Exposure Risks from Pollutants in Domestic Environments: The Urban Exposure Project

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Abstract
The Urban Exposure Project is an EU funded project to produce a state of the art, user-friendly management decision software tool for administrators to help them quantify and deal with the real health risks associated with pollution in urban environments. The project, which began in December 2002 will run for 3 years and will quantify the relationship between outdoor pollution measurements and actual exposure suffered by people in urban indoor environments. The resulting product will be extensively field tested in 2 European urban centres before being made available to administrators.

This paper gives an overview of the project and a summary of its achievements at the end of its first year.

Introduction
Airborne pollutants are recognised as a major cause of health problems in Europe. Most adverse health effects come from pollutants in the form of airborne particulate matter or aerosols. However the health risks from these aerosol pollutants are poorly understood. Legislation has been made at various levels to attempt to control the risks but is often based upon available technology, i.e., what it is possible to measure conveniently rather than what is most damaging and difficult to implement because of a lack of information on best practice.

Various regulations and guidelines have been
published attempting to limit human exposure to potentially harmful particulates in particular The Air Quality Framework Directive 96/62/EC [1] and World Health Organisation 2000 Air Quality Guidelines for Europe, 2nd edition [2]. These standards are based upon exposure to pollutants measured outdoors. The problem is that in urban environments, most people spend most of their time indoors – at home or at work. This raises the questions of how do particulate concentrations from outdoor sources translate into concentrations inside a building and what are the indoor sources of particulates and what concentrations result from these in indoor air?

Both of these questions lead to others such as how the measured concentration translates into exposure; what this means, in terms of the risk of adverse health effects to real people and how should governments – local, regional and national – manage these risks?

The first 2 questions were addressed by an EU funded project called Urban Aerosol (EU contract number EVK4-CT-2000-00018) carried out by a consortium of European universities and research institutes including the Aerosol Science Group at the University of Essex. Urban Aerosol aimed to measure and characterise the concentration and chemical composition of aerosols in indoor and outdoor urban locations across the EU (see, for example [3] and the project web pages [4])

The specific aims of the project were:

- to characterise chemically the particulate matter (PM) associated with actual human exposure in selected residential European urban areas;
- to provide an integrated European exposure assessment database for urban PM characterisation through indoor/outdoor monitoring and modelling;
- to study and evaluate the mechanisms controlling the outdoor/indoor relationships of PM by taking into account infiltration, meteorological conditions, indoor sources of PM, physical and chemical processes indoors, and the composition/size distribution of indoor generated PM, by using mechanistically based models;
- to link human exposure to PM indoors with physiologically based mechanistic dosimetry models.

The results from the project based on a mid-term assessment report (unpublished) can be summarised as

- preliminary results from indoor/outdoor measurements show the importance of specific indoor sources on the concentration of air pollutants inside a house;
- the variability in a room without major sources of particles is small compared to the outdoor concentration;
- particle number concentration characteristics indoors is correlated with outdoor concentration characteristics in the absence of important indoor sources;
- the infiltration rate is the most important function which determines the indoor-outdoor exchange and is well correlated with meteorological conditions and house use;
- the variability of the human respiratory tract is an important factor which determines the deposition of particulate matter in humans;
- comprehensive dosimetry tools have been developed during the project. A comprehensive indoor/outdoor model has been developed for determining the dynamics of pollutants indoors and can be used as an early warning tool in cases of severe outdoor pollution events.

The subsequent questions about exposure, risk and management are being addressed in a project called Urban Exposure, which began at the end of 2002. A new consortium was formed to undertake this project consisting of members of the Urban Aerosol project with the addition of toxicologists, epidemiologists and a public health authority.

The aim of the project, which will last 3 years, is to build upon the data gathered in the Urban Aerosol project to investigate the toxicological and epidemiological effects of indoor and outdoor pollution in urban environments. In addition to particulate pollution, a study will also be made of the effects of by products of drinking water disinfection. These data will be used to develop and implement integrated modelling tools for calculating exposure through inhalation and through dermal adsorption for compounds relevant to air pollution.

**Methodology**

Internal doses of particulate matter and gaseous pollutants will be estimated using a new model for inhalation, which will be based on a mechanistic description of particle dynamics in the human respiratory tract. The inhalation dosimetry component to be used in combination with the proposed micro-environmental model for particulate matter and gaseous pollutants will provide a new and integrated exposure and dosimetry assessment approach for human receptors indoors. Realistic development of dosimetry modelling for the human inhalation exposure...
to air pollutants is an important step for understanding the complete exposure-dose-response relationship [5-7]. Determination of the particle deposition efficiency at different parts of the human respiratory tract will provide information and characterisation for the first step of the relationship between exposure to particulate matter and toxicological response in human subjects. Therefore, integration with dosimetry modelling will provide useful information to link exposure to internal dose and human health and furthermore will determine variability in dosage associated with (a) different components of the particulate matter and (b) different physiological attributes of individuals. In this dosimetry model the Aerosol General Dynamic Equation is solved numerically during inhalation using a discrete-nodal point method for describing the particle size distribution. This model incorporates explicitly the mechanisms of nucleation, condensation, coagulation, convection and deposition of gases and particles, as well as a module for considering gas phase reactions. The model predicts the evolution of the size distribution and composition of inhaled particles and their deposition characteristics for each generation of the human airways. The model has modular structure and the user has the flexibility to include or exclude specific physical processes in a particular simulation.

**Results and Discussion**

Urban dwellers are exposed to a multitude of air pollutants of many origins. Some of the pollutants that are present in the air can have important routes of exposure other than inhalation. Examples of pollutants where it is necessary to consider multiple pathway exposures are heavy metals (e.g., lead), or some organic compounds (e.g., polychlorinated biphenyls, dibenzodioxins and dibenzofurans). Chloroform, which is a water disinfectant by-product present in municipal tap water and in swimming pools, is one such compound having multiple pathways. Previous epidemiological studies of the indoor environment have considered only tap water as a chloroform source [8–11]. Another important source of chloroform is the ocean. One of the main objectives of the proposed project is to develop a more sophisticated approach for the estimation of dermal uptake by extending what are known as lumped parameter models (LPM) [12,13] through the use of a distributed parameter skin compartment in order to deal with spatial variability. The proposed distributed parameter model (DPM) will account for accumulation in the skin’s barrier layer, the stratum corneum, based on the intrinsic properties of this tissue [14,15] and on fundamental equations of transport phenomena. The DPM will be parameterised for chloroform, and will be compared with 2 LPM models in which the skin is represented by 1 and 2 compartments. The 3 models will be identical in all respects except for the representation of the skin and the processes associated with dermal absorption.

The modelling framework is intended to be modular and very flexible to offer the possibility of evaluating a variety of exposure scenarios. Figure 1 below depicts the environmental framework within which the exposure modelling modules will be built. The final result will be a European exposure database available on a public access website and management decision software tools to enable local authorities to assess the risk presented by measured air pollution levels and act accordingly. The tools will have a geographical information system (GIS) type interface, which is essentially a map from which spatial distributions of pollution sources, monitoring stations, measurement, model results and other geographically linked information can be presented. Two local authorities in urban locations in the EU have volunteered to act as guinea pigs to test the “product” in the last year of the project. The management decision software tool will then be disseminated by arranging demonstrations to interested parties in Europe.

The reasons behind the project – apart from scientific curiosity – lie in EU regulations and goals. The Treaty of Amsterdam (EU Art. 136) sets out objectives for social policy in the EU, which include both improved living and working conditions. Articles 35 and 37 of the EU provide for a high level of human health protection and protection and improvement of the environment. In addition, one of the priorities set in DG Environment “Clean Air for Europe” is to address problems associated with particulate matter. There are also provisions for the provision of safe drinking water: however there are concerns regarding the by-products of the disinfection process.

In order to help in achieving these goals, information concerning concentration and chemical characteristics of particulate matter and gaseous pollutants in urban areas and in indoor air will be used to assess actual human exposure characteristics. The aim is to quantify the correlation between the complex system of human indoor exposure and outdoor monitoring measurements. This will enable governments to quantify risks and hence costs associated with urban air pollution and ultimately to produce abatement strategies.

The end product of this project – the management
decision software tool – will take into account exposure in the outdoor and indoor environment. The main emphasis will be on inhalation of particulate matter but it will also be calibrated for inhalation and dermal adsorption of chloroform as an indicator of drinking water disinfection by-products. The tools will be validated in 2 in-depth case studies in Oslo and Katowice.

In order to have any value for decision making, tools available to administrators must be easy to use. To achieve this, the aim is to integrate any tools developed into the existing AirQUIS air quality management system (AQMS). This system has been successfully implemented in several European cities (including Stockholm and Bucharest) after selection in open competition. It has also been used in several urban areas in Asia in development projects funded by NORAD and the World Bank. The project is dedicated to serve the real needs of end users through a combination of scientific excellence and emphasis on user friendliness. To help achieve this, a user panel will be enlisted consisting of 9 representatives from ministries or local government across the EU, including Essex County Council in the UK. The user panel will advise on policy relevance and general direction of the project and individual case studies. It will also help in the dissemination of information at the end of the project and make suggestions for further research, development and implementation at a local level.

Along with the final “product” information from the project will be disseminated through the usual channels of peer-reviewed articles and conferences.

We expect 2 detailed case studies and 4 smaller “demonstration” studies to be completed by mid-2005. The database website should be online and the management software available as a stand-alone product by the end of that year.

**Progress**

The project has been broken down into various work packages (WP) consisting of the following:

- WP 1 Project Management
- WP 2 Management tools interface
- WP 3 Development of the Environmental Modules for Human Exposure
- WP 4 Validation of the Management Tool and its Scientific Components
- WP 5 Comprehensive Case Studies in a European Framework
- WP 6 Demonstration of the Management Tool to End Users
- WP 7 Dissemination and Exploitation

At the end of its first year the project is on schedule with all milestones and deliverables having been met. Specifically the following objectives have been achieved.

For WP 2 a description of alternative interfaces between AirQUIS and the modules (see WP3 below) has been developed.

WP 3 consisted of 4 sub tasks:

![Image](14(3)IBE054017(q).pdf)
WP 3.1 Statistical Exposure Tool
WP 3.2 Integrated Micro Environmental Model
WP 3.3 Inhalation Dosimetry
WP 3.4 Dermal Absorption

All of these are now largely complete and a further sub task WP 3.5 Module Connectivity will be the subject of a technical meeting in the near future.

A validation framework for WP 4 has been agreed and AirQUIS is currently being installed in Oslo and Katowice to carry out the case studies for WP 5. The case studies will begin towards the end of 2004. Dissemination and exploitation (WP 7) has consisted so far of the production of a project leaflet and website along with the publication of various articles and conference presentations (see [16,17]). Once the case studies at Oslo and Katowice are complete a series of demonstration studies and workshops throughout Europe is planned. In addition a comprehensive survey of chloroform and other drinking water disinfection by-products has been carried out to feed into the dermal absorption module.

References

1 The Air Quality Framework Directive 96/62/EC.
4 http://www.nilu.no/projects/urban-aerosol.