

GUIDELINES FOR AIR QUALITY

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Note to the user:

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Foreword

Achievements in air quality management underlie increased economic and social welfare in many developing countries. Sound air quality management is also a proven way of enhancing public health, since air pollution is associated with increases in outpatient visits due to respiratory and cardiovascular diseases, in hospital admissions and in daily mortality. Recent estimates of the increase in daily mortality show that on a global scale 4-8% of premature deaths are due to exposure to particulate matter in the ambient and indoor environment. Moreover, around 20-30% of all respiratory diseases appear to be caused by ambient and indoor air pollution, with emphasis on the latter. It is suggested that without clean air, a sound economic development becomes virtually impossible and social conflicts inevitable.

Although enormous progress has been made in developing clean air implementation plans for urban areas, especially in developed countries, a substantial number of people living in urban areas - around 1.5 billion, or 25 per cent of the global population - are still exposed to enhanced concentrations of gaseous and particle compounds in the air they breathe. And the use of open fires for indoor cooking and heating currently exposes about 2 billion people to quite substantial concentrations of suspended particulate matter, 10-20 times higher than ambient concentrations according to the limited measurements available.

Other sources of air pollution include industrial and vehicular emissions, as well as vegetation fires. Furthermore, the rate of population growth continues to increase and is likely to peak around the year 2000, leading to a doubling of the global population by the middle of the 21st century. Most population growth will occur in low-income countries and will stress already inadequate infrastructures and technical and financial capacities. In parallel, the process of urbanisation will continue, such that the proportion of the global population living in cities will increase from around 45% to around 62% by the year 2025, creating dense centres of anthropogenic emissions.

The primary aim of the WHO *Guidelines for Air Quality* is to protect public health from the effects of air pollution, and to eliminate or minimize exposure to hazardous pollutants. Air quality guidelines are set up to help governments derive legally enforceable air quality standards, and to guide the environmental health authorities and professionals who are trying to protect people from the harmful effects of environmental air pollution.

Agenda 21 states in Chapter 6 on human health and environmental pollution:

Nationally determined action programmes in this area, with international assistance, support and coordination where necessary, should include:

(a) *Urban air pollution:*

(i) *Develop appropriate pollution control technology on the basis of risk assessment and epidemiological research for the introduction of environmentally sound production processes and suitable safe mass transport.*

(ii) *Develop air pollution control capacities in large cities, emphasizing enforcement programmes and using monitoring networks, as appropriate.*

(b) *Indoor air pollution:*

- (i) *Support research and develop programmes for applying prevention and control methods to reducing indoor air pollution, including the provision of economic incentives for the installation of appropriate technology.*

- (ii) *Develop and implement health education campaigns, particularly in developing countries, to reduce the health impact of domestic use of biomass and coal.*

The WHO *Guidelines for Air Quality* should help to greatly reduce the burden of excess mortality and preventable disability suffered by the poor. It should also help counter potential health threats resulting from economic crises, unhealthy environments and risky behaviour. In this sense, the *Guidelines* contribute to meeting two of the key challenges that were highlighted in the 1999 World Health Report and, thus, they contribute to making health a fundamental human right.

Dr Richard Helmer
Director, Department for Protection of the Environment

Preface

The risks posed to human health by air pollution have been evaluated since the 1950s and guideline values were derived in 1958. In 1987, the WHO Regional Office for Europe EURO published the *Air Quality Guidelines for Europe*. Since 1993, these guidelines have been revised and updated. In a recent Expert Task Force Meeting convened in December 1997 in Geneva, Switzerland, the Guidelines for Air Quality was extended to provide global coverage and applicability, and the issues of air quality assessment and control were addressed in more detail. The WHO *Guidelines for Air Quality* document is the outcome of the consensus deliberations of the WHO Expert Task Force.

The WHO *Guidelines for Air Quality* provides a basis for protecting public health from the adverse effects of environmental pollutants and for eliminating, or reducing to a minimum, contaminants that are known or likely hazards to human health and well-being. The *Guidelines* does so by providing background information and guidance to governments for making risk management decisions, particularly in setting standards. It also helps governments carry out local air quality control measures.

The WHO *Guidelines for Air Quality* values are levels of air pollution below which lifetime exposure, or exposure for a given averaging time, does not constitute a significant health risk. If these limits are exceeded in the short-term it does not mean that adverse effects automatically occur; however the risk of such effects increases. Although the *Guidelines for Air Quality* values are health- or environment-based levels, they are not standards *per se*. Air quality standards are air quality guidelines promulgated by governments, for which additional factors may be considered. For example, the prevailing exposure levels, the natural background contamination, environmental conditions such as temperature, humidity and altitude, and socio-economic factors.

When proceeding from the *Guidelines for Air Quality* to standards, policy options include such questions as what proportion of the general population, and which susceptible groups, should be protected. Several additional items must also be considered: the legal aspects; a definition of what constitutes adverse effects; a description of the population at risk; the exposure-response relationship; the characterisation of exposure; an assessment of risks and their acceptability; and the financial costs of air pollution controls and their benefits.

The *Air Quality Guideline* has been prepared as a practical response to the need for action with respect to air pollution at the local level, and for improved legislation, management and guidance at the national and regional levels. WHO will be pleased to see that these *Guidelines* are used widely. Continuing efforts will be made to improve its content and structure. It would be appreciated if users of the *Guidelines* would provide feedback and their own experiences. Please send your comments and suggestions on the WHO *Guidelines for Air Quality – Guideline document* directly to the Department of Protection of the Human Environment, Occupational and Environmental Health, World Health Organization, Geneva, Switzerland (Fax: +41 22-791 4123, e-mail: schwelad@who.int).

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Executive Summary

Introduction

Air pollution is a major environmental health problem, affecting developed and developing countries around the world. Increasing amounts of potentially harmful gases and particles are being emitted into the atmosphere on a global scale, resulting in damage to human health and the environment. It is damaging the resources needed for the long-term sustainable development of the planet.

There are three broad sources of air pollution from human activities: Stationary sources, Mobile sources, and Indoor sources. In developing countries, indoor air pollution from using open fires for cooking and heating may be a serious problem. It has been estimated that about 1.9 million people die annually due to exposure to high concentrations of suspended particulate matter in the indoor air environment, while the excess mortality due to suspended particulate matter and sulphur dioxide in the ambient air amounts to about 500 000 people annually. Although the indoor air database is weak due to the scarcity of monitoring results, these estimates indicate that a serious indoor air problem may exist in developing countries.

Air pollutants are usually classified into suspended particulate matter (dusts, fumes, mists, smokes), gaseous pollutants (gases and vapours) and odours. Current techniques used to measure the mass concentration of particles in air make use of size-specific sampling devices. Thus the mass of particles less than 10 μm diameter may be determined (PM_{10}) as an index of the mass concentration of particles that can penetrate into the human thorax. The mass concentration of particles of less than 2.5 μm diameter ($\text{PM}_{2.5}$) is a means of measuring the total gravimetric concentration of several chemically distinct classes of particles that are emitted into, or formed within, the ambient air as very small particles.

Fine and coarse particles generally have distinct sources and formation mechanisms, although there may be some overlap. Biological material such as bacteria, pollen and spores may also be found in the coarse mode. Fine and coarse particles typically exhibit different behaviour in the atmosphere and these differences must be taken into consideration when interpreting central-site monitored values, as well as the behaviour of particles after they penetrate homes and buildings, where people spend most of their time. Fine accumulation-mode particles typically have longer atmospheric lifetimes (days to weeks) than coarse particles, and tend to be more uniformly dispersed across an urban area or large geographic region. Larger particles generally deposit more rapidly than small particles; as a result, total coarse particle mass is less uniform in concentration across a region than that of fine particles.

This publication is focused on those gases and particulate matter that have been accepted as posing a threat to health. The relative health threat of different pollutant gases and particles varies with their concentrations over time and distance, implying that the effects of air pollutants on health may vary from country-to-country. Consequently, careful monitoring of the concentrations of polluting gases, as well as of the particle size distribution, concentration and composition, is needed before an acceptable estimate of the effects can be produced. The picture is further complicated because some pollutant combinations act in an additive manner and some perhaps synergistically.

WHO's air quality guidelines were first published as *Air Quality Guidelines for Europe* in 1987 (WHO 1987). Since 1993 the *Air Quality Guidelines for Europe* has been revised and updated, incorporating a review of the literature published since 1987 (WHO 1999a). Also, the following additional compounds were considered in the review procedure: 1,3 butadiene, environmental tobacco smoke (ETS), fluoride, man-made vitreous fibres and platinum. Parallel to the review of the air quality guidelines for Europe, the Environmental Health Criteria series of the International Programme on Chemical Safety has

continued and the health risks of more than 120 chemical compound and mixtures were assessed between 1987 and 1998.

The WHO *Air Quality Guidelines for Europe* (WHO 1987) were based on evidence from the epidemiological and toxicological literature published in Europe and North America. They did not consider the effects of exposure to the different ambient air particle concentrations in developing countries, as well as the different conditions in these countries. However, these guidelines were used intensively throughout the world. In view of the different conditions in developing countries, the literal application of the WHO *Air Quality Guidelines for Europe* could be misleading. Factors such as high and low temperature, humidity, altitude, background concentrations and nutritional status could influence the health outcomes after the population has been exposed to air pollution. To make the WHO *Air Quality Guidelines for Europe* globally applicable, a task force group meeting was convened at WHO Headquarters from 2-5 December 1997. The outcome of that meeting is this publication of globally applicable air quality guidelines.

The objective of WHO's *Guidelines For Air Quality* is to help countries derive their own national air quality standards. The guidelines are technologically feasible and consider socio-economic and cultural constraints. They provide a basis for protecting public health from the adverse effects of air pollution and for eliminating, or reducing to a minimum, those air pollutants that are likely hazardous to human health. Consequently, the instruments of air quality management are also addressed in this publication.

2. Factors affecting the concentrations of air pollutants

Local concentrations of air pollutants depend upon the strength of their sources and the efficiency of their dispersion. Day to day variations in concentrations are more affected by meteorological conditions than by changes in source strengths. Wind is of key importance in dispersing air pollutants and for ground level sources pollutant concentrations are inversely related to wind speed. Turbulence is also important: a "rough" terrain, as produced for example by buildings, tends to lead to increased turbulence and better dispersion of pollutants.

3. Exposure to air pollutants

The total daily exposure of an individual to air pollution is the sum of the separate contacts to air pollution experienced by that individual as he/she passes through a series of environments (also called micro-environments) during the course of the day (e.g. at home, while commuting, in the streets, etc.). Exposures in each of these environments can be estimated as the product of the concentration of the pollutant in question and the time spent in the environment..

There are many factors that can account for the substantial differences between the concentrations of pollutants measured at central sites and those in the breathing zone of residents of the community. Many of these factors can be modelled and such models have been used for estimating dose distributions associated with ambient air concentrations.

4. Health significance of air pollution

A new database of epidemiological studies emerged in the late 1980s and 1990s. This database of time-series studies was developed first in the United States and later in Europe and other areas. In essence the time series approach takes the day as the unit of analysis and relates the daily occurrence of events such as deaths or admissions to hospital to daily average concentrations of pollutants whilst taking careful account of confounding factors such as season, temperature and day of the week. Powerful statistical techniques have been applied and coefficients have been produced that relate the daily average concentrations of pollutants to their effects. Associations have been demonstrated between daily average concentrations of particles, ozone, sulphur dioxide, airborne acidity, nitrogen dioxide, and carbon monoxide. Although the associations

for each of these pollutants were not significant in all studies, taking the body of evidence as a whole the consistency is striking. For particles and ozone it has been accepted by many that the studies provide no indication of any threshold of effect.

5. Air pollutant concentrations and factors affecting susceptibility

The concentrations of classical pollutants in ambient air of European countries and of the United States have been extensively discussed in the *Air Quality Guidelines for Europe* (WHO 1999a). In developing countries, by contrast, the concentrations of pollution levels in ambient air are higher by an order of magnitude, according to the main source of information on air pollution in developing countries, the Air Management Information System (AMIS).

Indoor air pollutants usually differ in type and concentration from outdoor air pollutants. Indoor pollutants include environmental tobacco smoke, biological particles, non-biological particles, volatile organic compounds, nitrogen oxides, lead, radon, carbon monoxide, asbestos, various synthetic chemicals and others. Degradation of indoor air quality has been associated with a range of health effects, from discomfort and irritation to chronic pathologies and cancers.

On a global scale, biomass fuels are used daily in about half the world's households as energy for cooking and/or heating. Biomass smoke contains significant amounts of several important pollutants: carbon monoxide, particulate matter, hydrocarbons and to a lesser extent, nitrogen oxides. However, biomass smoke also contains many organic compounds, including PAH that are thought to be toxic, carcinogenic, mutagenic or otherwise of concern. In China, coal burning is a major source of indoor air pollution and coal smoke contains all of these pollutants as well as additional ones, e.g. sulphur oxides and heavy metals such as lead.

An unknown, but significant, proportion of biomass fuel burning takes place in conditions where much of the air-borne effluent is released into poorly ventilated living areas. Therefore, some of the highest concentrations of particulate matter and other pollutants occur in rural, indoor environments in developing countries. Due to the high pollutant concentrations and the large populations involved, the total human exposure to many important air pollutants can be much higher in homes of the poor in developing countries than in the outdoor air of cities in the developed world.

Altitude, temperature and humidity vary significantly across the globe. At increased altitude the partial pressure of oxygen falls and inhalation increases in compensation. For particles, this increased inhalation will lead to an increased intake of airborne particles. On the other hand, for gaseous pollutants no increase in effects over those experienced at sea level would be expected. Temperature has a very significant effect on health, whereas humidity is unlikely to have a significant effect on the toxicity of gaseous pollutants.

The age structure of populations differs markedly from country to country. Old people tend to show increased susceptibility to air pollution. Very young children may also be at increased risk. People with a poor standard of living suffer from nutritional deficiencies, infectious disease due to poor sanitation and overcrowding, and tend to be provided with a poor standard of medical care. Each of these factors may render individuals more susceptible to the effects of air pollution. Diseases which produce narrowing of the airways, a reduction in the area of the gas-exchange surface of the lung and an increased alteration of inhalation-perfusion ratios are likely to make the subject more susceptible to the effects of a range of air pollutants.

6. Role of guidelines and standards

The purpose of the *Guidelines for Air Quality* is to provide a basis for protecting public health from adverse effects of air pollution and for eliminating, or reducing to a minimum, those contaminants that are known to be, or likely to be, hazardous to human health and well being. The *Guidelines* should provide background information for nations engaged in setting air quality standards, although their use is not restricted to this.

These *Guidelines* are not intended as standards. In moving from guidelines to standards, prevailing exposure levels and environmental, social, economic and cultural conditions in a nation or region should be taken into account. In certain circumstances there may be valid reasons to pursue policies which will result in pollutant concentrations above or below the guideline values.

In the updated version of the Air Quality Guidelines for Europe, a similar approach to that in the 1987 air quality guidelines was used. However, total tolerable intakes were calculated for multimedia pollutants first, and then adequately partitioned among the different exposure routes. The term "protection factor" used in the 1987 guidelines was abandoned. Instead, uncertainty factors were used to account for the extrapolation from animal to man (alternatively, human equivalent concentrations were calculated), and to account for individual variability. Wherever information on inter- and intraspecies differences in pharmacokinetics was available, data-derived uncertainty factors were employed. Additional uncertainty factors were applied whenever necessary to account for the nature and severity of the observed effects and for the adequacy of the database. For most of the compounds considered, information on the dose/exposure response relationship was provided, to give policymakers clear guidelines on the possible impact of the pollutant at different exposure levels and to permit an informed decision making process to take place. For some compounds, e.g. platinum, a guideline value was considered unnecessary as exposure through ambient air levels was considerably below the lowest level at which effects were seen. For other compounds, for example particulate matter (PM₁₀), no threshold of effect(s) could be found and therefore no guideline value could be derived. Instead, exposure-effect information highlighting the public health impact of different pollutant levels was provided.

In the updating process for carcinogens, a more flexible approach than in the 1987 air quality guidelines was applied. As a default approach, low-dose risk extrapolation was conducted for the IARC groups 1 (proven human carcinogen) and 2A (probable human carcinogen, limited evidence), and an uncertainty factor was applied for agents in IARC groups 2B (probable human carcinogen, inadequate evidence) and 3 (unclassified chemicals). However, the mechanism of action of the carcinogen was the determining factor for the method of assessment. Hence, it was decided that compounds classified under 1 or 2A could be assessed using uncertainty factors, if evidence for a non-threshold mechanism of carcinogenicity existed. By way of contrast, compounds classified under 2B could be assessed by low-dose extrapolation methods, if a non-threshold mechanism of carcinogenicity in animals was proven. Flexibility was also given in the choice of the extrapolation model, depending on the available data (including data for PBPK modelling). The linearized multistage model was used as a default approach. Besides providing unit risk estimates in cases where low dose risk extrapolation was conducted, levels associated with excess cancer risk of 1 : 10000, 1 : 100 000 and 1 : 1000 000 were calculated.

7. Exposure-response relationships

These guidelines place some emphasis on epidemiological data. Epidemiological studies are sometimes preferable to controlled exposure studies in that they provide information on responses in populations and on the effects of real exposures to pollutants and pollutant mixtures. However, the results of epidemiological studies are less easy to use than the results of controlled exposure studies in defining guidelines.

For both particles and ozone an assumption of linearity was made when defining the exposure-response relationships included in the revised guidelines. Extrapolation beyond the available data is dangerous;

however, as there is evidence to suggest that the exposure-response relationship may become less steep as ambient levels of particles rise. For ozone, the relationship at low concentrations may be concave upwards. These are important points to be considered if the guidelines are to be used in countries with levels of pollution different from the range covered by the guidelines.

8. Moving from guidelines to standards

An air quality standard is a description of a level of air quality, adopted by a regulatory authority as enforceable. At its simplest, an air quality standard should be defined in terms of one or more concentrations and averaging times. Further information on the form of exposure (e.g. outdoor), on monitoring to assess compliance with the standard, and on methods of data analysis and Quality Assurance and Quality Control requirements should be added. Other factors to be considered in setting an air quality standard include the nature of the pollution effects and whether they represent adverse health effects; and whether special populations are at risk.

The development of air quality standards is only a part of an adequate air quality management strategy. Legislation, identification of authorities responsible for enforcement of emission standards and penalties for exceeding standards are also necessary. Emission standards may play an important role in the management strategy especially if exceeding air quality standards is used as a trigger for abatement measures. These may be needed at both the national and the local level. Air quality standards are also important in informing the public about air quality. Used in this way they are a double edged weapon as the public commonly assumes that once a standard is exceeded adverse effects on health will occur. This may not be the case.

The transfer of the dose-response relationships to other parts of the world, especially for particulate matter, should be conducted with caution for several reasons. These include:

1. The chemical composition of the particles.
2. The concentration range.
3. The responsiveness of the population.
4. The limitations of the established relationships.

9. Cost-benefit analysis and other factors

Cost-benefit analysis is one way of formally weighing the costs of reducing air pollution against the benefits produced. The concept is that emissions are reduced until the marginal costs and benefits are equal. While the cost of abatement measures may be relatively easy to quantify, this may not be the case when non-technical measures are employed. In any case, it is likely to be more difficult to assign monetary values to the benefits obtained. Some aspects of reduced morbidity, such as the reduced use of hospital facilities and drugs are comparatively easy to cost; others, such as reductions in premature deaths and symptoms, are not. Applying monetary values based on a "willingness to pay" basis has been suggested, and has been accepted as appropriate by many health economists. This approach has been seen as preferable to one based only on such indices as loss of production, earnings or hospital expenses.

Factors other than monetary factors also need to be considered when considering the setting of national air quality standards. These include the technical capacity of a country to achieve and maintain an air quality within the desired standards, the social implications of adopting certain standards to ensure equity of costs and benefits among the population, and environmental costs and benefits.

10. Health-based Guidelines

For the purpose of presenting the health-based air quality guidelines, the key air pollutants, also termed "classical" air pollutants - SO₂, NO₂, CO, O₃, SPM, and lead are briefly described with respect to health risk evaluations and recommended guideline values. Particular emphasis is given to suspended particulate

matter <10 µm diameter (PM₁₀) and < 2.5 µm diameter (PM_{2.5}). The guidelines are presented in Chapter 3 in tables 3.1 to 3.5 and in figures 3.1 to 3.9. The information available for a number of other air pollutants (including carcinogens and non-carcinogens) is also summarized and presented in synoptic tables.

11. Classical air pollutants: applicability of WHO Air Quality Guidelines for Europe on a world wide scale

In the derivation of the WHO *Air Quality Guidelines for Europe*, assumptions were made for some compounds, which may not be applicable in some parts of the world. For example, the importance of different routes of exposure for some pollutants may vary from country to country.

It should be understood that if such factors were to be taken into account then different guidelines could be derived. For a number of pollutants a Unit Risk (UR) assessment has been provided. These assessments are also dependent upon considerations of the comparative importance of different routes of exposure.

It is important that regulatory authorities should evaluate whether local circumstances give cause to doubt the validity of the guideline set out in the WHO *Guidelines for Air Quality* as a basis for setting local guidelines or standards.

12. Indoor Air Quality

Indoor spaces are important microenvironments when assessing risks from air pollution. For many air pollutants most of the daily exposure by inhalation occurs indoors because of the amount of time spent indoors or because of the pollutant concentration levels encountered. The air quality inside buildings is affected by many factors. In an effort to conserve energy, modern building design has favoured tighter structures with lower rates of ventilation. By contrast, in some areas of the world, natural ventilation only is used; in others, mechanical ventilation is common. In modern buildings most of the pollution problems arise from low ventilation rates and the presence of products and materials that emit a large variety of compounds, whereas the inhabitants of many less developed countries face problems related to pollutants generated by human activities, in particular by combustion processes.

If only the health effects of air pollution are being considered, it does not matter if a pollutant is inhaled by breathing outdoor or indoor air. However, there are important differences in the composition of pollutant mixtures in outdoor and indoor air. For example, in outdoor air there are traffic-generated emissions, whereas indoor air pollution is generated from tobacco smoke or from cooking with biomass-fuelled stoves. Not all of these compositions have been taken into account in developing the *Guidelines for Air Quality*, and they may not be applicable under all circumstances, so care should be taken to avoid misinterpretation.

13. Ambient Air Quality Monitoring and Assessment

The three main air quality assessment tools are: i) ambient monitoring; ii) models and iii) emission inventories/measurement.

The ultimate purpose of monitoring is not merely to collect data, but to provide the necessary information required by scientists, policy makers and planners to enable them to make informed decisions on managing and improving the environment. Monitoring fulfils a central role in this process, providing the necessary scientific basis for policy and strategy development, objective setting, compliance measurement against targets and enforcement action. However, the limitations of monitoring should be recognised. No monitoring programme, however well funded and designed, can hope to comprehensively quantify

patterns of air pollution in both space and time. In many circumstances, measurements alone may be insufficient or impractical for the purpose of fully defining population exposure in a city or country. Monitoring therefore often needs to be used in conjunction with other objective assessment techniques, including modelling, emission measurement and inventories, interpolation and mapping. At best, monitoring provides an incomplete, but useful, picture of current environmental quality.

Reliance on modelling alone also is not recommended. Although models can provide a powerful tool for interpolation, prediction, and optimisation of control strategies, they are effectively useless unless properly validated by real-world monitoring data. It is important, also, that the models utilised are appropriate to local conditions, sources and topography, as well as being selected for compatibility with available emission and meteorological datasets. Many models depend on the availability of reliable emission data.

A complete emissions inventory for a city or country may need to include emissions from point, area and mobile sources. In some circumstances, assessment of pollutants transported into the area under study may also need to be considered. Inventories will, for the most part, be estimated using emission factors appropriate to the various source sectors (verified by measurement), and used in conjunction with surrogate statistics such as population density, fuel use, vehicle kilometres or industrial throughput. Emission measurements will usually only be available for large industrial point sources or from representative vehicle types under standardised driving conditions.

All three assessment tools are interdependent in scope and application. Accordingly, monitoring, modelling and emission assessments should be regarded as complementary components in any integrated approach to exposure assessment or in determining compliance with air quality criteria.

14. Ambient Air Quality Management

Some basic principles guide international and national policies for the management of all forms of air pollution. An important global initiative occurred in 1983 when the UN General Assembly established the World Commission on Environment and Development, headed by Gro Harlem Brundtland. The report produced by the Commission was entitled *Our Common Future* and it was presented by the UN General Assembly in 1987 and endorsed by it. It has been influential in bringing environmental issues into the global arena, and in expressing some concepts that have been influential in air quality management.

The Brundtland Commission suggested that to meet the legitimate aspirations of the world's population without destroying the environment, sustainable development would be required. It defined **sustainable development** as: *development that meets the needs of the present without compromising the ability of future generations to meet their own needs*. This concept has been embraced as an apparent means of integrating environmental policy and economic development.

Following from the Brundtland Commission, the UN Conference on the Environment and Development was held in Rio in 1992. The aim was to ensure that practical foundations for sustainable development were put into place. The Agenda 21 document and the Rio declaration were the most obvious results of this conference. Agenda 21 is a document covering sustainable development which is not binding on countries, but national implementation is reviewed by the Sustainable Development Commission and the UN General Assembly. Agenda 21 supports a number of environmental management principles on which some government policies including air quality management are based. These include:

- **precautionary principle** - where there is a clear possibility of damaging environmental consequences, action should be taken to protect the environment without awaiting the full scientific proof that the environment will be damaged by the proposal.

- **polluter pays** - the full costs associated with pollution (including monitoring, management, clean-up and supervision) should be met by the organisation responsible for the source of the pollution.

In addition, many countries have adopted the principle of **pollution prevention**, which aims to reduce pollution at sources.

The responsibility of national governments for international reporting on the environment of their country has enabled greater exchange of air quality information around the world.

The foundation for air quality management is the government policy framework. Without a suitable policy framework and adequate legislation it is difficult to maintain an active or successful air quality management programme. A policy framework refers to transport, energy, planning, development, and policy in other areas, as well as environmental policy. Air quality objectives are more readily achieved if these interconnected government policies are compatible, and if mechanisms exist for co-ordinating responses to issues, which cross different areas of government policy. Measures to achieve some integration of air quality policy with health, energy, transport and other policy areas have been adopted in many developed countries.

The goal of air quality management is commonly stated to be to maintain a quality of air that protects human health and welfare. This goal recognises that air quality must be maintained at levels, which protect human health, but it also must provide protection of animals, plants (crops, forests and natural vegetation), ecosystems, materials and aesthetics, such as natural levels of visibility. To achieve an air quality goal requires the development of policies and strategies.

15. Management of indoor air quality

Most human beings spend most of their time in indoor environments, where they can be exposed to poor air quality. Pollution and degradation of indoor air cause illness, increased mortality, loss of productivity and have major economic and social implications. Health effects can include increased rates of cancer, lung disease, allergy and asthma as well as fatal conditions such as carbon monoxide poisoning and legionnaires' disease, as discussed in Section 4.1. The medical and social cost associated with these illnesses, and the related reduction in human productivity, result in staggering economic losses.

Indoor air quality problems affect all types of buildings including homes, schools, offices, health care facilities and other public and commercial buildings. Indoor air problems can be reduced by better urban planning, design and operation, as well as maintenance of buildings, materials and equipment in buildings.

This document considers the management of indoor air quality in developed countries, and in some situations in developing countries, and then focuses on the important and widespread problem of how to manage indoor air quality associated with biomass fuel combustion in developing countries.

16. Priority Setting in Air Quality Management

It is important to give guidance to countries on how to set priorities in rational air quality management. Actual priorities will differ for each country; therefore, each country sets priorities in air quality management according to its policy objectives, needs and capabilities. Priority setting in air quality management refers to prioritising health risks to be avoided, with corresponding prioritisation of air pollutant compounds, and concentrating on the most important sources of the pollutants. Conceptually, prioritising health risks is straightforward. High priority of health risks will be given to those compounds

for which “high” toxicity and “high” exposure of the population are entailed. Conversely, low priority health risks involve agents of “low” toxicity and “low” exposure. “Medium” priority risks include compounds in which either toxicity or exposure is “low” while the other is “high”.

A framework for a political, regulatory and administrative approach is required to guarantee a consistent and transparent derivation of air quality standards and to ensure a basis for making decisions on risk-reducing measures and abatement strategies. In such a framework the following considerations need to be included:

- The legal aspects.
- The potential of air pollution to cause adverse effects on health, taking into account the populations at risk.
- The exposure-response relationships of pollutants and pollutant mixtures and the actual exposure responsible for related health and/or environmental risks.
- The acceptability of risk.
- The cost-benefit analysis.
- The stakeholder contribution in standard setting.

17. Enforcement of air quality standards: Clean air implementation plans

The enforcement of air quality standards aims to evaluate the need for control action on emission sources to attain compliance with the standards. The instruments used to achieve this goal are the Clean Air Implementation Plans (CAIPs). The outline of such a plan should be defined in regulatory policies and strategies. Clean air implementation plans were developed in several developed countries during the 1970s and 1980s. Air pollution was characterized by a multitude of sources of many different types of air pollutants. Consequently it was extremely difficult to assess the public health risks associated with a single source, or even a group of sources. As a consequence, on the basis of the polluters pay principle (Chapter 6), sophisticated tools were developed which assessed the sources, air pollutant concentrations, health and environmental effects and control measures, and which made a causal link between emission, air pollution and the necessary control measures. A typical clean air implementation plan (CAIP) includes:

- A description of the area.
- An emissions inventory.
- An air pollutant concentrations inventory - monitored and simulated.
- A comparison with emissions and air quality standards or guidelines.
- An inventory of the effects on public health and the environment.
- A causal analysis of the effects and their attribution to individual sources.
- Control measures and their costs.
- Transportation and land-use planning.
- Enforcement procedures.
- Resource commitment.
- Projections for the future.

In developing countries, the air pollution situation is often characterized by a multitude of sources of few types, or sometimes few sources. Using the experience obtained in developed countries, the control action to be taken is very often obvious. As a consequence, in cases where little useful monitoring data are available, less monitoring could be sufficient, and dispersion models could help to simulate spatial distributions of pollutant concentrations. Much simplified CAIPs would have to be developed for cities of developing countries or countries in transition. At present, the main sources of emissions in many cities of the developing world are old vehicles and some industrial sources such as power plants, brick kilns, cement factories and a few others. Their relative contribution to air pollution could be determined by use of rapid emission inventories. The emission factors used in such inventories are published and a PC programme is available, which enables an estimation of emissions and ambient air concentrations, and

evaluates the impact of possible control measures. Projections for the future can also be evaluated by the programme.