Associación Ecologista de Defensa de la Naturaleza (Spain)
Associazione Utenti del Transporto Publico (Italy)
Cesky a Slovensk Dopravní Klub (Czech Republic)
Danmarks Naturfredningsforening (Denmark)
Environmental Transport Association (United Kingdom)
Fédération Nationale des Associations d'Usagers de Transports (France)
Groupement des Usagers ded Transports Intercommunaux Bruxellois (Belgium)
Komitee Milieu en Mobiliteit (Belgium)
Lega per l'Ambiente (Italy)
Liikennelitto (Finland)
Magyar Közlekedési Klub (Hungary)
Norges Naturvernforbund (Norway)
Stichting Natuur en Milieu (Netherlands)
Svenska Naturskyddsföreningen (Sweden)
Transport 2000 (United Kingdom)
Verkehrsclub Deutschland (Germany)
Verkehrsclub Österreich (Austria)
Verkehrsclub der Schweiz (Switzerland)
Wijs op Weg (Netherlands)

Associate members

Community of European Railways
European Cyclists' Federation
Union International de Transport Public
Worldwide Fund for Nature, EC office

The World Health Organization is currently engaged in revising its guidelines for air-quality standards. At the same time the European Union is working on an adjustment and extension of its mandatory limits for concentrations of air pollutants.

TO CLEAR THE AIR OVER EUROPE both surveys the present situation and puts forward proposals for revision of the system of guidelines and standards for air quality. Showing by innumerable examples the effects of air pollution particularly on health, it proposes a general tightening of air-quality standards in order to ameliorate the effects both on health and the environment.

TO CLEAR THE AIR OVER EUROPE has been produced by the Swedish NGO Secretariat on Acid Rain in collaboration with the European Federation for Transport and the Environment. The text has been researched and written by Magnus Nilsson, a journalist with a long career of reporting on environmental matters, including experience from Sveriges Radio and as a press secretary for the Swedish Society for Nature Conservation. He is now editor of Trafik & Miljö, a magazine devoted to traffic and environmental issues.

The Swedish
NGO Secretariat
on Acid Rain

European Federation for
Transport and Environment