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## AIR QUALITY GUIDELINES IN THE EUROPEAN REGION

Report on a third workshop

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This activity was organized jointly by the WHO Regional Office for Europe and the OECD Environment Directorate to promote work aimed at achieving the following target in the health for all strategy.<sup>a</sup>

## **TARGET 21**

### **AIR QUALITY**

*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.*

#### **Keywords**

AIR QUALITY  
AIR POLLUTION – prevent/control  
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<sup>a</sup> *Updating of the European HFA targets.* Copenhagen, WHO Regional Office Europe, 1991 (document EUR/RC41/Inf.Doc./1 Rev.1).

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## INTRODUCTION

Following publication of the WHO Air Quality Guidelines for Europe volume<sup>(1)</sup> in December 1987, follow-up meetings were arranged in several sectors of the European Region to consider the nature of the air pollution problems currently experienced, control measures employed, ways in which the Air Quality Guidelines could assist in the setting of standards or goals and requirements for any extensions of the guidelines work. A report based on the meetings held in Athens in December 1988 and in Warsaw in June 1989 was published in 1991,<sup>(2)</sup> and the present report links with it and covers the discussions in a further meeting in the series, held at the OECD premises (Château de la Muette) in Paris in July 1991. It was jointly organised by the WHO Regional Office for Europe in collaboration with the Environment Directorate of the Organisation for Economic Co-operation and Development (OECD) and with the support of the Commission of the European Communities. There were 26 participants from 12 western and northern European countries, drawn from both health and environmental departments, a delegate from Western Australia, a WHO panel of 8 experts previously involved in the Air Quality Guidelines project, and an OECD consultant from the US Environmental Protection Agency.

The meeting was entitled "Workshop on Air Quality Guidelines for Air Pollution Control Strategies in Western and Northern Europe" and discussions fell under four general headings:

- i. Air Quality Guidelines (AQG) and national air pollution control strategies: an assessment of how the AQG were being used in control policies, the need for further guidance and recommendations on the handling and presentation of monitoring data.
- ii. Air quality indicators: their definition, identification and potential use. Consideration of possible bases, including the use of a single pollutant as an indicator of a complex mixture, indices based on several pollutants and health, ecological or environmental outcome variables.
- iii. Priority hazardous pollutants for the year 2000: the question of how far pollutants covered by the AQG coincide with those considered to be important in the coming decade, and procedures for establishing priorities for other pollutants.
- iv. Revision of the AQG: to consider proposals for revision of any of the AQG material arising from discussions under the above headings.

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1. *Air Quality Guidelines for Europe, WHO Regional Office for Europe. Copenhagen, 1987 (European Series No 23).*
  2. *Air Quality Guidelines in the European Region. Report of two workshops, WHO Regional Office for Europe, Copenhagen, 1991 (EUR/ICP/CEH 079).*

During the course of the meeting detailed discussions on each of these topics were carried through by 4 sub-groups, with a fifth sub-group finally consolidating the material and preparing draft conclusions and recommendations for consideration and approval by the participants collectively.

## **2. AIR POLLUTION PROBLEMS AND CONTROL STRATEGIES IN INDIVIDUAL COUNTRIES**

### **General situation**

National delegates had provided written papers as listed in Annex 1, outlining the air pollution situation in their own country and strategies adopted or being considered for control. Points from each of the introductory presentations made by the authors are noted below, and it was clear that in all the countries currently represented a wide range of regulations and/or guidance on ambient air quality and the control of emissions already existed, some preceding and others following the publication of the AQG volume.

### **Australia**

Though outside the Region primarily concerned in the present meeting, an outline was given of the current situation in Australia. Responsibility for pollution control lies mainly with State agencies, but negotiations are in progress for the establishment of a national Environment Protection Authority. A comprehensive set of air quality standards has been established in the state of Victoria, leading to controls on emission sources, and these are used also by other States.

### **Belgium**

The basic air quality standards are those prescribed in EC Directives, covering SO<sub>2</sub>, suspended particulates, NO<sub>2</sub> and lead. For certain industries emission standards are laid down in their operating licences, and there are proposals to extend the range of pollutants covered on the lines of controls as in Germany. Much attention is given to the preparation of emission inventories, covering contributions from industrial, road traffic and space heating sources. There are several types of monitoring networks, some being automatic, and from the collated results comparisons are made with WHO guidelines as well as EC limit values.

### **Denmark**

National guidelines have been set up that include limit values for the emission of pollutants from industrial sources, based on Best Available Technology (BAT) and "immission concentration thresholds" defined as the individual plant's permitted contribution to the environmental concentration of a pollutant 1.5m above ground level. The levels are set so as to protect health and the environment, and the WHO AQG are among the data sources used, though some questions of consistency of approach across different pollutants have been raised. An extensive list of "air toxics" has been prepared, covering pollutants liable to be emitted into the air in Denmark, separating "high priority hazardous pollutants" for which BAT must always be used and "priority hazardous pollutants" for which BAT should be applied where costs are not excessive.

## **Finland**

Although Finland is a sparsely populated country remote from major industrial areas, with generally good air quality, pollution has been increasing overall to levels that exceed critical loads for sensitive ecosystems. There are also local problems related to traffic emissions or to malodorous gases emitted from pulp mills. An Air Pollution Act was introduced in 1982, the objectives of which are to protect human health, flora, fauna and the environment generally and to prevent economic losses or a decline in the quality of life due to deterioration in air quality. The Act provides for recommendations or regulations concerning air quality guidelines, maximum concentration or deposition levels, fuel and product specifications and maximum emission levels. Air quality guidelines were defined in 1984 for SO<sub>2</sub>, TSP, NO<sub>2</sub> and CO in terms of arithmetic mean values or upper percentiles, the values being generally consistent with the WHO AQG recommendations. More stringent long-term goals have also been set out, to protect forests and nature conservation areas. Monitoring networks have been established at background sites and in urban areas, about 40 of which now have continuous instruments. The data are used to assess compliance with guidelines and in decision making in relation to emission limits for new installations or traffic planning. The WHO AQG are valuable in developing further control strategies, particularly for non-regulated pollutants. There have been discussions also on the use of air quality indicators, to express total loads of air pollution, and the Ministry of the Environment is starting a re-assessment of air quality guidelines, considering such features as what averaging periods and statistical values are most appropriate, whether existing guidelines should be changed and new ones added.

## **France**

The rapid increase in the proportion of electricity generated by nuclear energy, and energy conservation measures have contributed to a substantial reduction in the emission of SO<sub>2</sub> and oxides of nitrogen from stationary sources. For industrial sources in general the most effective and economically feasible technology for abatement is required to be used, and there are emission limits for particulates and a range of specific hazardous pollutants. Requirements of EC Directives to control emissions from motor vehicles are followed, as are those for air quality standards. There is an Air Quality Agency that co-ordinates the research and development of the air quality monitoring that is carried out in local and national networks. In addition to routine measurements of the common urban air pollutants, studies on the concentrations of VOCs, PAHs and heavy metals have been carried out in several cities.

## **Germany**

In Germany the term "immission" is used in respect of air quality and immission standards provide the main basis for emission limits that are applied to industrial sources. Immission standards have been established for 13 pollutants, with different levels for health and for "disadvantage and nuisance". Extension or revision of these lists is considered by a Federal Government/Federal States Working Group. A need is seen to include carcinogenic substances, but this poses problems in establishing acceptable risks. Smog alert plans have been drawn up for some designated areas: these include short-term measures to reduce pollutant emissions in weather conditions leading to "winter smog". Procedures for advising

the population about "summer smog" episodes, with elevated concentrations of ozone, so that people at risk may limit their activities have also been established. Air quality monitoring is mainly the responsibility of the Federal States, and it includes automated networks for pollutants such as SO<sub>2</sub>, NO, NO<sub>2</sub>, CO, suspended particulates and O<sub>3</sub>.

### **Ireland**

Concern in relation to air pollution is centred mainly on Dublin, where for a number of reasons the use of bituminous coal for home-heating increased during the 1970s. Action was then needed to comply with the 1980 EC Directive on SO<sub>2</sub> and smoke, and an Air Pollution Act, similar to the UK Clean Air Act, was passed in 1987. This included provision for the establishment of smokeless zones, that would gradually extend over much of the city, and a requirement for licences for industrial plant, ensuring compliance with emission limits and the use of "best practicable means" to control emissions. Air pollution from motor vehicles creates unpleasant conditions in Dublin streets, but photochemical smog problems have not as yet been reported.

### **Italy**

There are a number of Acts regulating the emission of pollutants from industrial sources and in connection with these emission inventories have been prepared, mainly for sulphur oxides (SO<sub>x</sub>), nitrogen oxides (NO<sub>x</sub>), total suspended particulates, volatile organic compounds (VOCs) and carbon monoxide. These cover transport and various non-combustion sources as well as industrial emissions of all types. In the case of VOCs, a large proportion comes from evaporative rather than combustion sources. A substantial reduction in emissions of SO<sub>x</sub> was achieved during the 1980s, but there were increases for some of the other pollutants.

There is growing awareness of air pollution problems and increased resources are being devoted to the preparation of emission inventories, abatement measures, and the development of monitoring networks. To link with these activities, more attention is however needed on models for the dispersion and transformation of pollutants.

### **The Netherlands**

There is a two-pronged approach to air pollution control, one being source-oriented, leading to emission standards and the other effect-oriented, leading to air quality standards. A long-term strategy for environmental policy has also been developed, based on the principle of "sustainable development". This takes into account all aspects of effects of pollutant emissions on the environment, including climate change and acidification as well as health. One concern is with the temporary increase in concentrations of air pollutants during periods of poor dispersion or enhanced photochemical activity (winter and summer smog episodes). A provisional response system has been developed, with three progressively more serious smog phases, defining measures to take in each. There is also a framework for risk management within which a range of "priority substances" has been defined, for the establishment of environmental standards. Air quality monitoring is covered by a dense national network, including automatic observations of SO<sub>2</sub>, NO/NO<sub>2</sub>, O<sub>3</sub>, CO, suspended particulates, lead and fluorides.

## Norway

Outdoor air pollutants are controlled under the Pollution Control Act of 1981 and air quality guidelines have been established for carbon monoxide, nitrogen dioxide, ozone and photochemical oxidants, sulphur dioxide and suspended particulates, and fluorides. Reports relating to these, and to some further pollutants are currently being revised and consideration is being given to the type of guideline (an upper limit similar to WHO guidelines, a range, or a guideline that may be exceeded for a certain percentage of time) and to the averaging times appropriate to each pollutant. The guidelines are meant as recommendations and one application is in the determination of chimney heights, to keep ground level concentrations of emitted pollutants within specified limits.

Separate criteria documents have been prepared for indoor pollutants, covering CO, CO<sub>2</sub>, formaldehyde, NO<sub>2</sub>, particles in general, and specific particles (those from combustion sources, micro-organisms, mites, asbestos, synthetic mineral fibres), radon, tobacco smoke and volatile organic compounds. The guideline values proposed are intended to be incorporated in regulations that will apply to indoor areas accessible to the general public, including schools and kindergardens.

## Sweden

During the 1980s attention was given to the development of air quality standards. The WHO AQG work had an important influence on this, reaching similar conclusions for the principal pollutants, though in the case of NO<sub>2</sub> the WHO guideline was considered to be on the high side. Emission of pollutants from traffic has become the main problem in recent years, and in many streets the air quality standards set for CO (6mg/m<sup>3</sup> as 98 percentile of 8 hour averages for 6 months) and NO<sub>2</sub> (110µg/m<sup>3</sup> 98 percentile of 1 hour averages for 6 months) are exceeded. Risk assessments have been made for a range of hydrocarbons, yielding generally lower values than US estimates.

## Switzerland

As in a number of other countries, control strategy is based on the dual approach, source oriented (through emission standards) and effect-oriented (through air quality standards). Regarding emissions these are in general required to be limited as far as technically and economically feasible, and more stringently if there are harmful or nuisance effects. Emission standards have been set for a wide range of pollutants from stationary sources, modelled on the German "TA Luft" guidelines, and there are standards also for emissions from each type of motor vehicle. Air quality standards have been set taking health and environmental effects together and they are broadly consistent with the WHO AQG. The extent to which exceedances occur indicate needs for improved emissions control. This arises particularly for ozone, calling for reductions in the precursor VOC emissions, and there is an overall pollution control strategy setting goals for reductions in the national emissions of SO<sub>2</sub>, NO<sub>x</sub> and VOCs. There is a national monitoring network covering 16 representative sites, supplemented by further locally operated fixed and mobile stations. Pollutants measured on a continuous basis include SO<sub>2</sub>, NO, NO<sub>2</sub>, CO, O<sub>3</sub> and suspended particulates.

## United Kingdom

Strategy for the 1990s has been laid out in a recent government paper, "This Common Inheritance". Action on air quality is to be increasingly based on the definition of acceptable standards for the protection of health and the environment. Regulations implementing EC directives for smoke, sulphur dioxide, lead and nitrogen dioxide, and WHO guidelines for a wider range of pollutants have provided a basis to date, and an expert panel is to be established to advise on air quality standards generally. An adequate monitoring network is considered essential for implementation and an automated system is now in place for key pollutants, providing on-line data from which bulletins are prepared, classifying air quality in terms of "bands" for public information. There is a wide range of other monitoring activities, including large scale use of simple diffusion tubes to assess the spatial pattern of NO<sub>2</sub> concentrations over the whole country.

### 3. AIR QUALITY GUIDELINES AND THE DEVELOPMENT OF CONTROL STRATEGIES

#### The role of the AQG

The point made in the AQG volume that the guidelines were not in themselves standards was re-stressed. WHO had no regulatory role, and the setting of standards was a matter for consideration by national governments and/or other bodies such as the European Community. While the guidelines were health-based, since the WHO definition of health covered "wellbeing" in general, the impact of air pollution on ecology and the environment was also considered relevant. A further important point was that there should never be any tendency to build up towards guideline values in localities where the air was already clean.

There were large differences between countries in the range of pollutants considered and the types of approach used for control, but there was wide agreement on the stimulus that the AQG project had provided towards improved abatement measures and increased governmental and public awareness of the problems.

While it was noted that the AQG are applicable to indoor as well as outdoor air quality, the focus of control measures was seen to be on the latter. However, a need was recognised for more attention to be given to total exposure, through indoor and outdoor activities, when assessing impact on health. Also, it was noted that the form in which standards were expressed was driven partly by the ways in which monitoring data were available, and there was a need to look at the AQG more closely in relation to averaging times.

Concern remained about how best to handle carcinogens. Apart from a need to reconsider the basis of some of the risk estimates, for practical purposes guidelines were called for and opinions differed as to whether these could be inferred from the risk estimates merely by specifying some general "acceptable" level of risk. A further practical problem was that most of the AQG and national strategies concerned individual pollutants, whereas in general the air contained complex mixtures, and there was a need to consider combined effects. Further, effects of pollutants were liable to be inter-related with those of other factors, such as exposure to allergens and climatic extremes, and these needed to be taken into account in the development of measures to protect public health.

## **Emission controls**

In most countries there is a "source-oriented" (emission control) approach closely coupled with the "effect oriented" (air quality guideline) approach to air pollution control. Historically emissions of a wide range of pollutants from industrial sources have been limited as far as technically and economically feasible, and in more recent years the AQG have provided a valuable basis for determining, in conjunction with dispersion modelling, criteria for maximum emission rates. Scope was seen for providing further guidance on such procedures.

Emission controls were also prominent in dealing with pollution from motor vehicles, seen as the most widespread current problem, important for the direct impact of primary pollutants in streets and for its role in the formation of secondary photochemical and acidic pollutants, having transboundary as well as more local effects. While there was a high level of agreement among countries in W and NW Europe to introduce successively more stringent limits on emissions of the principal pollutants from new vehicles, a wider range of strategies needed to be considered to minimize the impact of road traffic in general on air quality. Options included checks on vehicles in use, improved traffic management, alternative fuels, promotion of public transport and basic town planning considerations.

## **Monitoring data**

The AQG had been developed in an exposure-oriented manner, expressing values in terms of exposure to given concentrations over periods ranging from 1 hour or less up to a year, depending on the nature of the effects considered and the exposures documented in original work. In the case of risk estimates for carcinogens, these related to average lifetime exposures. Monitoring data were not necessarily aggregated in analogous ways, the networks often being set up for other purposes, such as compliance with regulatory air quality standards, based sometimes on upper percentiles of the distribution of values rather than absolute limits. In the case of continuous instruments, and most readily in computer-linked networks, the data could in fact be aggregated in a great variety of ways, allowing cross-checks with AQG as well as other yardsticks. As the use of such systems spread, advantages were seen in providing standardised software to allow analysis in a form suitable for linking with the AQG. Observations based on discrete sampling needed to take into account the averaging periods over which relevant AQGs were expressed. However, as noted above, these latter averaging times were themselves often dictated by the available monitoring data, and there was a case for reconsidering the most appropriate time-spans over which effects may arise.

## **Presentation and interpretation of the AQG**

The varying nature and severity of the effects considered for each pollutant had not always been appreciated by authorities trying to apply the AQG to the development of control strategies, nor had the basis of protection factors been adequately understood. Although spelt out in the text, there had been a tendency to work direct from the tables of guidelines, without qualification. A further point was that the tables were related only to lowest observed effects, whereas for the development of control procedures, and particularly those related to episodes of high pollution there was a need also for links with the types of effects

expected at successively higher concentrations. The AQG volume had been widely studied not only by professionals, but also by public interest groups and to assist them further guidance on interpretation would be helpful.

### **Updating**

For a number of the pollutants in the AQG volume additional information from both experimental and epidemiological studies was reported, and a need was seen to update some sections in due course. A further point about the epidemiological work was that it could only deal with the actual mixtures that existed, at the time and place of the studies concerned. This mixture was changing with time, as controls were introduced, as fuels for such purposes as home heating changed, or as traffic sources became more important, and it was likely to differ substantially between countries or even between different localities in the same country. Concentrations of just one or two of the principal components were not necessarily an adequate guide to effects, and it was stressed that care was needed in extrapolating findings to dissimilar situations.

Public complaints about air pollution were often related to odour, often discernible when identifiable pollutants were below the guideline values for other effects, and in subsequent updating consideration might be given to guidance on the assessment of sensory effects.

## **4. DEFINITION, IDENTIFICATION AND USE OF AIR QUALITY INDICATORS**

### **Introduction**

Several attempts have been made in the past to produce general air pollution indicators or air quality indexes. These index values have included a mixture of different pollutants collectively examined and transformed into a normalized number to provide a measure of the total air pollution load. As general indicators of air quality they have not however been widely accepted. There remains a need to create a system to simplify the large amount of available data on air pollution for trend analyses and to compare air pollution levels between different cities, countries or regions. Several background papers on this topic, as listed in Annex 1, were presented and the principal points emerging in discussion were as noted below.

### **Parameters to consider**

One goal for establishing a set of indicators is to assess the air quality as measured or estimated in relation to effects such as impact on human health, flora, fauna and materials. Such a set of indicators or parameters should be used in a simplified scheme, which is understandable and can be applied in interpretation of monitoring programmes.

To define the criteria for the development of an appropriate system for air quality classification a variety of factors has to be taken into account such as:

1. Air pollution conditions, dependent upon emission source types, meteorological conditions, scale of the problem and season.

2. Data availability, measurement methods and available air pollution monitoring programmes.
3. Air pollution effects on human health, flora, fauna and building materials.

The air pollution load is a function of several different factors which also might influence the selection of relevant indicators. The type of air pollution source, meteorological and climatological conditions, topographical features, scales in space and time are some of these factors.

### **Emission source type**

The type of air pollutants, the release configuration and the environmental impact strongly varies dependent upon the type of sources in question. Natural sources, sources of agricultural activities, air pollution from industry and energy production and emissions from transport systems all represent different source types and they result in environmental impact and implications on different scales. For stationary sources the effective height of release, involving the stack height, emission velocity and buoyancy of the plume is important in determining dispersion characteristics. While concentrations of pollutants at ground level can be minimized through the use of tall stacks, there can then be long-range transport with possible environmental impacts at great distances from the source. Emissions from motor vehicles have different characteristics, being dispersed very close to the ground, within the breathing zone, and concentrations of the primary pollutants are then highest amidst the traffic, often declining sharply in moving away from the edge of the roadway.

### **Meteorological conditions**

Dispersion conditions vary with meteorological parameters such as wind direction, wind speed, turbulence, stability and mixing heights and also with surface conditions, surface inhomogeneities and topography. In some areas adverse meteorological conditions are important, as they will cause an increased impact of air pollution on health.

High pressure situations with elevated inversions due to subsidence and low wind conditions at the surface has been known for decades to produce air pollution episodes in Europe. Also calm conditions with surface based winter type inversions have been the reason for the exceedance of existing air quality standards in many cities.

### **Topographical features**

Topographical features might influence the meteorological and climatological conditions in a specific area and also influence the dispersion conditions to yield a high air pollution impact in certain areas.

### **Scale in space and time**

Air pollution levels and impacts vary considerably from microscale problems in street canyons to global air pollution problems. Typical scales described by different areas are given in Table I.

**Table 1 Air pollution scales, air pollution levels and typical effects**

Area	Size (km)	Typical concentrations ( $\mu\text{g}/\text{m}^3$ )	Typical effects of concern
Street	0,01	100- 1 000	Acute health effects
City blocks	0,1-1	20-500	Health, Discomfort
Local	1-10	10-100	Health, Materials,
Regional	~ 100	5-50	Acid precipitation, Vegetation
Continental	~ 1 000	1-10	Acid precip., Forest damage
Global	~ 10 000	< 1	Climatic change, Ozone depletion

*Source: Development of air quality indicators. Background document prepared by B Sivertsen, Norway*

### Season

Seasonal variations in climate and dispersion conditions together with variations in insolation, surface conditions and biota mean that different pollutants play different roles during summer and winter. The most interesting components, receptors, effects, and averaging time might vary from winter to summer, e.g.  $\text{SO}_2$  and aerosols give impacts to human health during several days of urban winter episodes, whereas high short term (one hour) ozone maxima during high pressure summer conditions might give rise to vegetation damage.

### Measurement equipment and methods

Classification of air quality through the use of air quality indicators (AQI) has to rely upon measured data. The quality of the AQI is dependent upon measurement equipment, the methods available and the siting of the instruments.

When selecting and using air quality indicators one has to ensure that:

- instruments are available for the specified pollutant
- the time resolution is adequate
- instrument locations are representative for the problem in question
- the equipment has been proved operative during all relevant conditions
- simplifications satisfy user qualifications and requirements
- analytical methods are calibrated and controlled
- quality assurance schemes are implemented.

### Air pollution monitoring programmes

Air pollution monitoring programmes are being conducted, at varying intensities, in most countries. These programmes include:

- surveillance of local industrial sources
- local community or urban air pollution monitoring
- national surveillance for urban and suburban areas
- national monitoring in remote background areas
- international programmes for urban and rural areas
- international programmes for regional and long range transport of air pollutants
- national and international programmes for global air pollution studies.

Some of these programmes are linked to air pollution transport and dispersion models where local, regional and global meteorological and climatological data, together with emission inventories, represent the input. The models can produce concentration distributions on different scales.

The air pollutants considered in each of these programmes have been selected dependent upon the problem that is being addressed.

#### **Urban, residential and industrial areas**

In the monitoring programmes conducted in cities, residential areas and in industrial areas, six air pollutants have been extensively studied. These pollutants are usually emitted in large quantities and they are known to cause health effects at commonly occurring levels. The pollutants are:

- Sulphur dioxide (SO<sub>2</sub>)
- Suspended particulate matter (SPM)
- Nitrogen dioxide (NO<sub>2</sub>)
- Carbon monoxide (CO)
- Lead (Pb)
- Ozone (O<sub>3</sub>)

The main source of these pollutants is fuel combustion by home heating, industry and vehicles. Several indicators have been used for particles in the air (SPM). The simplest one to measure has been black smoke or soot by reflectometric methods (OECD). At present

particulates are often measured gravimetrically using size-selective samplers, some having a cut-point at 10 micrometres ( $\mu\text{m}$ ) and others dividing the particles into two fractions (fine particles, less than  $2.5\mu\text{m}$ , and coarser ones above). There are also total suspended particulate (TSP) measurements, without specific size limitation.

In some cases, representativeness of sampling site locations is controlled by the use of source oriented dispersion models or source receptor models. The possibility of classifying the air pollution situation increases considerably by the additional use of models.

### **Rural and background areas**

In rural and background areas components, sampling times and frequencies as well as requirements for detection levels and accuracies are different from those in urban areas. Typical compounds investigated in background area programmes are:

Aerosols ( $\text{SO}_4^{2-}$ ,  $\text{NH}_4^+$ ,  $\text{NO}_3^-$ )

$\text{SO}_2$

SPM

Ozone

$\text{NO}_2$

Precipitation chemistry

Toxic metals

$\text{C}_2$ - $\text{C}_9$  hydrocarbons

Sampling methods and analytical methods might vary from one programme to another. The implementation of quality control routines and follow-up has shown a substantial variation in data quality.

### **Global air pollution**

The focus on global air pollution problems has increased during recent years. Examples of particular importance are:

- Global warming and greenhouse gases ( $\text{CO}_2$ ,  $\text{CH}_4$ , CFC, particles).
- Stratospheric ozone depletion (Ozone, column density, CFC,  $\text{N}_2\text{O}$ ).
- Long lived toxic micro pollutants (PCB, DDT, pesticides).

At the Norwegian global air pollution research station at Ny-Alesund ( $79^\circ\text{N}$ , 475 m above sea level) all these parameters are measured together with sulphur and nitrogen compounds in long range transported air masses.

The most important requirement for the selection of air quality indicators should be a consideration of potential effects of the various air pollutants on:

- health and the well-being of humans,
- flora and fauna,
- materials (building stock and monuments).

The time scale is again of great importance. Short-term acute toxicity, represented by very high concentrations over short periods of time, acts differently from long periods of exposure. Short-term high concentrations are often linked with accidental releases or weather conditions leading to air pollution episodes. Different pollutants have to be considered on different scales in time and space.

### **Assessment of effects**

#### **Human health**

Human exposure to air pollution usually concerns a mixture of different pollutants from different sources. It has thus been difficult to establish reliable dose/response relationships from actual field data. Interesting results have recently been presented from a study on health impact of traffic air pollution in Norway. From more than one thousand persons followed through diaries and questionnaires the statistical analyses indicated that various symptoms of health and well-being were correlated with exposures to traffic pollution equivalent to NO<sub>2</sub> levels even less than 200µg/m<sup>3</sup> as a one hour average. Headaches, coughing, eye irritations, throat problems and depression were some of the symptoms asked about.

The best available background material for evaluation of health impacts is the USEPA criteria documents and the air quality guidelines (AQG) for Europe. These AQGs are formulated to ensure that populations exposed to concentrations lower than the guideline values should not suffer harmful effects. In cases where the guideline for a pollutant is exceeded, the probability of harmful effects will increase.

There are also several national standards or proposed guidelines available related to human health impact. Some of these are also under revision.

#### **Flora and fauna**

The air quality guidelines should also have been extended to represent the potential impact on vegetation and animals.

Studies of plant damage and air pollution impact on plant growth have been performed for several individual air pollutants and for air pollution mixtures. In the discussion of specific indicators we will have to take into consideration recent scientific results on plant damage.

Also the consideration of critical loads should be taken into account. The critical load value

is defined as a quantitative estimate of the exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge.

The critical load for a given area depends strongly upon geology, vegetation and soil properties. It might thus be difficult to generalize. However, for acid deposition compounds and ozone a considerable step forward has been made during the last two years. A map for the exceedance of critical loads for the fresh water system in Southern Norway was presented in 1990.

The impact on animals is often linked to uptake, intake and food chain processes. Effects of specific toxic substances, especially some toxic heavy metals, long lived chlorinated compounds, organic compounds and fluorides might be of interest. None of these compounds has, however, been included in the list of AQI in this paper. For further evaluation some of them might be of importance.

### **Building materials**

The concern for our cultural heritage and for the general life-time of buildings and constructions has increased during the last few years. Considerations for this part of our environment and for the cost of restoration and rebuilding, should be built into the air quality levels when considering air pollution indicators.

As for human health the impact is usually a result of mixtures of components, including air pollution, climate, weather, wind, humidity, temperature, erosion, freezing, etc.

Dose response relationships have been established for a few specific air pollutants. For SO<sub>2</sub> these data have been used in cost/benefit analyses for sulphur-reduction measures linked to the use of fuel oil in Europe.

### **Definitions**

In order to avoid confusion on terminology, it is useful to provide definitions of important terms. The concentrations of a particular pollutant can be presented as an annual mean, one or more peak statistics or exceedances of a specific WHO guideline value. Such statistics can be used as ambient air quality indicators. If ambient air pollution data are not available, air pollution surrogate indicators such as emission inventories or economic activities related to emission, such as fuel consumption, energy production etc may replace them.

Combining multiple pollutants (or parameters) to generate a normalised number can result in an air quality index. The purpose of an air quality index is to take daily air pollution information for multiple pollutants with short-term air quality standards or WHO guidelines, etc and turn the data from these multiple pollutants into a single air quality index. Air quality indices have successfully been used in the United States, Canada, Mexico and other countries to report air pollution information to the general public. They provide a normalised number, such as 100 when a standard value is reached, a descriptor word such as "good", "moderate", "unhealthful", etc and cautionary language when appropriate for sensitive members of the population. Like air quality indicators, they can be used for presenting air

pollution trends. The principal disadvantage is that an air quality index can mask significant trends in component pollutants. For example, most indices in USA metropolitan areas are dominated by the pollutants Ozone and CO. When the index presents the trend in the maximum air quality index value or the number of days greater than 100, an increasing trend in NO<sub>2</sub> would go unnoticed.

### **Objectives and properties of air quality indicators**

The purpose of indicators is to collapse a very large number of measurements of air pollutant concentrations into a much smaller set of numbers that can be communicated to the public and to decision makers.

In particular, the use of air quality indicators covers the following major categories:

1. Release of information to the public, eg on a day-by-day basis including the warning of sensitive parts of the population under circumstances of episodes of high air pollution.
2. Guarantee the uniformity of recording of air pollution data to permit comparison between different locations.
3. Establishment of trends over longer periods of time to permit, eg the control of the success of abatement measures.

A large variety of air quality indicators can be proposed for different purposes and for application on different scales. The indicators to be selected have to be linked to measurement methods and to available and - if possible - future monitoring systems. This is of importance in the development of control programmes and for international harmonisation of monitoring and surveillance programmes.

### **Ambient air quality indicators for consideration**

The ambient air quality indicators that are proposed for consideration are based on the measured ambient air quality data and health effects. In general, as many as three types of indicators are proposed for each of the major pollutants. The indicators are based on guidelines, such as the WHO AQG and reflect:

1. an average air quality statistic (annual or seasonal mean, as appropriate);
2. a peak statistic (expressed as an upper percentile); and
3. an exceedance statistic (expressed as the number of exceedances of the relevant health related short-term WHO guideline).

With respect to the exceedance statistic an adjustment must be made for missing data. In the pollutant-specific summary of recommended air quality indicators which follows, it is assumed that the gaseous pollutants are sampled continuously, while some particulate sampling (PM<sub>10</sub>, TSP) is done intermittently, such as once every 6 days. Only those WHO

guidelines with an averaging time of one hour or greater for gaseous pollutants are recommended for indicator comparisons, because with the exception of CO, WHO guidelines principally deal with one-hour or greater averages.

**Table 2 Possible pollutant specific ambient air quality indicators**

<u>POLLUTANT</u>	<u>AMBIENT AIR QUALITY INDICATOR</u>
SO <sub>2</sub>	<ul style="list-style-type: none"> <li>- Annual mean statistic - this can be related to the WHO annual mean guideline</li> <li>- Peak statistic (99th percentile of one- and 24-hour average data)</li> <li>- Exceedance of WHO Guideline of 125µg/m<sup>3</sup>- 24-hour average and 350µg/m<sup>3</sup>- one hour average</li> </ul>
Black Smoke	<ul style="list-style-type: none"> <li>- Annual mean statistic or 99th percentile of 24-hour data.</li> <li>* This can be related to appropriate WHO annual mean guideline</li> </ul>
TSP PM <sub>10</sub>	<ul style="list-style-type: none"> <li>- Annual mean statistic</li> </ul> <p>NOTE: Because of the intermittent sampling that is normally done for these particulate parameters only one indicator should be used.</p>
CO	<ul style="list-style-type: none"> <li>- Peak statistics</li> <li>* 99th percentile of eight-hour averages</li> <li>* 99th percentile of one-hour averages (optional)</li> </ul> <p>(NOTE: Because the 8-hour average is more likely to be exceeded than the one-hour or half-hour average, it is of greater interest.)</p> <ul style="list-style-type: none"> <li>- Exceedance of WHO guidelines</li> <li>* Eight-hour guideline (10mg/m<sup>3</sup>)</li> <li>* One-hour guideline (30mg/m<sup>3</sup>) (Optional)</li> </ul>

POLLUTANT

AMBIENT AIR QUALITY INDICATOR

NO<sub>2</sub>

- Peak statistics
  - \* 99th percentile of one-hour averages
  - \* 99th percentile of 24-hour averages
- Exceedance of WHO Guidelines
  - \* One-hour guideline (400µg/m<sup>3</sup>)
  - \* 24-hour guideline (150µg/m<sup>3</sup>)
- annual mean statistic which can be compared to national standards (Optional)

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O<sub>3</sub>

- Peak statistics
  - \* 99th percentile of one-hour averages
  - \* 99th percentile of 8-hour averages
- Exceedance of WHO Guidelines
  - \* One-hour guideline (150-200µg/m<sup>3</sup>)
  - \* Eight-hour guideline (100-120µg/m<sup>3</sup>)
- mean seasonal statistic (April-September) for comparison to WHO guideline for growing season (Optional)

NOTE: While the WHO guideline suggests using the growing season for each country (which would vary according to latitude), a six month time period is recommended for this statistic to maintain a common basis for comparison.

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NMHC  
(non-methane  
hydrocarbons)

- Peak Statistics (Optional)
  - \* 99th percentile of hourly averages
- Seasonal mean statistic (June-August) (Optional)

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Trace Elements

- Annual mean statistic (Optional)
-

In using the recommended ambient air quality indicators given above, each should meet an annual data completeness criterion. In general, gaseous monitors are operated continuously, producing a measurement every hour for a possible total of 8760 hourly measurements a year or less in the case of ozone during a specified season. An annual data completeness criterion of collecting at least 50% of scheduled measurements is recommended for use. For a site to be included in a 10-year trend analysis, it might be desirable to require an historical data completeness criterion in at least 8 of the 10 years.

### **Air pollution surrogate indicators**

The term "air toxics" is being used for a very large number of chemical species, which are released from a large variety of sources and which have different effects. Sources may include mobile or diffuse sources and strong point sources. Some air toxics such as CFCs or methane involved in global warming have their effect at the global level. Others are long lasting compounds and can also have a cumulative effect on the natural environment. They can also accumulate in the human body and can be assessed by measuring their concentration in body fluids and tissues. Photochemical transformation in air can convert chemical species to more toxic forms that can be deposited and occur in areas at long distances from their sources.

Very few instances exist where air toxics are monitored in the environment on a consistent basis, with heavy metals measured from particulate samples as one exception. There may, in the future, be some monitoring of species that are widespread such as benzene.

#### **a. Global and regional effects**

For globally acting pollutants an important air pollution surrogate indicator can be the world production, or national contributions to total world releases, or per capita releases. Examples of this type of concern are:

<u>Effect</u>	<u>Environmental Indicator</u>
1. Climate Change	Net emission of greenhouse gases in carbon dioxide equivalents per capita.
2. Depletion of the stratospheric ozone layer	Emission of ozone depleting substances in ODP-units per capita (ODP = ozone depletion potential).
3. Acidification	Emission density for sulphur and nitrogen in tons/km <sup>2</sup> as an average for a certain area.
4. Eutrophication of soil (nitrogen saturation)	Emission density for nitrogen in tons/km <sup>2</sup> as an average for a certain area.
5. Eutrophication of coastal areas	As 4 and transport of nitrogen and phosphate in kg per capita from the drainage area to a coastal region.

- |    |   |   |
|----|---|---|
| 6. | Elevated concentrations of tropospheric ozone | Emission density of nitrogen oxides and reactive hydrocarbons in tons/km <sup>2</sup> as an average for a certain area. |
| 7. | Elevated metal concentrations                 | Emission density of mercury and cadmium in tons/km <sup>2</sup> and emission in kg per capita.                          |
| 8. | Residual persistent synthetic chemicals       | Use of chemicals per capita without guarantees for safe handling.   |

b. Local Effects

1. Many air toxics are released from point sources such as refineries, chemical manufacturing and waste disposal facilities. Indicators describing and assessing such exposures are derived from local measurements usually in combination with source strength assessment and dispersion modelling.

2. Carcinogenic Priority Pollutants: Air toxics that have carcinogenic potential usually receive special attention. It is possible in many cases to estimate carcinogenic impact in an exposed population based on toxicologic information by extrapolation from animal-derived unit risk factors to human populations.

Most common concerns of this type arise around point sources. Concentrations can be measured near the source or for proposed installations can be estimated from projected source strength dispersion models. It is possible, in the case of exposure to multiple carcinogens, to estimate the total risk to the surrounding population. These estimates have to be considered with some caution in view of the uncertainties in the risk assessments.

c. Time Series Trends

For priority pollutants of all kinds it is usually most important to establish and follow the time trend exposures based on whatever indicator is available for a given pollutant. Trends should preferably be based on concentration measurements in which case they can be related to NOEL, unit risk of cancer or other guideline values. If trends are based on regional or national estimates of releases such comparisons with guideline values cannot usually be made.

If concentrations for a Priority Pollutant are not available, trend assessments can be based on annual estimates of production, utilisation or emission related statistics.

d. At the current level of industrial capacity new chemicals can be inserted into and distributed across the environment very rapidly and in large quantities. Special attention should be devoted to the safety of such new products. Whenever an air toxic is substituted for by another species, careful consideration should be given to possible toxicity of the substituting species.

## 5. PRIORITY AIR POLLUTANTS

### Introduction

Prioritisation of hazardous air pollutants is of much importance to international agencies such as WHO and OECD in their coordination of activities designed to assist Member States in dealing with air pollution problems. Discussions of priority air pollutants aimed at serving two purposes:

1. To provide recommendations concerning prioritisation steps that may assist OECD and/or WHO in establishing databases on priority air pollutants and, in the long-term, to provide bases for future AQG evaluations.
2. To provide recommendations to WHO with regard to the short-term need to revise the 1987 Air Quality Guideline (AQG) for Europe, both in terms of updating the existing evaluations and extending the AQG coverage to additional pollutants.

### Prioritisation for database inclusion

Hazardous air pollutants posing risks for human health and the environment come from many diverse sources. As the pollution from hazardous air pollutants is most appropriately controlled at the primary source, the description of the substances in the initial stage case should be related to the sources. Although differences exist between Member countries in the priorities given to sources and substances, the overlap is anticipated to be significant. These areas of overlap form a basis for cooperation in data collection and assessment. A scheme should be developed or expanded to allow Member countries to submit information on sources and substances to OECD/WHO. One example of the needed type of scheme is shown in Table 3. Based on the national submissions, the lists of present and near-future hazardous air pollutants can then be developed and prioritized for inclusion in OECD and/or WHO databases. If a given substance is submitted from several sources and Member countries, it should be given a high priority for joint work in developing information to be entered into priority air pollutant databases and for possible consideration for AQG evaluation. Looking at industry as an example, several sub-categories exist. Detailed information should only be given for a few, for instance: rubber, plastic, electronics, glass, furniture and other types of industries. For the other industry categories the information should be given as a gross list.

Together with nominating particular substances, Member countries might also report on any existing air quality standards and emission standards, where they are available. Such information on available standards would be included in database entries for a given pollutant, along with concise summaries of key information on health and/or ecological effects, biokinetics and exposure aspects. It is expected that the numbers of air pollutants identified by this process for inclusion in OECD or WHO databases will be much larger than the ones selected for evaluation as part of updating and extending the WHO AQGs, for Europe.

Table 3

Matrix of typical emissions from industrial sources

Chapter Industrial Sources	2	3	4	5	6/7	8	9	10	10	11	12
Substance	Mineral	Coal	Oil	Power	Metal	Chemical	Forestry	Food	Animal	Other	Comb./waste
Particulates	X	X	X	X	X	X	X	X	X	X	
Sulfur oxides	X	X	X	X	X	X	X	X	X		
Nitrogen oxides	X	X	X	X	X	X	X	X	X		
Carbon monoxide	X	X	X	X	X	X		X			
Hydrocarbons	X	X	X	X		X	X	X	X	X	X
Chlorinated HCOs						X			X	X	
Ammonia compounds	X	X	X			X	X	X	X		X
Asbestos	X					X					
Chlorine	X			X	X	X	X			X	
Bromine						X					
Fluorides	X			X	X	X				X	
Hydrogen sulfide		X	X			X	X	X	X		X
Acetic acid								X	X		
Hydrochloric acid						X		X			
Hydrogen cyanide		X				X				X	
Nitric acid						X					
Phosphoric acid						X					
Sulfuric acid						X					
Aluminium					X						
Antimony	X										
Arsenic						X					
Beryllium											
Cadmium				X					X		
Chromium	X			X					X		
Copper	X										
Iron						X					
Lead	X		X	X	X				X		
Magnesium	X				X	X					
Manganese											
Mercury				X		X					
Molybdenum											
Nickel			X	X							
Selenium	X										
Silica	X				X					X	
Vanadium			X	X							
Zinc				X		X					
Organics		X	X			X	X	X	X	X	
Amines						X			X	X	X
Aldehydes			X	X		X	X		X	X	X
Carbon disulfide		X	X			X					
Mercaptans		X	X			X	X	X	X	X	X
Phthalic anhydride						X					
Toluene isocyanate						X					
Trichloroethylene						X			X	X	
Vinyl chloride						X				X	
Carbon black					X						
Phenols		X					X		X	X	
Odours		X	X			X	X	X	X	X	

Source: Suess M J, Grefen K and Reinisch D W, eds. *Ambient Air Pollutants from Industrial Sources. A reference handbook, Elsevier, Amsterdam, 1985.*

## **Prioritization for AQG evaluation**

It is recommended that selection of high priority air pollutants for AQG update evaluation or new developments should be based on several considerations. These include the evaluation of widespread potential exposure problems across various Member countries and should include, as well, consideration of potential for total human exposure to a given substance or class of substances in terms of both ambient (outdoor) and indoor air contributions. Various air pollution problem areas or issues require the assessment of particular air pollutants for entry into databases and for possible future AQG evaluations to assist Member states in dealing with such issues in the 1990s and beyond. Several important examples of such problem areas are noted below, along with identification of particularly key air pollutants or classes of pollutants associated with each that might be recommended for inclusion in priority air pollutant databases and/or for future AQG development efforts. Certain of the priority pollutants can be identified as being of known concern in connection with continuing air pollution problem areas, whereas others can be reasonably projected to be of increasing concern due to evolving new technologies or improved recognition of roles played in already identified problem areas.

### **Continuing traditional air pollutant problems**

Over the decade, up to the year 2000, substantial progress towards achieving AQGs is anticipated in many countries through implementing air pollution control policies. In Western Europe, this progress is likely to be substantial with respect to lead and other trace elements, carbon monoxide, hydrocarbons, oxides of nitrogen, sulphur oxides and suspended particulate matter. However, some pollutants can be expected to continue to pose problems in Western Europe which are likely to persist throughout the decade, and these include ozone and radon as two key examples.

Also, in the next decade ambient air pollution problems resulting from combustion of coal will still be continued in Central and Eastern Europe. Global energy production from coal is expected to increase by ca. 20% in 2000 as compared with 1985, and this increase will clearly continue in the 21st century. This problem is especially serious in Central and Eastern Europe where combustion of coal is the principal source of energy, and this situation is not likely to be changed in this decade. Rapid switching to the use of clean fuel may not be possible due to the poor economy. In this European region high concentrations of SO<sub>2</sub> and SPM will continue, as will CO and PAH concentrations. Therefore, new data on the health effects of these pollutants should be followed and periodically evaluated. Guideline values for acidic aerosols should also urgently be developed.

It is also expected that high emissions of toxic and carcinogenic metals will continue in this part of the region in the next decade due to the use of leaded gasoline and old techniques in the metallurgic industry. Among metals of much concern for possible further AQG evaluation and development are: lead, arsenic, mercury and cadmium.

Taking into account the above examples of continuing air pollution problems (and others not described), as well as new health effects or ecotoxic effects data for some substances, recommendations can be made for possible updating of AQG evaluations for various pollutants that were included in the 1987 AQG volume.

## Emerging problem areas

Besides the above examples of continuing problem areas, several emerging problem areas can be identified as posing increasingly more concern during the 1990s, raising the possible need for AQG evaluations for key air pollutants associated with each problem area.

### Novel and reformulated motor vehicle fuels

The identification of potential air quality impacts and associated risks of novel and reformulated motor vehicle fuels is a high priority for the 1990s. Motor vehicles and their fuels are all pervasive and make a major contribution to primary and secondary air quality. Although increasing numbers of vehicles are being equipped with exhaust and evaporative emission controls, a significant proportion of uncontrolled vehicles will still be in use in the year 2000. Novel and reformulated motor vehicle fuels offer some potential benefits of decreasing further the impacts on air quality of vehicles fitted with emission controls and dramatically reducing the impacts of uncontrolled vehicles.

Existing motor fuels are largely derived from crude oil and contain a mixture of alkanes, alkenes and aromatics. Reformulated gasolines would differ from existing motor fuels in their basic composition and probably contain significant quantities of novel components. There is a complete spectrum of possibilities between existing motor fuel and reformulated gasoline in which alcohols and ethers, for example, are employed initially as additives, then as blending components and finally as major constituents.

Motor vehicles and their fuels impact on air quality in several ways:

1. through evaporation and spillage from the entire distribution system which extends from the refinery through to the garage forecourt;
2. through exhausts and evaporative emissions from inservice vehicles;
3. through occupational exposure of parking attendants, fuel distribution workers, vehicle tunnel staff, toll booth staff, etc.

In addition, primary emitted pollutants may be converted into hazardous secondary pollutants by atmospheric transformation processes for which hazard assessments should be made.

To weigh the potential benefits of novel and reformulated motor vehicle fuels against existing fuels, a comparative risk assessment scheme is proposed in Table 4. A number of gaps in current understanding are immediately apparent and may set some priorities for investigation during the period up to the year 2000, as follows:

1. no AQG are available for alcohols, ethers and aldehydes (except formaldehyde, a known carcinogen), derived from new or novel gasolines or blending components;
2. no AQG are available for 1:3 butadiene derived from the alkenes present in existing motor fuel;

3. no AQG are available for the novel secondary air pollutants such as formate or acetate esters derived from the atmospheric degradation of new or novel gasolines or blending components.
4. updated AQG evaluations would be useful for manganese in view of proposed use of methylcyclopentadienyl manganese tricarbonyl (MMT) as a gasoline additive.

It is difficult to build up a picture of the air quality impacts of motor vehicles and their fuels based on single-component or substance studies alone. There is an important requirement to develop total vehicle exhaust studies of the health impacts of existing and novel motor vehicle fuels and, possibly, to develop AQGs for motor fuel mixtures that come to be identified as likely to gain serious consideration for introduction into widespread use.

**Table 4 Comparative Risk Assessment Scheme for Reformulated Gasoline and Existing Motor Vehicle Fuels**

Gasoline or Exhaust Component	Primary Health Risks			Secondary Health Risks from Ozone, PAH & HCHO			Comments
	Carc.	Tox.	Other	Carc.	Tox.	Other	
Alkanes				x	x		mainly butanes and pentanes from fuel evaporation
alkenes	x			x	x		alkenes decompose to 1:3 butadiene in engine system
aromatics	x	x	x	x	x		aromatics decompose to benzene in engine system
lead additives		x					
methanol	x			x	x		decomposes to formaldehyde
ethanol	x			x	x		decomposes to formaldehyde and acetaldehyde
t-butanol				x	x		
methyl t-butylether				x	x	?	oxidised to t-butylformate in the atmosphere
ethyl t-butylether				x	x	?	oxidised to t-butylacetate in the atmosphere
MMT		x			x		disfunction of catalyst systems

## **Respirable Particles and Fibres**

### Respirable Particles

There are some animal inhalation studies which indicate the induction of certain health effects correlated with size and structure of the surface of ultrafine particles (aerodynamic diameter  $< 1.2\mu\text{m}$ ) and not with substance-specific reactions. The existing abatement technologies are primarily developed to reduce the particle mass and are less effective in reducing the finest particle fraction. On the other hand, the emission of particles will be influenced by the physico-chemical processes involving automobile catalyst systems, the catalyst metals themselves or fuel additives used to modify combustion processes.

Various well-known toxic metals are emitted from numerous sources such as metal industries, fuel combustion from stationary and mobile sources, waste treatment and the use of products. Some of these materials can be emitted as fine and ultra-fine particles that might affect health directly or indirectly. The introduction of high-tech products like semiconductors, catalytic converters, aeronautic materials, memory alloys, etc will produce emissions of new substances, in particular, metals and metalloids that have not been fully assessed with respect to health and environmental impacts. These new substances may include beryllium, platinum, rhodium, selenium. Other high-tech materials and substances that need to be assessed might be semiconductor materials like gallium arsenide and other gallium compounds.

### **Respirable Fibres**

Fibres with diameters of less than 3 micrometers can penetrate deep into the human respiratory system constituting a potential threat to health. The asbestos group of naturally occurring hydrated mineral silicates has been shown to induce fibrosis, lung cancer and probably other kinds of intestinal cancer. However, it is not fully understood whether the health impact is due to the physical properties of the fibres or due to toxic compounds absorbed on the fibres. Respirable fibres are emitted by various industrial processes, the use of substances and materials, and by the transport sector. Of further concern is the fact that due to long atmospheric residence time, toxic fibres may be transported over long distances and may have a large scale impact.

Recent concern has been expressed with respect to the use of new substances and materials including stone- and glass-wool fibres for insulation purposes. It is believed that these inorganic fibres may have similar health impact properties as asbestos fibres. Other inorganic fibres, eg occurring from the use of ceramics, are to be assessed with respect to environmental and health effects. Assessment is needed of pollution and health impacts due to exposure to organic fibres from the production, handling and use of polymers and other carbon-composite materials.

### **Global climate change**

Global climate change, due to global warming processes and to stratospheric ozone depletion, is expected to continue as a very major international issue of importance to European and other countries in the 1990s and well beyond. This means that the vast array of effects

projected as likely to be associated with global warming will continue to demand extensive research and policy attention and, accordingly, there may exist some utility for AQG evaluation of radiatively important greenhouse gases, eg carbon dioxide (CO<sub>2</sub>) or methane (CH<sub>4</sub>), unless other adequate evaluative mechanisms (eg IPCC assessment efforts) exist. There will also exist a continuing need to evaluate the climatic, ecological and human health impacts of ozone-depleting substances currently in widespread use (eg CFCs used as refrigerants or halons used for fire extinguishers/fire retardation systems). There is also a growing need to evaluate, for comparative risk purposes, analogous types of impacts of substances (eg HFCs or HCFCs) contemplated to be introduced as substitutes for CFCs or other currently-used ozone-depleting compounds. For both categories, ie ozone-depleting agents in current use and possible substitutes, AQG derivations (or recommendations concerning emissions limitations) would be useful to assist OECD and WHO Member countries, as well as others, in dealing with this important issue. The evaluation should not only focus on assessment of comparative potency of the subject pollutants regarding their stratospheric ozone-depleting characteristics, and consequent impacts on UV-B penetration and effects on climate, but also on formation and concentrations of "conventional" air pollutants (eg tropospheric ozone, acidic aerosols, etc), and their effects on agriculture and natural aquatic and terrestrial ecosystems, and human health. The evaluation and derivation of guidelines should also consider:

1. human health and ecotoxic effects of direct exposures to the CFCs, other ozone-depleting agents, or proposed substitutes;
2. potential contributions to global warming processes and trends of CFCs or proposed substitutes; and,
3. overall consequent social/economic impacts.

### Indoor air

Chemical substances occurring in ambient air may also in many cases play a decisive role in the quality of indoor air. Consequently, particular attention should be paid to those chemical substances which in ambient air prove to be hazardous to health and which may enter inside, eg through ventilation. Some of these chemicals may have their origin in traffic, heating and industrial processes as well as in construction materials, furniture and other interior materials.

In assessing possible health hazards caused by chemicals to man, reliable and economically feasible methods for analysing and indexing the concentrations of volatile organic chemicals (VOCs) in indoor air are needed. So far, those methods that have tried to do this have not proved to be adequately developed and standardized. Methods for indexing and assessing VOCs should be further elaborated and efforts made not only to update existing AQGs for certain individual VOCs, but also for total VOC exposures, if possible. With regard to issues concerning indexing of total VOCs, consideration should be given to the use of indicator VOCs that represent a criterion fraction of a total monitored VOC mixture as surrogates for the entire mixture. Also, consideration should be given to AQG evaluation of total VOCs (especially as an indoor air pollutant issue), in view of published reports of total VOC mixtures being effective in inducing neurobehavioural effects due to exposures to

mixes of multiple VOCs at subthreshold concentrations for individual compounds.

Biological pollutants, such as mites, fungi and other microorganisms are also important indoor air contaminants that should be considered for AQG development. In addition, in view of their long-term adverse health effects, continuing contributions to total human exposure problems and the widespread nature of exposures, AQG updates are recommended in particular for such indoor air pollutants as: asbestos, radon and environmental tobacco smoke (ETS).

## 6. REVISION OF THE AIR QUALITY GUIDELINES

Continuing concern is to be anticipated throughout the 1990s in many European countries in respect of pollutants already covered in the AQG. The evaluations that form the basis of the present guidelines were, however, carried out five or more years ago, and since new data are likely to have become available since then, revisions are considered necessary. Suggested priorities for this updating are shown in Table 5.

The odour of various substances is of serious concern in relation to the well-being of many people. Although the subject of odour annoyance is dealt with in the present AQG, it deserves a more extensive and systematic treatment in future evaluations. In the evaluation of the potential health effects from nitrogen oxides no attention has been given to nitric oxide. Particularly in urban areas nitric oxide is emitted in large amounts by traffic. In any revision of the guideline for  $\text{NO}_2$  the physiological role and possible health effects of NO should also be considered.

**Table 5 Suggested priorities for updating existing AQG evaluations for hazardous air pollutants based on the widespread nature of expected exposure over the next decade and/or availability of important new health or ecotoxic effects data**

No.	Substance	Priority	Comments
1.	Cadmium	medium	widespread
2.	Carbon disulfide	low	-
3.	Carbon monoxide	high	widespread, new info
4.	1,2-Dichloroethane	low	-
5.	Dichloromethane	low	-
6.	Formaldehyde	high	widespread, new info
7.	Hydrogen sulfide	low	-
8.	Lead	high	widespread, new info
9.	Manganese	high	widespread, new info
10.	Mercury	high	widespread, new info
11.	NO <sub>2</sub>	high	widespread, new info
12.	Ozone	high	widespread, new info
13.	Styrene	medium	widespread
14.	SO <sub>2</sub>	medium	widespread
15.	Particulate matter	high	widespread, new info
16.	Tetrachloroethylene	high	widespread, new info
17.	Toluene	low	-
18.	Trichloroethylene	high	widespread, new info
19.	Vanadium	low	-
20.	Acrylonitrile	low	-
21.	Arsenic	high	widespread, new info
22.	Benzene	high	widespread, new info
23.	Chromium (VI)	medium	widespread
24.	Nickel	medium	local, new info
25.	PAH	high	widespread, new info
26.	Vinyl chloride	low	-
27.	Radon	medium	widespread (indoor)
28.	Asbestos	high	widespread, new info

In addition it is recognised that a number of substances or groups of substances for which AQG are not yet available should be addressed when updating the guidelines. Suggestions for inclusion are:

- Acetaldehyde
- Acid aerosols
- Alcohols (methyl, ethyl)
- Biocontaminants (indoor)
- 1,3-Butadiene
- Dioxins
- Environmental Tobacco Smoke (ETS)
- Ethers (MTBE, ETBE)
- Fluorides
- Man-made inorganic and organic fibres
- Metals (platinum, rhodium)
- PCBs
- Substances of global importance (CFCs, HFCs, CO<sub>2</sub>, CH<sub>4</sub>)
- Total volatile organic compounds (VOCs - indoor)

## 7. CONCLUSIONS AND RECOMMENDATIONS

### Conclusions

1. The AQG have provided a valuable, uniform basis for governments in extending or modifying national standards and guidelines and in the development of strategies for the control of air pollution, contributing to maintaining and improving the health of their populations.
2. The AQG have led to greatly increased public and government concern over both common urban air pollutants and less widely distributed ones from specific industrial sources. The importance of this stimulus can be measured in terms of action taken to reduce levels of air pollution.
3. Many factors determine which air pollution control strategies are appropriate and feasible in any one country or locality. If standards are to be based on the AQG, there is in any case a need to consider them in relation to the statistical distribution of monitoring values.
4. The AQG cover health and to some extent also ecological effects. Control strategies may need to take account of either or both sets of criteria, depending on the circumstances in individual countries or localities.
5. Problems continue to be encountered in evaluating risks from exposure to carcinogens. In the light of recent developments in the understanding of carcinogenesis, the possibility of putting forward guideline values rather than risk estimates requires further consideration.
6. The AQG have been used as a data source together with dispersion modelling in determining criteria for emissions from single sources. There have also been applications in urban planning when considering the impact of multiple sources, including domestic, industrial and traffic emissions. In some regions, attention still needs to be paid to strategies for controlling single sources but, generally, the most widespread remaining problem relates to controlling emissions from traffic.
7. The AQG are expressed in terms of averaging periods that are effect-based, but monitoring data are constrained by measurement procedures and needs for other purposes. Efforts are needed to reconcile these different aspects, if possible, to avoid misinterpretation.
8. To improve the effectiveness of strategies to protect the health of the public, further guidance is needed on ways of determining the exposure of population groups to prevailing levels of air pollution.
9. New, important data, generated on health effects (eg carcinogenicity, mutagenicity, immunotoxicity, reproductive toxicity, neurotoxicity) requires the reconsideration of existing AQG values. Depending on the type of health effect, different approaches may be required for assessing the inherent risks.

10. The risk evaluations forming the basis for the present AQG were performed five years ago, and several considerations now point to the need for updating and extending the AQG volume. One consideration relates to new findings on health and ecotoxic effects that may substantially alter the bases and values for some AQG pollutants.

11. Evaluation of traditional types of air pollution problem and/or emerging air pollution issues of widespread concern to many European countries requires considering adding other air pollutants to the AQG.

12. A need exists for improved and expanded mechanisms by which OECD countries and WHO Member States can gain access to and share information on the health and ecological effects of high priority air pollutants, as well as pertinent associated emissions, ambient air, and population exposure data and trends.

13. In addition to the major pollutants such as suspended particulate matter, SO<sub>2</sub>, CO, NO<sub>2</sub> and O<sub>3</sub>, ambient air pollution measurements are also needed for other pollutants (such as compounds responsible for global warming) to describe the state of the atmospheric environment.

14. Air quality indices are useful for presenting air pollution trends and for public reporting. Their principal disadvantage is that they may conceal significant trends in component pollutants.

15. If direct measures are not available, air pollution surrogate indicators such as data from emission inventories or production figures can be used to describe the condition of the environment.

### **Recommendations**

1. All efforts should be made to reduce emissions of pollutants, whether or not existing air quality guidelines are met, and the need to protect uncontaminated areas should be emphasised.

2. Full use should be made of experience of abatement measures already successfully applied elsewhere in combating problems remaining in certain heavily polluted localities of the European Region.

3. The dialogue established during the course of the AQG project and the follow-up workshops between those involved in the health and environment fields should be maintained, with cooperation between WHO and OECD continuing in both of these areas.

4. Based on examination of newly available information, a selection should be made of substances or groups of substances for early addition to and revision of the AQG. More specifically, a working group of experts should be convened as soon as feasible to consider pertinent information such as new health or ecotoxicity data, to determine the list of pollutants of specific concern, and to prepare a plan for developing guidelines for the selected pollutants.

5. Appropriate international organisations such as WHO and OECD, with the help and contribution of the countries, should further promote and facilitate the exchange of air pollution information of widespread interest to European countries. In particular, efforts should be made (a) to expand or develop databases that include information on health and ecotoxic effects of air pollution, and on sources and emissions, (b) to widen distribution to existing and potential users, and (c) to facilitate access to such databases, taking into account any legal strictures.
6. WHO should give high priority to providing the necessary resources to support the continuous assessment of information relevant to the AQG and the establishment of an adequately funded formal review process.
7. More emphasis should be placed on the introductory remarks in the AQG volume, stressing that the guidelines do not automatically transcribe into regulatory standards.
8. A revised AQG volume should contain a new chapter concerned with assessment of cancer risks in exposed population groups.
9. Information on air quality should be linked to other relevant factors producing adverse effects on health, including pollen concentration and climatic extremes.
10. Strategies for air pollution control continue to be based largely on information relating to single pollutants, but mixtures are often more critical and the AQG should provide guidance.
11. Information on total exposure to pollutants or health effects, whether from differing indoor and outdoor exposures or from contributions from different media, should be brought together to assist in overall strategies to protect health.
12. The AQG should provide more elaborate guidance on the assessment of sensory effects of odorous substances.
13. It is important that in specifying AQG values for revised and additional pollutants, there should be clear statements on the nature of effects being considered and the magnitude of the protection factors applied.
14. Uniform ambient air quality indicators should be used to describe air pollution trends and comparisons of levels between cities, countries or regions, so as to judge the effectiveness of programmes and to assist in formulating policies, enforcing environmental standards, and guiding the conduct of scientific research.
15. Pollutant-specific air quality indicators, using mean and peak value statistics, should be developed to allow, if possible, comparisons with the AQG serving as reference values.
16. Air quality indicators and indices should be considered for future use for both public reporting and trend comparisons. An additional working group should be convened to examine the possibilities of creating such indicators and indices.

17. In any future revisions or extensions of the AQG, every effort should be made to include advice in a form suitable for adaptation in regulatory measures to serve and accommodate the needs of national executives. These people identify themselves as users of the AQG, and their perception of air pollution problems often differs from that of national experts concerned primarily with exposure characterization or health effects assessment.

Annex 1 COUNTRY REPORTS AND DISCUSSION PAPERS

Country reports

1. *Australia*

Air quality standards and guidelines in Australia. P J Browne-Cooper.

2. *Belgium*

Approaches taken to reduce air pollution in Belgium. Kabinet van de Staatssecretaris voor Leefmilieu en Maatschappelijke Emancipatie.

3. *Denmark*

Working document on Danish experience with Air Quality Guidelines. National Agency of Environmental Protection.

4. *Finland*

Short resumé from Finland, Eija Lumme and Air Quality Management in Finland, 1989.

5. *France*

Approaches taken to reduce hazardous air pollutants in France. Paper to OECD Air Management Policy Group, 1991.

6. *Germany*

Discussion and background paper for the Workshop on Air Quality Guidelines. Umweltbundesamt (Federal Environmental Agency, Germany).

7. *Ireland*

Paper to Workshop on Air Quality Guidelines. B O'Donnell.

8. *Italy*

Air pollution in Italy. M Cirillo.

9. *Netherlands*

Air pollution control policy in The Netherlands. M E van Os-Hendrikse.

10. *Norway*  
Report on Norwegian activities related to Air Quality Guidelines. E Dybing, P E Schwarze.
11. *Sweden*  
Air quality standards and environmental problems in urban areas in Sweden. C-E Boström.
12. *Switzerland*  
Air pollution control in Switzerland. H U Wanner, B Achermann.
13. *United Kingdom*  
Air Quality Guidelines and air pollution control in the United Kingdom. R G Derwent.

#### Discussion papers

1. The Environmental Index - a basic concept for assessing environmental quality. G Persson.
2. Examination of alternative air quality indicators. W F Hunt.
3. Development of air quality indicators. B Sivertsen, Norwegian Institute for Air Research (NILU).
4. Priority hazardous air pollutants in some OECD countries. OECD Environment Directorate Secretariat.
5. The need for revision of and additions to the WHO book on Air Quality Guidelines for Europe. K R Krijgsheld.

#### Background documents

1. Air Quality Guidelines in the European Region Report of two workshops, WHO Regional Office for Europe, Copenhagen, 1991 (EUR/ICP/CEH 079).
2. Impact on Human Health of Air Pollution in Europe. WHO Regional Office for Europe, Copenhagen, 1991 (EUR/ICP/CEH 097).

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