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Emission model for roadside emissions of PM_{10}

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ABSTRACT

Vehicular emission and resuspension of particles caused by traffic are an important source for air pollution. In Nordic countries the use of studded tyres provide an additional source. An emission model for particulate matter from traffic sources has been developed, providing hourly emission rates for $PM_{2.5}$ and PM_{10} from vehicular traffic. It is used as a part the AirQUIS modelling system. For exhaust particles, emission factors are used. For the road dust, data from measurements close to roads have been used to derive empirical factors for the emission. An emission reduction algorithm for non-dry conditions has also been made.

1. INTRODUCTION

An operational model for hourly emissions of particulate matter (PM_{10}) from road traffic has been developed in several stages. The first version was designed to be able to calculate the emissions for dry road conditions during the season when studded tyres are in use. The next development included calculations for the reduction of emissions, due to meteorological conditions, using parameters available to the dispersion model. Subsequent adaptation of the model to different cities showed the need for local adjustment of the empirical factors. Examples are shown for the adaptation of the model to Stockholm, and a revision used in hourly hindcast calculations for a winter season in Oslo.

2. METHODOLOGY

Initial development

In order to quantify the source strength of the resupended roadside dust, some basic assumptions were made. The dependency of emission strength on the percentage of heavy vehicles for resuspended road dust was assumed to be linear, and the dependency on the average driving speed was assumed to be quadratic. In addition, the amount of dust available for resuspension was assumed to be linearly dependent on the use of studded tyres decreasing from 1 to 0.02 with decreasing studded tyre use from 100% to 0%. For a roadside measurement site it was assumed that the emission ratio for coarse fraction dust ($PM_{10} - PM_{2.5}$) to fine fraction dust ($PM_{2.5}$) would be directly proportional to the measured concentration ratio during hours with high concentration levels. Based on roadside measurements of particles, it was further assumed that near all of the coarse fraction dust would originate from the road surface, and that the amount of fine fraction dust from road surface was small compared to the coarse fraction.

Hourly measurements of roadside concentrations of PM_{10}, $PM_{2.5}$, traffic volume, traffic speed and heavy vehicle fraction made in Oslo were used to determine the linear coefficients for the dependency of the heavy vehicle fraction. This was achieved by a comparison of the concentration ratios for coarse fraction dust versus fine fraction dust for different heavy vehicle fractions. This was done for only the observational hours with the highest coarse fraction, since wet road surface conditions will severely limit the resuspension. From a separate analysis made on source contributions in dust pollution episodes (Larsen and Hagen ,1997), the ”episodic” fine particle contributions from road dust and exhaust particles were derived. The emission of exhaust particles pr. vehicle was calculated from exhaust particle emission factors and then divided by the ”episodic” exhaust particle fraction to get the combined fine road dust and exhaust particle emission. Equation 1 shows the resulting expression for emission pr. vehicle of PM_{10} for dry road surface conditions.

$$(1) \quad QPM = Q_{EP} + (QR_{2.5} + C * (A* TT + B) * (VD / VDref)^2) * (0.98* ST + 0.02)$$

where
QPM is the emission pr vehicle (g / vkm)
Q_{EP} is the average exhaust particle emission for the actual road (g/ vkm)
$QR_{2.5}$ is the emission of fine particles from the road (g/ vkm)
C is the emission of fine particles from the measurement series (0.24 g/ vkm)
A (0.258) and B (1.436) are the derived linear constants for heavy traffic

TT is the percentage of heavy vehicles (% of vehicles with weight > 3.5 tons)
VD is the driving speed (km/h) and VDref is the driving speed at the measurement site
ST is the fraction of in-use studded tyres.

Emission reduction due to surface condition

To be used for hourly emission calculations, a function for emission reduction due to non-dry (wet, snow-covered, ice, frost) conditions was introduced. The first simplified expression was derived by using the time elapsed since the last hour with precipitation to calculate a reduction factor increasing from 0.05 during precipitation to 1 if 8 hours had gone by without precipitation.

The emission reduction routine was later improved using data collected by the Norwegian road authorities (Tønnesen, 2003). These data included measurements of precipitation, temperature, dewpoint temperature, road surface temperature, road surface classification, vehicle counting and roadside concentration level of PM_{10}.

First, the concentration distributions of roadside dust during periods with different road classifications was examined and compared with each other in order to estimate the effect of the classified conditions on concentration level, and thus on emission intensity. By calculating the simplified reduction factor and comparing it to the actual road classifications a more elaborate scheme for emission reduction was made, taking into account the temperature balance between air and surface and sub-zero temperatures as well as precipitation effects. The main result was to reduce the time from stop in precipitation to non-reduced emission from 8 hours to 4 hours and to include the reduction effect of dewfall and frost. Table 1 shows the improvement in model ability to describe the road surface conditions.

Table 1. Effects from the improved routine to describe the road surface conditions based on standard meteorological parameters. Results are presented as a matrix for comparison of the number of observed and modelled hours for wet, transition or dry conditions. The original result / The revised result are shown for each condition.

	model wet	model transition	model dry
observed wet	111/106	90/104	14/0
observed transition	129/116	448/1014	872/509
observed dry	37/7	284/127	2306/2303

3. MODEL IMPROVEMENTS

Adaptation to Stockholm

The model has also been adapted for Stockholm in Sweden deriving separate emission factors to fit local conditions. In this adaptation, measurements of nitrogen oxides and particulate matter (both $PM_{2.5}$ and PM_{10}) from roadside and rooftop measurements where used. Nitrogen oxides were used as a tracer gas for vehicular emissions by calculating the ratio between emission as described through the Swedish emission factors and the measured concentration. This ratio was multiplied by the measured coarse fraction dust concentration, producing an hourly emission estimate. The A, B and C in equation 1 was then changed to give a best fit to the tracer calculated emission, including only cases with a significant road dust contribution with an hourly measured concentration of 100 $\mu g/m^3$ or more. The adaptation provided factors that were significantly higher than for Oslo as shown in table 2.

Table 2: Empirical factors A, B and C used in Equation 1, for Oslo and Stockholm

City	A	B	C
Oslo	0.258	1.436	0.24
Stockholm	0.62	3.32	0.54

In figure 1 the dispersion model results for a monitoring station is shown for the two different sets of constants, compared to the monitoring results, clearly showing the better performance of the locally adapted model.

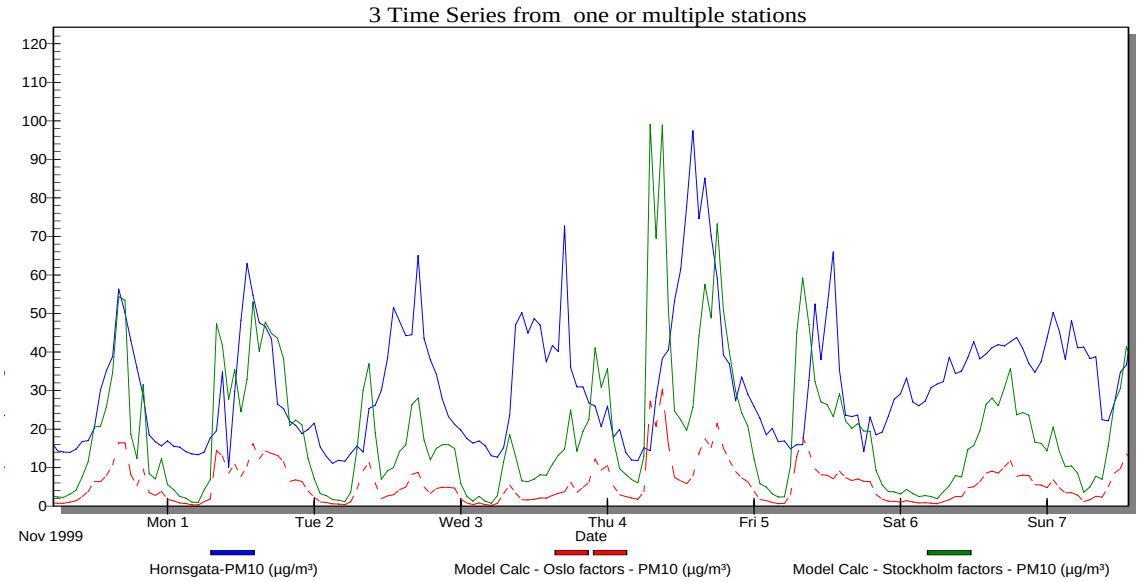

Figure 1: Modelled and measured concentrations of PM10 at a roadside location in Stockholm for unadapted (red) and adapted (green) emission model. Measurements are shown in blue.

Model adjustment in Oslo

Using the combined emission and dispersion model and comparing the results with monitoring results indicates that although the model provided reasonable results for most of the winter season, there are episodes, sometimes during autumn and very often in spring that the actual dust concentration level is systematically much higher than the model results (Laupsa et al., 2005). Simultaneous measurements of PM_{10} and $PM_{2.5}$ at roadside stations showed that their ratio significantly increased in the periods that the model underestimated the concentrations. The appearance of the springtime episodes is believed to be connected to a roadside deposit of dust that has built up during the winter and is released when it becomes sufficiently dry. This effect is not an integral part of the model at the moment. A preliminary solution for diagnostic modelling has been to increase the factor C in the emission equation during the periods as indicated by measurements. Examples of such adaptations are shown in figure 2 where unpaired daily average concentrations for PM_{10} are sorted in decreasing concentration. The figure shows the models ability to recreate the number of days at high concentration levels.

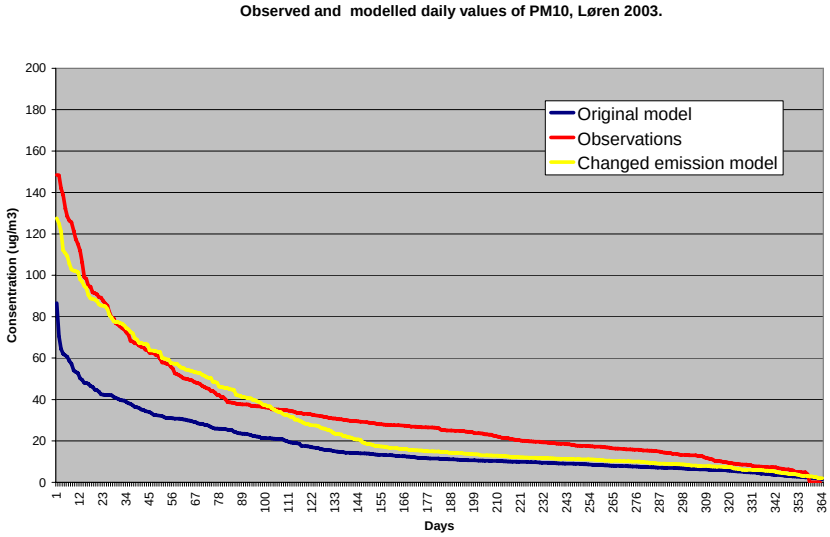

Figure 2: Unpaired daily average concentrations sorted in decreasing concentration level from a roadside location in Oslo. Measurements are compared to the unadjusted and adjusted emission model.

An improved description of the changes in road surface conditions and road shoulder conditions in time would be necessary to be able to model these episodes without such an adaptation. Comparisons with summertime monitoring results for roadside dust concentrations also indicate that the model dust generation outside of the studded tyre season is too low in the current model concept.

4. CONCLUSIONS

The dust emission model still requires further development in order to be able to describe high intensity periodes of road dust releases occuring in the spring. A better description of the fine fraction particles originating from the road is also needed. When more measurements of roadside concentrations in the summer season is available, a better expression for the dependency on use of studded tyres can be formulated. Despite its aknowledged shortcomings, the emission model provides crucical input to the dispersion modelling and awarness of the model weakness allows for adjustments to improve the result for diagnostic model runs.

5. ACKNOWLEDGEMENTS

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