

# **Role of Human Exposure Assessment in Air Quality Management**

Report on the Joint Workshop of  
World Health Organization  
Joint Research Center  
European Concerted Action “Urban Air, Indoor  
Environment and Human Exposure”

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## ABSTRACT

European air quality policy has so far focused on ambient (outdoor) air pollution. Accordingly, European countries have put major efforts into formulating and implementing abatement strategies for outdoor sources, while indoor sources may not have been adequately taken into account. Consequently, the present approaches may not be effective in reducing the health risks linked to pollution. This workshop evaluated how appropriate the current exposure assessment methods are when designing and implementing comprehensive policies and air quality management approaches to address the health risks of air pollutants from both outdoor and indoor sources. After reviewing the presently available methods of exposure assessment, the workshop participants agreed that, for certain air pollutants, well designed outdoor air quality assessment and management approaches may be appropriate tools to reduce the health risks of pollution. However, for the strong indoor pollutants, additional information is needed to increase the efficiency of present air quality management practice and to address exposure in all microenvironments. This should include models of exposure which can be applicable in various countries, provided that the local data on emission from indoor sources are available along with, pollution concentration in various microenvironments and population activities.

### Keywords

AIR POLLUTION – adverse effects  
AIR POLLUTION – indoor  
ENVIRONMENTAL MONITORING – methods  
ENVIRONMENTAL EXPOSURE  
PUBLIC HEALTH  
GUIDELINES  
RISK ASSESSMENT  
RISK MANAGEMENT

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## CONTENTS

	<i>Page</i>
Background .....	1
Scope and Purpose .....	2
Organization and Participation.....	3
Preparations and Output .....	4
Summary of discussion .....	4
What exposure information is needed to formulate and evaluate health-oriented policy options and mitigation strategies regarding individuals' exposures to pollution from outdoor and indoor sources? .....	4
Why should total exposure to specific air pollutants from different sources and in different environments be assessed?.....	5
What would be the public health advantage from exposure-based air quality management vs. ambient monitoring-based air quality management?.....	5
What situations require individual exposure or indoor monitoring vs. population level exposure data to increase effectiveness of risk management? .....	6
When is modelling the most effective tool supporting risk management? .....	6
When would ambient monitoring be sufficient for exposure and risk assessment? .....	6
How could current policies regarding outdoor air pollution be complemented to take into account indoor sources and individuals' activities? .....	7
What exposure assessment tools are ready for application in urban air quality management? .....	7
What assessment tools can be recommended for urban air quality management? .....	9
What are the urban air quality policy alternatives? What policy strategies can be recommended for urban air quality management?.....	10
Annex 1. List of Participants.....	13
Annex 2. Workshop Programme .....	17

## Background

European air quality policy has so far focused on ambient (outdoor) air pollution. Accordingly, in many European countries, the authorities responsible for air quality management have put major efforts into formulating and implementing abatement strategies for outdoor sources, while indoor sources may not have been adequately taken into account. From a public health standpoint, human exposure to hazardous substances should be reduced regardless of their origin (e.g. industrial processes, traffic, use of consumer products) or their location (e.g. in indoor, outdoor or transport environments), albeit integral air quality management will need to weigh the benefits and costs of reducing exposures to pollutants from the different sources. To date, it is not clear whether measures implemented on outdoor air pollution will prove effective (and sufficient), once the total picture, that is the relative contribution of indoor and outdoor sources to total human exposure, is clear.

It can be suggested that indoor air quality will also profit from measures taken to tackle outdoor air pollution. However, some measures, which are beneficial for ambient air quality, may have detrimental effects on indoor air. The construction of tighter building shells to save energy, for example, may lead to the accumulation of indoor pollutants, if no compensatory measures are taken (e.g. active ventilation by occupants). Indoor problems may require approaches not addressed in current (outdoor) air quality policies, e.g. reduction of gaseous emissions from materials or products or education and information campaigns.

Exposure assessment plays a prominent role in risk assessment and risk management. Currently there are two exposure assessment approaches used, one outdoor-oriented (deterministic) and the other people/microenvironment-oriented (probabilistic). The first approach uses emission inventories, physical dispersion and chemical transformation modelling and ambient air quality monitoring to create a detailed description of the outdoor concentrations in time and space. The second approach is based on measuring actual personal exposures and microenvironment concentrations, source apportionment of these concentrations and time-microenvironment-activity based exposure models using these data.

Regulatory authorities have basically two major policy options to mitigate emissions and related exposures: On the one hand through the change of conditions (traffic policy, urban planning, smoke free public spaces), on the other hand through measures targeting changes of behavior (this involves information and education of the public, but also providing conditions which make it easier to make the “right” choice). With regard to indoor exposures, inadequate behaviour of occupants may jeopardize the achievement of even ideally constructed, equipped and maintained buildings.

The approaches mitigating the impacts of air pollution indoors and outdoors, with their links and differences, were discussed in a workshop on “Urban air, indoor environment and human exposure” held in Thessaloniki, Greece, from 16–18 April 2000. The workshop recommended that “future clean air policies for Europe take into account the total air exposure of European citizens, which will necessarily include exposures to pollutants from both outdoor and indoor sources”<sup>1</sup>. To follow up on this recommendation, the WHO European Centre for Environment and Health, (WHO/ECEH) Bonn Office, the Institute for Environment and Sustainability of the European Communities Joint Research Centre (JRC) and the European Concerted Action (ECA)

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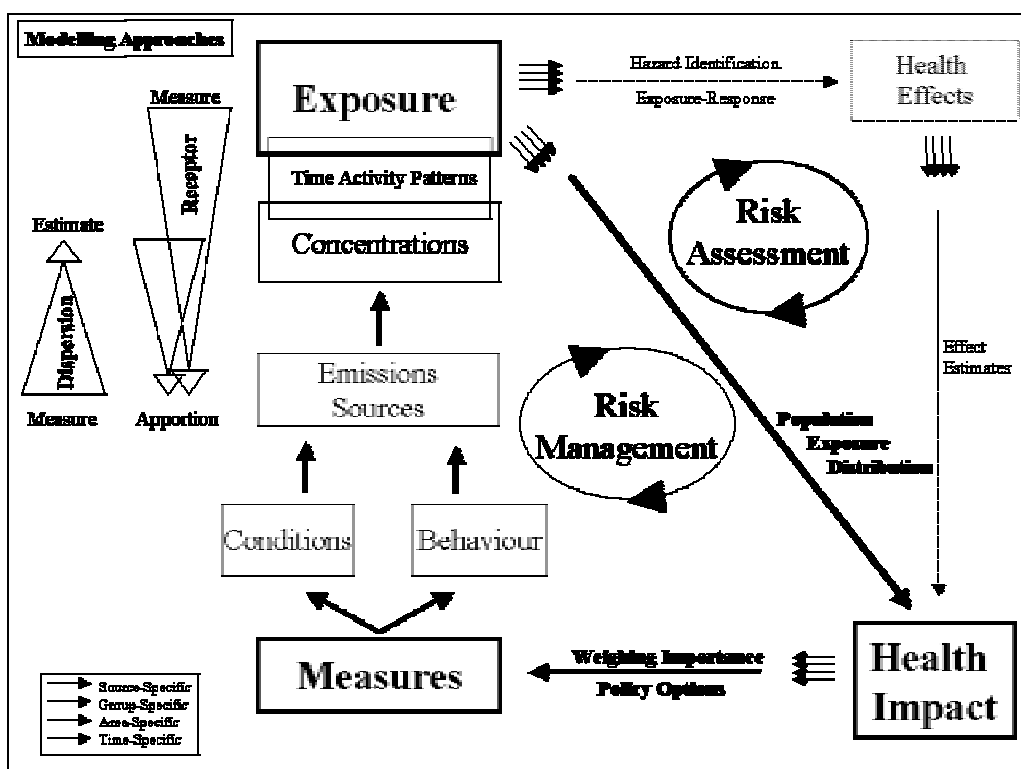
<sup>1</sup> Workshop proceedings, European Commission 2000, EUR 19646 EN

on “Urban Air, Indoor Environment and Human Exposure” organized the present meeting. Its core funding was provided to WHO by the German Ministry of the Environment as part of its commitment to finance activities of the WHO/ECEH Bonn Office. JRC supported the participation of experts from countries of central and eastern Europe (CCEE) and ECA supported travel costs of its members.

## Scope and Purpose

This workshop was convened to review current exposure assessment and regulatory approaches and to discuss how they would fit into a common framework to evaluate and weigh the public health relevance of indoor and outdoor air pollution sources. Such a framework is suggested in Figure 1. It relies on the four cornerstones of the public health cycle: 1) Exposure; 2) Health Effects; 3) Health Impact; and 4) Measures. Risk assessment and risk management fit into this frame. Exposure assessment of air pollutants, and thus their risk assessment, may need to be source specific (e.g. traffic, residential heating, gas cooking), population specific (e.g. susceptible groups like children or elderly), geographic area specific (e.g. because of heterogeneity of effect estimates) and/or time specific (e.g. past or current levels, future scenario), in order to provide the basis to formulate policy options and mitigation strategies.

Figure 1. Framework of the WHO/JRC/ECA workshop  
“Role of Human Exposure Assessment in Air Quality Management”



Framework of the WHO/JRC/ECA workshop “Role of Human Exposure Assessment in Air Quality Management”, including the Public Health Cycle (Exposure-Effects-Impact-Measures), Risk Assessment, Risk Management and Modelling Approaches. The focus of the workshop was on the triangle Exposure – Health Impact – Measures (bold). Exposure assessment approaches for health effects assessment (hazard identification and estimation of exposure-response estimates; fine lines) has been addressed in former WHO workshops and is not the topic of this workshop (L. Oglesby, 2002)

The sessions were designed to address the following topics and to answer these specific questions:

1. What tools exist for urban air quality managers to effectively and efficiently reduce human exposure to harmful pollutants in both outdoor and indoor air?
  - What would be the exposure information needed in order to formulate and evaluate policy options and mitigation strategies regarding individuals' activities, their exposures to outdoor and indoor pollution and the related health effects?
2. Current applications of exposure assessment in urban air quality management:
  - Why should total exposure to specific air pollutants in different environments and from different sources be assessed and what would be the advantage to public health resulting from air quality management based on exposure assessment versus the traditional approaches?
3. New ideas for urban air quality management, in particular regarding indoor sources and individual level activities:
  - Which situations require individual level exposure data or indoor monitoring air quality data? When is modelling most adequate and when would ambient monitoring be sufficient?
4. Policy advice on the main measures to be recommended using current understanding of health effects of exposures to air pollutants in indoor and outdoor environments, and its determinants.
  - How could current policies regarding outdoor air pollution be complemented in order to take account of indoor sources and individual-level activities?

The scope of this workshop did not include discussion on the exposure assessment methods needed to study the links between health and air pollution. Some of these methods were the subject of a meeting convened by WHO and the Health Effects Institute in Bonn, 3–4 February 2002<sup>2</sup>.

## Organization and Participation

The workshop was attended by researchers working on the assessment of human exposure to air pollutants at different stages of risk assessment and risk management, and by public health and environment managers responsible for prevention of impacts of air pollution on human health. The workshop was organized so as to involve wide representation from technical and scientific disciplines relevant to the assessment of levels and sources of indoor exposures, health effects and their mitigation through policy or technical means. To share the experiences and provide a forum for capacity-building, the participants came from all parts of the WHO European Region, including European Union Member States, countries of central and eastern Europe, and the newly independent states. In total, 51 experts from 25 countries, WHO and the European Commission participated in the meeting (see Annex 1).

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<sup>2</sup> WHO/HEI Workshop: Exposure assessment in studies on the chronic effects of long-term exposure to air pollution. Bonn, 4–5 Feb. 2002, WHO Regional Office for Europe 2003 (<http://www.euro.who.int/document/e78992.pdf>)

## Preparations and Output

In advance of the meeting, WHO identified invited speakers and asked them to prepare short summaries of their presentations. These were distributed to the meeting participants in advance, allowing them to prepare for the discussion.

The meeting was structured around a set of sessions, consisting of formal presentations and plenary discussion on the session's topic (see Annex 2). Discussion was also held in two smaller groups. Session Chairs and Rapporteurs summarized the results of the discussion in the session reports. These were used by the workshop Chairman (Matti Jantunen) and Rapporteur (Alena Bartonova) to prepare the summary presented below. The report was circulated to the meeting participants for comments and approval.

Several of the summaries of the invited presentations were updated after the workshop to better reflect the discussion. The summaries will be published in a Workshop Proceedings, prepared jointly by WHO and JRC.

Based on the workshop discussion and the reports of the session Chairs and Rapporteurs, the workshop's Chairman (Matti Jantunen) and Rapporteur (Alena Bartonova) prepared the summary of the main results. This summary was circulated among the workshop participants for comments and approval.

## Summary of discussion

### **What exposure information is needed to formulate and evaluate health-oriented policy options and mitigation strategies regarding individuals' exposures to pollution from outdoor and indoor sources?**

Policy-makers who examine the options affecting air quality management strategies need to take into account the impacts of pollution on public health as well as the benefits and costs of the measures to reduce the pollution. The effects of policies on health, however, may be difficult to measure directly. Rather, the evaluation needs to rely on exposure assessment as the necessary element of health risk assessment. For many air pollutants no threshold values of exposure can be defined under which the risk would be zero. This means that at all levels of exposures, there are individuals for whom exposure reductions would bring health benefits. Therefore, the whole exposure distribution is relevant for population level risk assessment, not only when it exceeds a particular exposure level. This information is needed for the general population as well as for population subgroups of particular interest, such as those who are vulnerable.

The most effective way to develop and select effective risk reduction strategies is to attribute exposures and associated risks to microenvironments, activities and emission sources. Exposure models are then needed to assess the consequences of alternative exposure scenarios and risk reduction strategies. Some specific questions that need to be addressed are:

- Does the population divide into identifiable subgroups with distinctly different exposure levels and patterns? If so:
  - Do sensitive individuals form such subgroups?
  - What are the patterns of exposure for susceptible populations?

- For which pollutants are indoor environments the primary sources of exposure, and to which activities they are related?
- How relevant are the “hot spots” in time/space for individual and population exposures and risks?
- What is the health relevance of long-term average exposures and short-term peak, single or repeated, exposures?

Models of exposure developed for one region can be transferred and applied in other locations, taking into account the contribution to pollution from various sources or the impact of personal activities, e.g. smoking, in various microenvironments. They need, however, to be validated with local data on individual microenvironmental concentrations and exposures, which cannot be transferred from one city or region to another any more than ambient air quality data can. Validated general exposure models are needed in Europe, with the information necessary for their local applications.

### **Why should total exposure to specific air pollutants from different sources and in different environments be assessed?**

An individual monitored parameter of air quality may indicate the composition of air pollution mix, or be a source marker or in itself a causal agent for health consequences. In risk management, these roles need to be differentiated to ensure the most beneficial exposure reductions. Source apportionment is an essential technique for this.

For an assessment of a pollutant’s health effects, it is essential to determine total exposure. If the total exposure is dominated by pollution in one microenvironment (e.g. ambient air), the control of the pollutant in this microenvironment assures control of the total exposure as well. However, in many other cases, total exposure results from a combination of sources and exposures specific to various microenvironments. In these situations total exposure is difficult to assess, and also difficult to tackle through a legislative framework that is feasible. In order to efficiently assess total exposure to air pollutants, exposure assessors need validated comprehensive models. Such models need to combine models for outdoor and indoor air. Ambient and microenvironmental dispersion models, time-microenvironment-activity models, airflow and surface interaction models are among those that can be used. To date, some exposure models have been developed which connect the outdoor, indoor and commuting sources via dilution factors and population time–microenvironment–activity patterns to exposures, but they have only rarely been validated.

### **What would be the public health advantage from exposure-based air quality management vs. ambient monitoring-based air quality management?**

All health effects caused by environmental contaminants are triggered through exposure; therefore exposure is a more direct environmental health risk indicator than ambient air measurements. A total exposure-based urban air quality assessment, also taking into account indoor environments, is advantageous for several risk management purposes:

- Comparison to exposure guidelines
- Setting of policy priorities
- Developing metrics for monitoring and regulation
- Informing/educating the public and policy-makers.



Cost-effective policies, resulting in the achievement of verifiable gains for public health, can most effectively be devised if the burden of disease arising from total exposure to air pollutants can be attributed to specific sources of exposure. Exposure-based air quality and related risk management has the highest probability to act upon the most relevant sources and activities.

Ambient monitoring does not usually capture all space and time variability in ambient concentrations. Combining total exposure assessment and health outcomes can help evaluate which part of the total exposure and risk is represented by the central site monitoring data, and which is not. When the size of this non-represented exposure is recognized, urban air quality managers can be given advice about what role the unmonitored exposures would have on health and what, if any, additional measures should be taken to reduce the relevant exposure burden.

### **What situations require individual exposure or indoor monitoring vs. population level exposure data to increase effectiveness of risk management?**

Individual exposure and indoor monitoring is necessary in the following cases:

- To assess individual or microenvironment level environmental health concerns, and to develop/provide effective means for behavioural and technical control of short exposure peaks.
- To compile population exposure distribution for, e.g. model validation or risk assessment in the case of effect threshold and/or non-linear dose/response;
- In research, to provide information for dose/response studies.

### **When is modelling the most effective tool supporting risk management?**

Models are used to predict the exposure consequences of different exposure scenarios. Alternative options for future exposure control can only be evaluated via exposure modelling, because there isn't yet anything to measure. In predicting the future, the only alternative to modelling is guessing.

For air quality management, modelling represents a tool to evaluate individual exposures and population exposure parameters and thereby modelling supports health risk assessment. The models used in air quality management can be expanded for calculations of outdoor and indoor pollution concentrations and personal exposures on a population basis. Models can estimate past exposures, and predict future exposures, as well as population exposure distributions that cannot be obtained by monitoring. It is emphasized that models should be further improved and their capacities exploited especially in connection to extensive surveys of health effects.

### **When would ambient monitoring be sufficient for exposure and risk assessment?**

For certain air pollutants and source contributions, optimally designed monitoring networks are capable of providing – information which is directly relevant to long term exposure, exposure distributions and even exposure peaks. Ambient monitoring is essential for assessing ambient concentration trend and outdoor source apportionment. Ambient concentrations provide useful surrogates for long-term population exposures of ambient origin particularly in relation to cumulative, chronic risks and stochastic effects like cancer, in particular for pollutants for which ambient sources dominate exposure.

## **How could current policies regarding outdoor air pollution be complemented to take into account indoor sources and individuals' activities?**

Urban air is an umbrella concept combining ambient and indoor air. It has usually been divided into indoor and outdoor microenvironments, each requiring a different approach and risk management strategies.

The legal and regulatory framework for regulating air quality – except in ambient air and certain workplaces – is still very diverse and mostly undeveloped. Management of outdoor air quality is far better developed than for indoor air.

Exposure-based urban air quality management could integrate the health-relevant air pollution impacts from residential, work, outdoor and transportation microenvironments as well as individuals' activities. Such an intersectoral approach could focus on the most efficient mitigation alternatives for maximum public health benefits or minimum cost/intervention, irrespective of which sector, microenvironment or activity they affect. Besides, for most pollutants, e.g. benzene, where no constituent differences exist and the toxicity of outdoor and indoor exposures are the same, optimal exposure-based air quality management would in some cities point to ambient, in other to indoor sources, even consumer products, depending on which sources dominate the personal exposures.

## **What exposure assessment tools are ready for application in urban air quality management?**

Some exposure monitoring/modelling tools are available for most of the regulated air pollutants. For reactive compounds, a number of organic compounds or microbial compounds, and the coarse fraction of PM<sub>10</sub>, exposure assessment is less developed. Regarding time scales, more information is available for longer-term exposures, while short time resolution data is lacking. A further limitation is the lack of integration across the microenvironments, as well as generally insufficient and/or incompatible information on time-microenvironment-activity patterns. Large differences exist between countries in the availability of tools and information. Validated tools developed in one country can, however, be applied also elsewhere. Table 1 shows one example of systematic description of main microenvironments (ME), and what information and tools are available for each of them.

Currently, no risk management body has responsibility for urban air in this broad sense. Table 2 shows an example of administrative responsibilities for individual microenvironments. For policies and management, ownership needs to be taken into account. Thus regulatory bodies are responsible for some microenvironments while for other microenvironments no regulatory body is responsible.

In public spaces large populations are affected, but exposure times are short for most. In private residences and workplaces, fewer people are affected in each, but their exposure times are quite long. This is reflected in the contribution to total exposure in each situation. The same monitoring techniques and models can be used irrespective of whether the space is public or private.

Table 1. Tools available for individual microenvironments

Microenvironment /Tools	Measurements	Models	Databases (GIS-link possible)	Other exposure assessment information	Comments
<b>ME 1</b> Urban ambient air	Stationary, Mobile	Dispersion Source apportionment	Population distribution, Building registers	Passive samplers (small scale variability) Personal sampling (active, passive) Lacks time–activity pattern	For urban background – tools are generally available
<b>ME 2</b> Street canyons	Stationary Mobile	Dispersion	Traffic flow	Lacks time–activity pattern	Tools are generally available; lacks overview of different street canyons, lacks combination of different scales (time and space)
<b>ME 3</b> Commuting	Personal sampling	Analytical box models	Mobility databases?	Some micro-environments not described (subways)	Microenvironment specific tools, availability varies
<b>ME 4</b> Industrial and other episodic hot spots	Episodic or targeted monitoring campaigns	Industrial dispersion models	Emission inventories limit modelling	Some personal sampling	Examples: Traffic stops, petrol stations, near industrial plants
<b>ME 5a</b> Indoor spaces, naturally ventilated; <b>ME 5b</b> Mechanically ventilated	Pollutant specific measurements  Ventilation rates	Ventilation models, Mass balance equations; ME-specific models	Emissions/ emission rates poorly characterized	Personal sampling Behaviour of dwellers	Limited understanding of absorption/desorption processes and penetration and deposition
<b>PE</b> Personal exposure	Personal monitors	Deterministic and probabilistic micro-environment models	TMAD databases, AAQ and Met databases, EXPOLIS database	Source emissions Smoking prevalence Consumer products etc.	Often highly localized information Very limited amount of population-based data available

Present microenvironmental exposure models group the microenvironments into typically 5–21 categories such as: main outdoor (e.g. street, garden, parking lot), indoor (home, workplace, restaurant) and commuting (car, subway) and exposure relevant activities (e.g. smoking, cooking with a gas stove). Inputs to such models include a concentration distribution for each microenvironment-activity category, either modelled or measured. Similarly, a real or modelled distribution of time spent in each microenvironment–activity needs to be specified. Furthermore, the correlations between the concentrations in different microenvironments (usually positive) and between the times spent in different microenvironments (mostly negative) need to be incorporated into the model. The (daily) exposure is now computed as the sum of the (daily) concentration-time contributions from each microenvironment-activity category. In probabilistic population exposure modelling, the whole input data distributions for the respective population are used to generate respective output data distributions.

Table 2. Administrative responsibilities and regulations for individual microenvironments

Managing body/administration	Urban background	Street canyon	Commuting	Hot spots	Personal exposure
Environmental authorities	xx	x		x	
Building authorities					xx
Traffic planning authorities			x		
Urban planning authorities	x		x	x	
Public health authorities				x	x
Occupation health authorities				x	x
Consumer products authorities				x	x

### What assessment tools can be recommended for urban air quality management?

The necessary tools have to cover the following elements:

- Ambient air quality monitoring and modelling
- Microenvironmental monitoring and modelling
- Time–microenvironment–activity monitoring tools and databases
- Exposure scenarios
- Exposure monitoring and microenvironmental based modelling.

The existing validated tools mostly follow this structure.

The recommended priorities for implementation of a total exposure based assessment system are:

- To use and improve tools that integrate across the microenvironments;
- To use tools that produce distributions of exposures and allow for uncertainty and sensitivity analyses;
- To develop and use tools to apportion the exposures to microenvironments, activities and sources for varying scales of space and time;
- For prioritization of tool improvement go compound-by-compound and/or problem-by-problem;
- Set up managerial framework to deal with total exposure metrics;
- Ensure adequate resources for adaptation of tools to specific application.

It is important that the resulting recommendations are straightforward and understandable (also for political decision-makers) and it should be possible to implement them. Consider the appropriateness of using proxy compounds in each application. While proxies may be convenient for descriptive purposes, their application for regulatory purposes is tricky and may lead to non-productive, yet costly actions. Managing a proxy or indicator for a harmful emission may well leave its health risk unaffected. Consider also that outdoor and indoor pollution, and personal exposures, have demonstrated impacts on corporate and public economies, not only costs due to disease, but also productivity losses. Resistance to new policies and policy changes can sometimes be overcome by addressing the underlying political and economical causes.

Intake fraction, defined as the fraction of all particles/molecules/atoms from a source, which are inhaled (or ingested) by the affected population, is a concept quite simple to apply in practical risk assessment and comparison. Deriving specific intake fraction values, however, can be a demanding and time consuming task. Modelling-based intake fractions are already available for some pollutants, sources and populations and development of calculation algorithms and models for intake fractions has also been started.

### **What are the urban air quality policy alternatives? What policy strategies can be recommended for urban air quality management?**

The main objective of urban quality management is to protect the health of its citizens. Current air quality management practices are based on the monitoring and control of outdoor air quality as the baseline for all urban environments, outdoor and indoor. For many air pollutants and their risks, however, the sources and highest concentrations occur indoors, where people spend most time, or in the traffic, where the exposure levels are often highest.

Public health risk reduction requires that different exposure patterns and dose-response relationships for different population subgroups be assessed. This is because different microenvironments contribute differently to the exposures of different population groups – due to different pollutant concentrations, activities and the time fractions spent in each microenvironment. At the same time, human health should be protected everywhere, and in particular indoors<sup>3</sup>, where the traditional approaches to air quality management may have limited effects. To optimize the source control investments (with the aim of reducing public health risks), the relative contributions of the sources to microenvironments and microenvironments to exposures should be known and the relevance of these exposure sources to health should be evaluated. Based on such assessment, control policies and actions may be suggested that affect sources also in microenvironments other than ambient air, and improve the efficiency of exposure and public health risk reduction.

In applying exposure based public health risk management policies, the commonly agreed principles need to be observed. These include the following:

- Precautionary principle
- Pollution prevention principle
- Principle of individual responsibility
- Cooperation principle
- Polluter's responsibility principle (Polluter pays)
- Right to know principle.

Three principles from radiation protection, all of which need to be met simultaneously, are also useful, namely:

- ALARA (as low as reasonably achievable), meaning that if exposure to a harmful agent can be reduced with reasonable effort, this should be done regardless of the risk assessment or concentration guidelines;

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<sup>3</sup> The right to healthy indoor air. WHO Regional Office for Europe 2000 (<http://www.euro.who.int/document/e69828.pdf>)

- Justification, meaning that each exposure-causing activity should with great certainty cause more overall benefits than harm/risk; and
- Individual protection, meaning that even when the two previous principles are met at population level, each individual must also be independently protected from any undue harm.

Table 3. Commonalities and differences for indoor and outdoor sources, and individual activities  
Possibilities for policy action: ++ strong possibilities, + possibilities, (+) weak possibilities, – not feasible

<b>Policy alternatives</b>	<b>Outdoor microenvironments</b>	<b>Indoor microenvironments</b>	<b>Personal activity</b>
Air quality standards and guidelines	++	+	–
Source control and dilution control	++ Traffic control measures (e.g. pedestrian zones)	++ Building codes and ventilation regulations. Regulations on building and consumer products, Smoking restrictions	+ Car inspections and emission controls. Wood stove catalyst requirements (e.g. in Oregon)
Information/education	+ Air quality warnings/predictions	+ Ventilation, behaviour; smoking, heating, cooking, product use, warning labels	+ General risk communication
Market-driven instruments (taxes, other)	+ e.g. emissions markets for acid rain precursors in US	++ “Eco” labelling of products, bans	+ Tobacco taxes, Traffic fuel taxes, Car pooling

A number of possibilities for policy action already exist (see Table 3). Considering that different administrative instruments exist for outdoor and for indoor microenvironments (compare with Table 2), they may be divided into instruments suitable for outdoor and for indoor microenvironment related actions. In both types of microenvironment, personal activities may determine the resulting exposures. Internalization of external costs and cost-benefit analysis are tools that may provide further insight necessary for priority settings.

Based on the above analysis, the following recommendations may be made.

- To efficiently reduce health risks from air pollution exposures, air quality management should be based on exposure and risk assessment, accounting for all sources, microenvironments and common activities.
- Exposure-based air quality management and the present ambient-based strategies are built upon the same principles. For the exposure-based assessment, however, additional information is needed, and microenvironmental and individual factors are weighted in a different manner.
- In the face of emerging information on relations of exposure to ambient pollution levels and on dose/response relationships, as well as on microenvironment concentrations and targeted subgroup exposures, the air pollution regulations need to be expanded and amended. An overall policy strategy for air quality management should be part of an integrated sustainable development strategy including public health; it should be combined with decision models, cost-benefit and cost-effectiveness analyses. It should be more

proactive than reactive and endorse precautionary as well as preventive principles. Finally, it should also include preparation and dissemination of information, and recommendations for the general public in a systematic way.

*Annex 1*

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Andre Zuber	European Commission Brussels, Belgium

### **Observer**

Roger Alesbury	BP plc Middlesex, United Kingdom
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### *World Health Organization Regional Office for Europe*

Günter Klein  
WHO European Centre for Environment and Health, Bonn Office,

Michal Krzyzanowski, Air Quality and Health  
WHO European Centre for Environment and Health, Bonn Office

### *Meeting Secretariat*

Elizabeth McCall, WHO European Centre for Environment and Health, Bonn Office

*Annex 2*

**WORKSHOP PROGRAMME**

**Monday, 14 October 2002**

Opening (9:00–9:25)

Chair: Matti Jantunen

Rapporteur: Alena Bartonova

- Opening and Welcome
  - Günter Klein and Michal Krzyzanowski, WHO Bonn
  - Emile de Saeger, JRC
  - Christian Cochet ECA
- Recollection of the conclusions from the Thessaloniki-Workshop, April 2000: “Urban Air, Indoor Environment and Human Exposures – Future needs for Policy-Science Interface in the EU” (*Thomas Lindvall, Karolinska Institute*)

Session I: Exposure Assessment from a Health Perspective (9:25–10:55)

Chair: Dimitrios Kotzias

Rapporteur: Alena Bartonova

- Why should exposure assessment play a role in urban air quality management? Reflections from a health perspective (*Heather Walton, Dep. of Health, United Kingdom*)
- Exposure domains: role of timing, pattern and magnitude of exposure on health risks (*John Vandenberg, USEPA*)

***Discussion of session I***

*Coffee Break (10:55–11:15)*

Session II: Air Quality Managers’ Perspective (11:15–12:45)

Chair: Kirk Smith

Rapporteur: Emilia M. Nicu

Topic: What tools exist for urban air quality managers to effectively and efficiently reduce human exposure to harmful air pollutants in both indoor and outdoor air: views of international, national and local level representatives

Leading Question: What would be the exposure information needed in order to formulate and evaluate policy options and mitigation strategies regarding exposures to outdoor sources, indoor sources and individual-level activities and related health effects?

- Representative of EC JRC (*Emile de Saeger, JRC*)
- Clean Air For Europe and the EU air quality thematic strategy (*Andre Zuber, EC Env*)

- Air Quality Management in Switzerland – BUWAL (*Gerhard Leutert, Swiss Agency for the Environment, Forests and Landscape, Bern*)
- Indoor air exposure research and actions on IAQ in California (*Jed Waldman, California Dept of Health Services, Berkeley*)
- Regional AQ Manager perspective (*Peter Bruckmann, NRW Env. Agency, Essen*)

### ***Discussion of Session II***

*Lunch (12:45–13:45)*

Session III: Exposure Assessors' Perspective (13:45–15:15)

Chair: Lars Molhave

Rapporteur: Peter Straehl

Topic: Overview of current exposure assessment applications and their use in the light urban of air quality management

Leading question: Why should total exposure to specific air pollutants in different environments and from different sources be assessed and what would be the advantage to public health resulting from air quality management based on total exposure assessment versus the traditional approaches?

- Predicting indoor pollutant concentrations: Applications to air quality management (*David Lorenzetti, Laurence Berkeley National Laboratory, Berkeley*)
- Applications to describe population exposure distributions (*Alena Bartonova, NILU*)
- Contributions of sources to indoor, outdoor and total personal exposure levels: assessment and application in air quality management (e.g. receptor models; source apportionment, CMB) (*Matti Jantunen, KTL*)
- Contribution of traffic emissions to air quality in urban areas (*Meno Keuken, TNO*)

***Discussion of Session III:*** Strengths and limits of the presented applications for air quality management, policy implementation and follow up

*Coffee Break (15:15–15.35)*

Session IV: New Ideas for Urban Air Quality Management (15:35–17:35)

Chair: Berndt Seifert

Rapporteur: Nikolaos Stilianakis

Topic: New ideas for urban air quality management, in particular regarding indoor sources and individual level activities.

Leading Question: Which situations require individual level exposure data or indoor monitoring air quality data, when is modelling most effective and when would ambient monitoring be sufficient?

- Population exposure calculations using air quality management systems: Example: AirQuis used in Oslo (*Steinar Larssen NILU*)

- Concept of intake fraction and its potential for regulation (*Kirk Smith, University of California, Berkeley*)
- Fine Particulate Air Pollution in the US: A Preliminary Analysis of the Value of Research (*Andrew Wilson, Harvard*)
- Cocktail Effect in Risk Assessment (CeIRA): Exposures – Biomarkers – Interactions. Report from Platform Conference of 27 May, Brussels (*Ingvar Andersson, EEA*)

***Discussion of Session IV ('30)***

**Tuesday, 15 October 2002**

Session V: Policy Options for Actions (9:00–10:15)

Chair: Thomas Lindvall

Rapporteur: Peter Wouters

Topic: Current and future policy options to advice on the main actions, which can be recommended using current understanding of health effects of exposures to air pollutants in indoor and outdoor environments, and its determinants.

Leading question: How could current policies regarding outdoor air pollution be complemented in order to take account of indoor sources and individual-level activities?

- Europe – Indoor Limits: DG SANCO funded IndEx-project (*Marc Seguinot, EC Sanco or Dimitrios Kotzias, JRC*)
- Approach to address indoor air issues in Switzerland (*Roger Waeber, BAG, CH*)
- California's sustainable building effort in state government indoor air quality specifications for open office systems furniture and building materials (*Leon Alevantis, California Dept of Health Services, Berkeley*)
- The economics of good Indoor Air Quality (*Sten Olaf Hanssen, Norwegian University of Science and Technology*)

*Coffee Break (10:15–10:30)*

***Discussion of Session V (10:30–11:00)***

Definition of final tasks and titles for the two Working Groups and formation of two working groups for session VI & VII (11:00–11:15).

Session VI: Working Groups Discussion (11:15–12:45)

- Group 1: What exposure assessment tools are ready for application in urban air quality management? Discussion of commonalities and differences for indoor and outdoor sources and individual level activities

Chair: Erik Lebret (RIVM)

Rapporteur: Lucy Oglesby (Basel Univ.)

- Group 2: What are the urban air quality policy alternatives? Discussion of commonalities and differences for indoor and outdoor sources and individual level activities.

Chair: John Vandenberg(US EPA)

Rapporteur: Stylianos Kephelopoulos (JRC)

*Lunch Break (12:45–13:45)*

#### Session VI: Working Groups – Proposals for Recommendations

- Group 1: What tools can be recommended for urban air quality management: commonalities and differences for indoor and outdoor sources and individual level activities?

Chair: Erik Lebret

Rapporteur: Lucy Oglesby

- Group 2: What policy strategies can be recommended: commonalities and differences for indoor and outdoor sources and individual level activities?

Chair: John Vandenberg

Rapporteur: Stylianos Kephelopoulos

*Coffee Break (15:15–15:30)*

#### Session VII: Recommendations and Conclusions of the Workshop

Chair: Matti Jantunen

Rapporteur: Alena Bartonova

- Presentation of the proposed recommendations and conclusions drafted by WG 1
- Presentation of the proposed recommendations and conclusions drafted by WG 2
- General Discussion
- Adoption of Recommendations and Conclusions

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