

Modelling Concentrations of and Human Exposure to Air Pollution in Danish Cities

Contribution to subproject SATURN

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Summary

Transport-chemistry models are strong tools for evaluation of emission reduction strategies, for providing information to the public, and as the central part of models for calculation of human exposure and for forecasting episodes. The NERI has developed two systems for such predictions. AirGIS is a GIS based system for human exposure modelling. THOR is an air pollution forecasting system that provides 72-h air pollution forecasts four times a day for three different scales: rural areas, urban background and street level. The forecasts from the THOR system are available at www.dmu.dk/AtmosphericEnvironment/thor. AirGIS was developed for automatic generation of needed input parameters from digital maps and register data for carrying out mapping of street pollution levels e.g. in entire urban areas using the street pollution model OSPM. Various human exposure studies have been and are being carried out in Denmark and serve the basis for the further model development and validation. Personal monitoring of particulate matter indicates that exposure to indoor air pollution plays an important role for the personal exposure to PM_{2.5}. The next few years the AirGIS system will be applied for calculating human exposures of cohorts in ongoing and historical epidemiological studies in Denmark. A description of the methodologies used in the Danish exposure studies is available on www.dmu.dk/AtmosphericEnvironment/Exposure.

Aim of the research

The main objectives are to further develop air quality models for urban streets, integrate these models in pollution forecasting systems and in comprehensive GIS based systems for regulative purposes, and extend these integrated systems with modules for estimating human exposure to air pollution. An important task is to characterise and model street scale particle pollution. The traffic (Operational Street Pollution Model – OSPM (Berkowicz et al., 1997)) and urban background (Urban Background Pollution Model – UBM (Berkowicz, 2000)) pollution models developed at NERI constitute the basic tools. Further development and validation of the street pollution forecasts from the NERI THOR system is another important element. THOR is based on meteorological data from the Eta weather prediction forecast model and air pollution forecast on regional scale from the Danish Eulerian Operational Model (DEOM), on urban scale from the UBM and finally on street scale from the OSPM. Another part of the project concerns determination of human exposure for assessment of health effects of traffic air pollution. Personal monitors for fine particles and nitrogen oxides are applied for use in connection with field studies in Danish cities. The results are evaluated with the aim of further developing the integrated model AirGIS based on OSPM and GIS.

Principal results

In a monitoring study, personal exposure to particles (PM_{2.5}), and nitrogen dioxide and in one campaign also BTX was monitored during four seasons for 50 students in Copenhagen. For 30 of the students, monitoring was furthermore performed at the front door of their residence and in the bedroom inside the residence. The particles were sampled by using a KTL PM_{2.5}

cyclone, BGI400 pump (flow 4 L/min and weight 0.6kg) (both from BGI in the USA) and battery for 48-h operation (weight 2.1kg). The equipment for the personal sampling was placed in a backpack carried by the study subjects. The equipment for the indoor sampling was installed in a plastic box placed on the floor in an open spot. The same box was used for outdoor sampling undertaken from old bicycles (bought at low cost from police auctions). Students handled setting up and taking down the equipment. Sampling was performed on a 37mm Teflon filter. Before and after the sampling the filters were weighted after conditioning for 24 h in the laboratory. Detection limit was found to be about 18 μ g (three times the standard deviation on blanks) - typically 5-20% for the performed samples. The nitrogen dioxide was measured using Radiello passive samplers. Thiethanolamine is used as substrate, and absorbs nearly 100% nitrogen dioxide and converts it to nitrite. The nitrite is analysed on segmented flow analyser using Saltzman's reagent, followed by spectrophotometric detection at 540 nm. Sampling was performed for 2-days periods for each study objects. The last 24-h urine was sampled in a plastic container and at the end of the campaign, blood samples were collected. Blood and urine samples were analysed for various biomarkers at Copenhagen University.

A Global Positioning System (GPS) was used together with a diary to trace the route of the study subjects during the campaigns. Until autumn 2000 a distortion was put on the satellite signals and therefore the GPS was only accurate within 50 to 100m. This was insufficient for our purpose and in the first three campaigns a Spot-FM corrector system developed by the Danish National Survey and Cadastre was applied in order to ensure accuracy within few meters. The Spot-FM was power demanding, which made it necessary to include a battery pack of extra 3kg. In May 2000 the distortion was removed from the satellite signals and the Spot-FM was therefore not used in the last campaign. The results from the GPS will be used together with the personal exposure data in testing and further developing the AirGIS system.

The indoor and personal monitored PM_{2.5} show a strong correlation, indicating that indoor concentrations play a significant role for the personal exposure (Figure 1). The correlation between indoor and outdoor PM_{2.5} is weak (Figure 1b). It should be noted that the Danish population spends about 90% of the time indoor and the campaign took place during a period with rather cold weather. Relationships between particle exposure and response in biomarkers are still being analysed, and the modelling part has just been initialised.

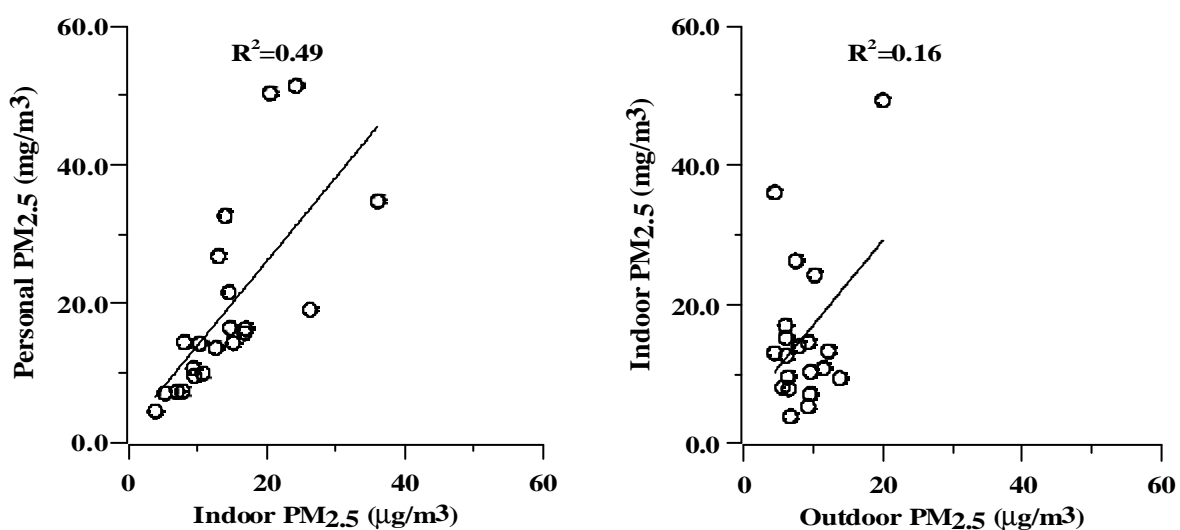


Figure 1. Comparison of personal exposure and indoor concentrations of PM_{2.5} during the second monitoring campaign in the Danish exposure study. The correlation 0.12 is for all data and 0.66 is when an outlier (placed outside the plot) is disregarded.

The data from the THOR system at www.dmu.dk/AtmosphericEnvironment/thor were made available for the public in 2000. The system generates 72-h pollution forecasts 4 times a day for pollution levels at three scales: rural areas, urban background and street level. The first street pollution forecasts were performed for Jagtvej in Copenhagen. In 2001 a number of streets in Aalborg in the northern part of the country were added to the system. An example of a comparison with measurements from the monitoring stations at Vesterbro in Aalborg with results from pollution forecasts produced by THOR is shown in Figure 2.

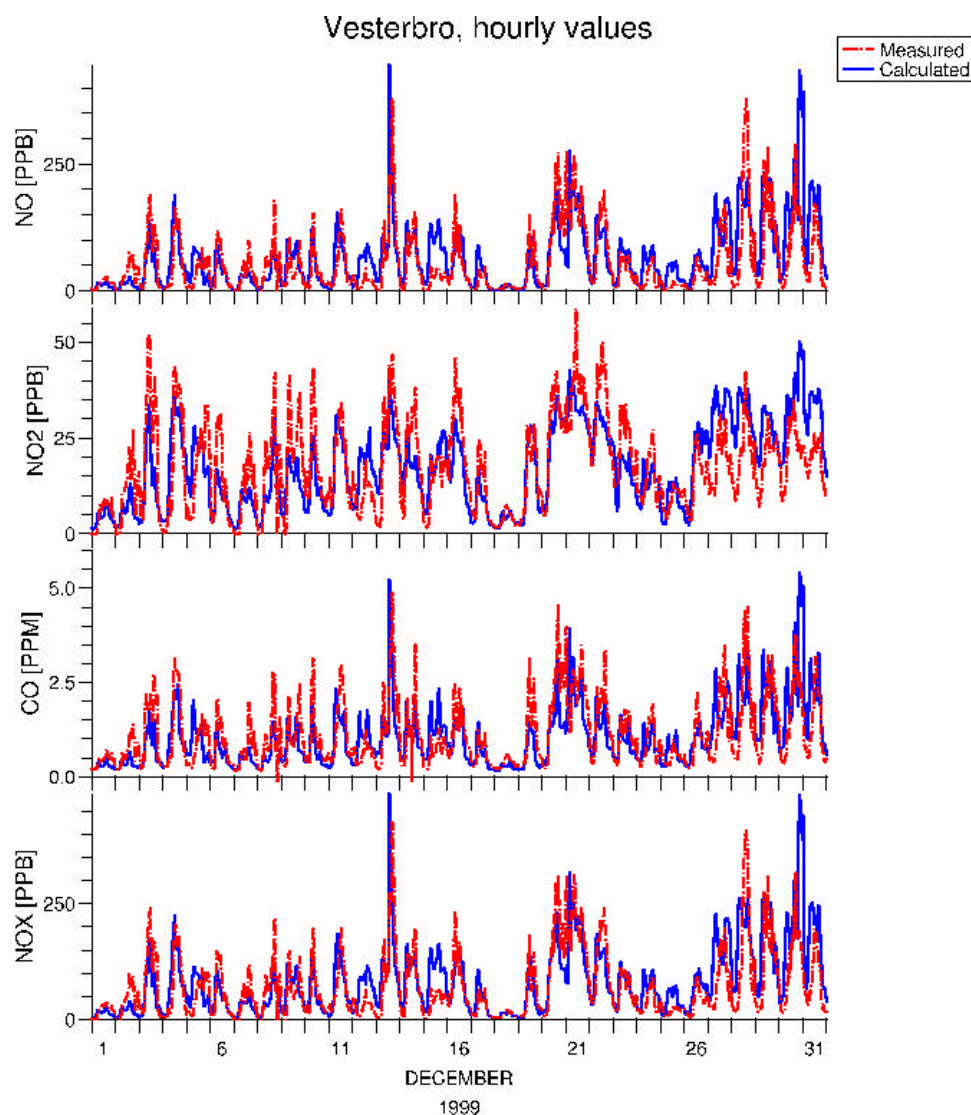


Figure 2. Comparison of prognoses from the THOR system with measurements from the street pollution station in Vesterbro, Aalborg.

Perspective

Studies on personal exposure to particle pollution and the possible link to health effects will be further explored in a series of Danish research projects over the next years. These projects will take advantage of a number of large ongoing epidemiological studies to address the most pertinent aspects of the health effects related to exposure to traffic generated air pollution, in particular particles. Modelling (application of AirGIS) will be used for exposure assessment, mainly in Copenhagen and surroundings. The health related studies include:

- Annoyance and symptoms in relation to exposure to air pollution from road traffic will be addressed for 20,000 people in the National Health Survey 2000.

- The risk of acute morbidity and mortality of cardiovascular and pulmonary diseases requiring admission to hospital is addressed in relation to traffic generated air pollution at the residence, workplace and commuter route. Nested case-control and time-series design is applied in four large population studies in Copenhagen providing a population at risk of approximately 25,000 (the Copenhagen Male Study, Copenhagen City Heart Study, Diet and Cancer Study and Glostrup Study). Exposure assessment will be particularly detailed by data from an ongoing measurement campaign of individual exposure.
- Intrauterine growth retardation and prenatal/infant mortality will be addressed in relation to exposure to traffic-related air pollution at the residence of 15,000 pregnant women from the Danish National Birth Cohort.
- Exposure to traffic generated air pollution as a causal factor in asthma development will be addressed by individual measurements of exposure to fine particles, NO_x and carbonyls (acetone, formaldehyde and acetaldehyde) in a study of 400 infants at high risk of asthma development (COPENHAGEN Study of Asthmatic Children)
- The development of self-reported asthma and bronchitis in relation to exposure to traffic generated air pollution at the small area level will be studied in a health survey conducted on 3000 persons from the Glostrup Study.

A large number of health effects of traffic generated air pollution are suspected. However, quantitative estimates required for risk assessment and management are extremely difficult due to lack of data and/or difficulties with extrapolating data from other geographical areas and time periods with large differences in composition of air pollution. Moreover, so far very few and mainly small studies have attempted to assess individual exposures and provide necessary confounder control.

Since particle concentrations in urban environments are only scarcely described, a series of projects will look into characterisation of particle pollution and establishing relationships between indoor and outdoor pollution levels. Palmgren and Wåhlin (this report) describe the particle characterisation projects in the work package.

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