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MODEL CALCULATIONS TO ESTIMATE URBAN LEVELS OF PARTICULATE MATTER IN OSLO, WITH RESPECT TO THE REQUIREMENTS OF THE EU DIRECTIVES

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ABSTRACT

During the winter and spring seasons, Norwegian cities are susceptible to poor air quality events that can lead to concentrations in exceedence of limit values. Such events typically take place during periods with strong temperature inversions, weak winds and little vertical mixing. For particulate matter, these episodes are enhanced during cold and dry conditions when emission of particulates from domestic wood burning and from traffic induced resuspension are at their highest. This paper presents a validation of model calculations for PM_{10} in the city of Oslo, 2003, as part of a larger study concerning recommended emission scenarios for 2010 and 2015. It discusses the problems in modelling the emission source associated with traffic induced resuspension as well as other areas of uncertainty in the modelling results.

1. INTRODUCTION

During the winter and spring seasons, Norwegian cities are susceptible to poor air quality events that can lead to concentrations in exceedence of limit values, as defined in the Council Directive 1999/30/EC (EC, 1999). Such events typically take place during periods with strong temperature inversions, weak winds and little vertical mixing. For particulate matter, these episodes are enhanced during cold and dry conditions when emission of PM from domestic wood burning and from traffic- induced resuspension are at their highest. In recent years air quality limit values has been exceeded at several measurement sites in Oslo.

The problem of PM emission by traffic resuspension is compounded in Scandinavian cities by the use of studded tyres, which produce a large reservoir of dust particles during their wintertime use as well as enhanced emission from impact with road surfaces. This reservoir is made available for resuspension when road surfaces become snow and water free, typically in spring but this can also occur during winter. This problem has been reduced in Norwegian cities by introducing a tariff for the use of studded tyres. The number of cars using studded tyres during wintertime has been reduced from 50% to 30% from 1998 to 2003.

Since PM is considered to be an important contributor to human health the Norwegian Pollution Control Authority have examined the consequences for Norwegian cities of the various recommendations made in connection with Revision 1 of the EC Daughter Directives. The current study, which looks at the results of modelling studies for 2003 of PM_{10} and $PM_{2.5}$, is part of a larger study intended to assess the impact of these recommendations by performing model simulations of ambient PM_{10} and $PM_{2.5}$ concentrations, as well as population exposure, in 2010 and 2015 for Oslo.

The problem of resuspension of particulates from road surfaces is well known but the ability to model this form of emission is not. Recently improvements have been made to the resuspension model used in the AirQUIS modelling system (Tønnesen, 2005). This is the system currently applied in Oslo, and several other Norwegian cities, to assess strategies for improving air quality. This paper deals with the evaluation of model simulations for PM_{10} in Oslo for the year 2003. An improved emission model for traffic induced resuspension is tested and the model concept is validated against available PM_{10} measurements.

2. METHODOLOGY

Modelling

The modelling system applied to simulate concentrations of particulates in this study is the AirQUIS modelling system, developed at NILU (AirQUIS, 2004). AirQUIS is a PC based integrated management system that includes a user interface, an extensive database solution, a comprehensive emission module, a suite of models for use in simulations, exposure models and a GIS based system for presentation and analysis.

The models used in the calculations are the MATHEW diagnostic wind field model (Sherman, 1978; Foster et al., 1995) and the EPISODE dispersion model (Slørdal et al., 2003). This dispersion model contains a standard Eulerian type model for calculating concentrations from area emissions as well as the line source model HIWAY-2 (Petersen, 1980) which is used to calculate traffic related contributions at receptor points close to roads.

The grid applied in the Oslo region is a 22 x 18 km grid, grid size 1 km, with 10 vertical levels up to 2400 m. The meteorological field is calculated with MATHEW using input from a meteorological mast. Calculations are carried out for a period of 1 year, 2003, and results at receptors points corresponding to the positions of monitoring stations in Oslo are recorded for comparison with observations. Average concentrations and exceedence fields are also used for mapping and exposure calculations. Background concentrations for the model are taken from a regional background station.

Emission from traffic is introduced into the model in two separate ways, namely as area or as line source emissions, dependent on the average daily traffic intensity. The Eulerian model is applied to calculate the concentrations levels in the model grid system and in individual receptor points. At receptor points close to main roads, where most monitoring stations are placed, the HIWAY-2 line source model is applied to estimate the contribution from the nearest roads. The contribution of road related sources greater then 500 m from the receptor points is calculated solely through the Eulerian model.

The emission model for traffic-induced resuspension of particulates is dependent upon traffic speed, heavy-duty vehicle fraction, percentage of studded tyres and road surface condition (Tønnesen, 2005). Due to the difficulty, but importance, in determining the state of the road surface (dry/wet) from available meteorological data, the surface condition is defined based on meteorological and monitoring station data (e.g. temperature, dew point temperature, precipitation).

Emissions of PM from wood burning are introduced into the model as area sources into the three lowest levels of the Eulerian model (71 m). These emissions are based on factors derived from wood consumption, fireplace type e.g. (Finnstad et al., 2004).

Measurements

Measurements of PM_{10} and $PM_{2.5}$ are carried out at 7 stations in Oslo using TEOM instruments. Hourly averages are available from two of theses stations for the entire 2003 period. These stations, Kirkeveien and Løren, are analysed in this study and are representative of traffic/wood burning and traffic stations respectively. In 2003 the number of days when the daily average concentration of PM_{10} exceeded 50µg/m^3 was 37 and 60 respectively at these two stations.

3. RESULTS AND DISCUSSION

Results of the model calculations have been compared to observed levels of PM_{10} at the two stations Kirkeveien and Løren for the year 2003. The statistical comparison is summarized below in Table 1.

Table 1: Statistical comparison between hourly measured and calculated concentrations of PM_{10} at Kirkeveien and Løren for 2003.

Unit (µg/m^3)	PM10			
	Løren		Kirkeveien	
	Obs.	Calc.	Obs.	Calc.
Average	33.6	28.1	27.2	19.1
Standard deviation	40.1	44.1	27.2	26.1
Maximum	391.7	533.1	534.9	367.1
Correlation coefficient	0.57		0.49	
Slope regression line	0.63		0.48	
Intercept	6.96		6.42	

By way of example, PM_{10} results are also presented as a time series for the month of March in Figure 1 for the traffic station at Løren. During this period the road surface and road shoulder became dry, 13.03.2003, leading to the availability of a large amount of accumulated dust. In addition, during this period, wind speeds were low with strongly stable conditions prevalent in the period 13 – 20 March. As a result high concentrations of PM_{10} were observed, up to 300 µg/m^3 as hourly means, with daily averages exceeding 148 µg/m^3. As seen in the figure these extreme PM_{10} levels are well reflected in the model.

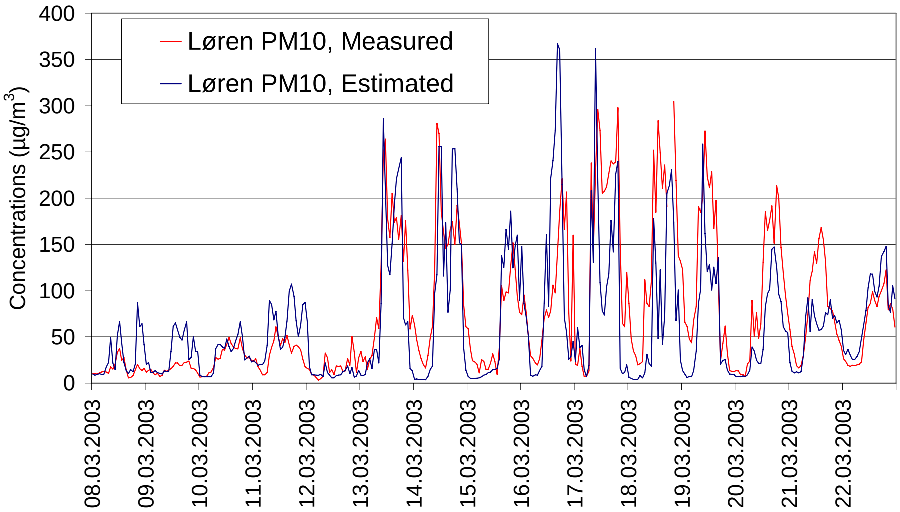

Figure 1: Observed and calculated PM_{10} levels during March 2003 at Løren.

For the year 2003, the calculated daily average concentrations of PM_{10} are shown, in order of descending concentration, in Figure 2 for both observations and model calculations. For the station at Løren there is good agreement between model and measurements though not all peak values are captured and the lower concentration levels, corresponding mostly to summer time periods, are also underestimated. However the number of exceedences is well modelled. At Kirkeveien the daily concentrations are slightly underestimated.

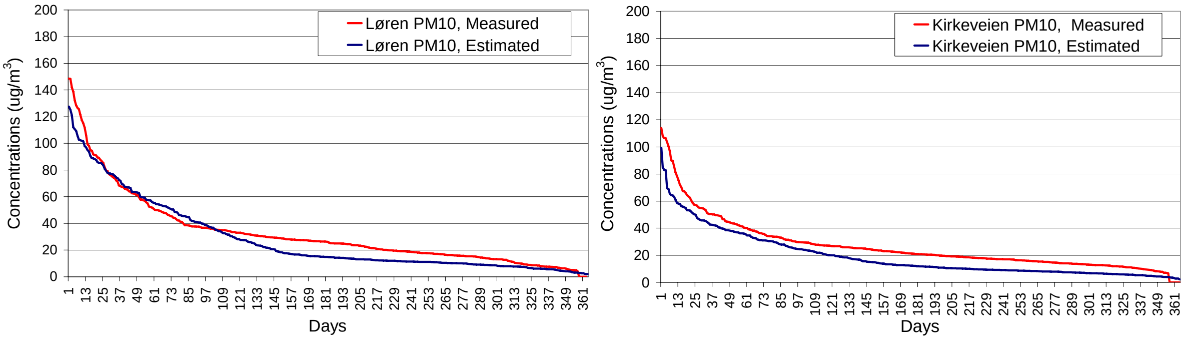

Figure 2: Unpaired daily average concentrations of PM_{10} ordered in descending concentration for the stations Løren (left) and Kirkeveien (right).

The ability of the model to correctly simulate particulate concentrations is dependent on many factors but these can be essentially split into 3 aspects; the models description of meteorology, of emissions and of transport processes. For traffic related stations the correlation between observed and calculated concentrations is to a large extent dependent on the timing of traffic. Meteorological information, used in the model, also influences correlation. The station Løren, which is situated closest to the meteorological mast used as meteorological input, shows the best correlation of all the stations in Oslo, for all pollutants.

The emission model for resuspension of particles is currently empirically adjusted emission intensity in order to reflect road surface conditions. This is necessary because the data required for establishing road wetness is not available. Even though near surface humidity stations could be established near roads, the complexity of the surface coverage, e.g. snow on curbs, and its small-scale spatial variability may make such objective determinations unreliable. However, it is clear that much can be gained by improvements in the resuspension model. This will in the future require active field campaigns and committed sensors for detection of road surface conditions.

The model used to determine near road concentrations is an open line source model. In reality most stations are only partially 'open' and many are significantly influenced by nearby buildings and other obstacles. The largest deviations between calculated and observed values often occur when wind directions are not properly defined for the line source model.

4. CONCLUSIONS

The model evaluation presented in this study shows that the applied AirQUIS system is able to reproduce observed PM_{10} concentrations rather well. The system is consequently well suited for studies of air quality exceedences of the proposed limit values of the EC Daughter directives. On request, by the Norwegian Pollution Control Authority, NILU has examined the consequences for Norwegian cities of the various recommendations made in connection with the first revision of these directives.

One of the main challenges in modelling the high percentiles of PM_{10} in Norwegian cities is linked to the process of traffic-induced resuspension. It is therefore of high importance to estimate the particle emission well during these episodes. One of the main problems is to define the state of the road surface (ice coverage/wetness), which to a large extent determine the source strength of the resuspension. The emission model for resuspension of particles is currently empirically adjusted in order to reflect road surface conditions. This is necessary because information about the reservoir of dust particles is lacking and data required for establishing road wetness is not available. It is clear that much can be gained by improvements in the resuspension model. Knowledge about the emission intensity from these reservoirs over time together with information about surface condition is critical. This will in the future require active field campaigns and committed sensors for detection of road surface conditions.

5. ACKNOLEDGEMENTS

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