Modelling of Particulate Matter and the Exposure of Population to Air Pollution in Urban Areas - Annual Report 2001

A contribution to subproject SATURN

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Summary

This contribution addresses the modelling of urban particulate matter concentrations, the evaluation of models against field-scale data sets and the development of a population exposure model. We have evaluated quantitatively the influence on aerosol evolution of various chemistry and aerosol processes, utilising an aerosol dynamical model MONO32. We have developed a semi-empirical model for evaluating the urban PM_{10} concentrations. A modelling method was also developed for predicting the urban $PM_{2.5}$ concentrations. The evaluation of the OSPM model against the dataset measured in Runeberg St. has been published in cooperation with NERI. The evaluation of the CAR-FMI model against a field dispersion dataset in a roadside environment has been published. Graz University of Technology, Austria, and Finnish Meteorological Institute (FMI) have jointly evaluated also the predictions of the Lagrangian dispersion model GRAL against this data set. The model EXPAND ("EXPosure to Air pollution, especially Nitrogen dioxide and particulate matter") has been developed for the evaluation of population exposure.

Aim of the research

The project aims to extend the existing modelling system (Karppinen et al., 2000a,b, Kousa et al., 2001) to allow for urban particulate matter and the exposure of population to air pollution. Two field-scale datasets have been produced and utilised in the evaluation of model performance.

Activities during the year

The work includes the following items:
1. Modelling of aerosol processes in vehicular exhaust plumes in urban areas,
2. Publishing of a semi-empirical model for evaluating urban PM_{10} concentrations,
3. Developing of a modelling method for evaluating urban $PM_{2.5}$ concentrations,
4. Evaluation of emission and dispersion models against two field scale data sets and
5. Refinement and publishing of a population exposure model.

Mr. Ari Karppinen has completed his doctoral dissertation, part of which has been a contribution to SATURN (Karppinen, 2001).

Principal results

Modelling of aerosol processes in urban environments

We have applied an aerosol dynamical model MONO32, developed by Pirjola and Kulmala (2000), in cooperation with the University of Helsinki. The model takes into account gas-phase chemistry and aerosol dynamics, and includes the following processes: (i) chemical reactions in the gas phase, (ii) the dry deposition of particles and gases, (iii) homogeneous binary H_2SO_4-H_2O or ternary H_2SO_4-H_2O-NH_3 nucleation, (iv) the multicomponent condensation of H_2SO_4, H_2O, HNO_3, NH_3 and some organic vapor onto particles, and (v) the inter- and intramode coagulation of particles. The particles can be classified into four different size modes which are monodisperse.

We have compiled a number of vehicular exhaust scenarios in selected urban environments. The model input data includes vehicular exhaust particulate matter size distribution and chemical composition, and urban particulate matter and gaseous urban background concentrations. We have evaluated quantitatively the influence on aerosol evolution of various chemistry and aerosol processes, and written a draft of a journal article that describes the main results.

A semi-empirical model for evaluating urban PM_{10} concentrations

We have developed a model for evaluating the PM_{10} concentrations of urban particulate matter. The basic model assumption is that local vehicular traffic is responsible for a substantial fraction of the street level concentrations of both PM_{10} and NOx, either due to primary or secondary emissions. The performance of the above-mentioned semi-empirical PM model was evaluated against measured PM_{10} data (Kukkonen et al., 2001c).

The model has been applied and evaluated also in several other cities nationally. With a re-evaluation of a few parameters that can be determined empirically, the model could be evaluated and most likely applied in urban areas in other countries.

Developing of a modelling method for evaluating urban $PM_{2.5}$ concentrations

A modelling method was developed and applied for predicting the urban concentrations of $PM_{2.5}$. The regionally and long-range transported contribution is evaluated based on a semi-empirical mathematical model; the model utilises as input values the daily sulphate, nitrate and ammonium measurements at the EMEP stations. The influence of primary vehicular emissions from the nearest roads is evaluated using a roadside emission and dispersion model CAR-FMI (e.g., Härkönen et al., 1995, Kukkonen et al., 2001b), used in combination with a meteorological pre-processing model MPP-FMI (Karppinen, 2001).

The modelling system was tested by comparing the predictions with the data from a fine particle measurement campaign that was conducted in suburban environment near a major road in Kuopio, Central Finland from August 3 to September 9, 1999. This campaign was performed by the University of Kuopio. The comparison of the predicted results and measurements yields information on the relative importance of various source categories on the measured concentrations of $PM_{2.5}$.

Two journal articles have been submitted that describe the modelling system and its evaluation against data measured in the cities of Kuopio and Helsinki. The model presented could also be

applied in other European cities for analysing the source contributions to measured fine particulate matter concentrations.

Evaluation of emission and dispersion models against two field scale data sets

We have developed a modelling system for predicting the traffic volumes, emissions from stationary and vehicular sources, and atmospheric dispersion of pollution in an urban area (Karppinen et al., 2000a,b). We have compared the NO_x and NO_2 concentrations predicted using this modelling system with the results of an urban air quality monitoring network (Kousa et al., 2001).

The processing of the field dispersion dataset during a so-called intensive measurements period in the street canyon Runeberg St. in Helsinki has been completed. The evaluation of the street canyon dispersion model OSPM against this dataset has been published by (Kukkonen et al., 2001a). This work has been cooperation with NERI (National Environmental Research Institute, Denmark). The dataset is properly documented and it is available for evaluation of other street canyon dispersion models.

A field dispersion dataset in a roadside environment in Elimäki in Southern Finland, and the evaluation of the CAR-FMI model against this data has been published (Kukkonen et al., 2001b). Graz University of Technology, Austria, and FMI have evaluated a Gaussian finite line source dispersion model (CAR-FMI) and a Lagrangian dispersion model (GRAL) against this data set (Öttl et al., 2001).

Refinement and publishing of a population exposure model

The model EXPAND ("EXPosure to Air pollution, especially Nitrogen dioxide and particulate matter") has been developed for the evaluation of population exposure, and the computed results are processed and visualised using the Geographical Information System (GIS) MapInfo. The main objective was to evaluate the exposure of population with a reasonable accuracy, instead of the personal exposures of specific individuals. We also evaluate directly only the exposure to ambient air pollution.

The population exposure model consists of two parts: exposure in traffic and exposure elsewhere (work, home, other). The exposure in traffic is computed separately for each street section, and the exposure elsewhere is computed in a grid with spatial resolution of 100 m. The population exposure model has been applied in the modeling of population exposure to NO_2 in the Helsinki Metropolitan Area (Kukkonen et al., 2001f).

This work has been cooperation of YTV (Helsinki Metropolitan Area Council), and National Public Health Institute. The model developed has been designed to be utilised by the municipal authorities in urban planning, e.g., for evaluating impacts of future traffic planning and land use scenarios. We have submitted a journal article that describes in detail the structure of this model and presents examples of its application.

Aims for the coming year

A more detailed simulation of the PM_{10} and $PM_{2.5}$ concentrations in the Helsinki Metropolitan Area, and the related model development. The computed PM concentrations will be compared

with the measured data from the YTV monitoring network, and with those measured in the EXPOLIS project.

We will continue the work for evaluating the influence of various chemistry and aerosol processes on the evolution of urban aerosol, using the aerosol dynamical model MONO32.

Refinement and testing of the population exposure model EXPAND. We aim to extend the model, e.g., to evaluate the indoor-outdoor concentration ratios.

Publication of the evaluation of the OSPM model against the whole year of data (1997) measured in Runeberg St. in Helsinki.

Publication of the new version of the CAR-FMI model, including the extension of the model for particulate matter.

Publication of the papers that describe the modelling system for evaluating urban fine particulate matter concentrations.

The SATURN work will be closely linked to a new project called “Health Effects caused by Urban Air Pollution for the Transport System Plan Scenarios in Helsinki Area – HEAT”, 2002 – 2004. Funding for this project has been grated by the Academy of Finland. For more details, please see http://www.fmi.fi/research_air/air_18.html.

References

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