NORPAC workshop at Norrköping 2005-10-04 to 2005-10-05.

Summary and conclusions

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Agenda

Workshop on modelling of PM emissions in different Nordic traffic environments SMHI 4-5 October 2005		
	Preliminary program	
Tuesday	**4 October**	
1200 -1300	**Lunch**	
1300-1315	Welcome	Gunnar Omstedt and Matthias Ketzel
1315-1330	Status of the Nordic database	Lars Gidhagen, SMHI
1330-1415	Comparison of exhausted and non-exhausted emission factors in Northern Europe	Matthias Ketzel, NERI
1415-1500	Dependence of PM_{10} concentrations in Stockholm on road moisture, studded tires, wind speed, dust binding CMA and road cleaning	Christer Johansson, ITM/SU
1500-1530	**Coffee**	
1530-1615	Results of PM_{10} and $PM_{2.5}$ calculations with OSPM using standard emission factors	Ruwim Berkowicz, NERI
1615-1700	Particle emission work at Finnish Meteorological Institute	Jari Härkönen, Mervi Haakana and Mia Pohjola, FMI
1700-1745	Modelling of PM emissions at Hornsgatan, Jagtvej and Runebergkatu	Gunnar Omstedt, SMHI
1900	Dinner at La Mansion	
Wednesday	**5 October**	
0900-0935	Comparison of different approaches to obtain size distributed emission factors of submicrometer particles from traffic	Sara Janhäll, GU
0935-1010	Speed reduction, effects on roadside PM_{10}. Results from Oslo	Dag Tonnesen, NILU
1010-1045	PM_{10} from road pavement and winter tyre interaction	Mats Gustafsson, VTI
1045-1200	**Discussion and summary**	

Short summary for each talk

All the talks are accompanied by the power point presentation presented at the Workshop, except the welcome by Gunnar Omstedt and Matthias Ketzel.

Welcome by Gunnar Omstedt and Matthias Ketzel

Everyone was welcomed by Gunnar.

The purpose of these NORPAC meetings is to stimulate the Nordic cooperation. There are similarities between the countries: traffic situation and the weather but also interesting differences, such as the use of studded tyres, which gives a unique possibility for comparisons.

The aim of this workshop is to draw some conclusions and to think about possible further work.

Matthias emphasized that it is important to give thanks to NORPAC for the funding when submitting abstracts to conferences (and presenting at conferences), for example to the NOSA conference. It is also important to show results from NORPAC at conferences such as NOSA.

The next NORPAC meeting will be in Gothenburg at 2:nd of November (the evening before the NOSA-conference). Planning for a (possible) next year will take place at that meeting.

A status report is due 15: th of December. We have to do better in this report compared to the last.

Lars Gidhagen: Status of the Nordic database

The database has been under development since the beginning of NORPAC. The database is easily accessible and the data is somewhat prepared and quality checked, but there is still need for some caution.

Data from three different streets were discussed: Jagtvej in Copenhagen, Hornsgatan in Stockholm and Runeberg Street in Helsinki. The streets have close to the same geometry, but the meteorology differs somewhat. The Copenhagen Street is more windy. PM10, PM2.5 and NOx are measured as well as meteorology.

The diurnal variation is similar for the three sites. The daily variation of NOx shows that Hornsgatan has the highest values. One reason for Copenhagen having lower values is the wind situation – the measurement is made on the windy (not windward) side. There was some discussion as to what type of traffic that is important for the emission factors. The heavy duty traffic at Hornsgatan is mainly ethanol busses and not diesel driven, as opposed to Jagtvej.

For the daily accumulated PM10, the number of days with higher concentration is higher for Hornsgatan than the other streets, but for lower concentrations the number of days was more for the other streets.

There is a problem in Helsinki that the background values are sometimes higher than the street values. This would be helped if the background measurements were conducted at the rooftop instead of in an open area as it is today. There is also roof top data available for the winter 2003/2004 period (Kaisaniemi).

There is no springtime peak in Copenhagen (Jagtvej or HCAB=H.C. Andersen Boulevard) but there is such for the two other stations (Hornsgatan and Runeberg street). This is due to the use of studded tyres in wintertime in Sweden and Finland, but not in Denmark.

Matthias Ketzel: Comparison of exhaust and non-exhaust emission factors in Northern Europe

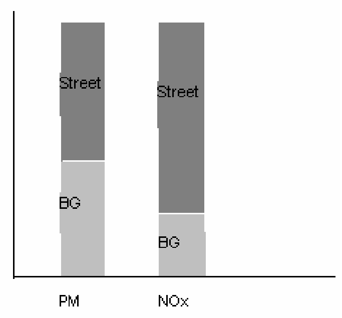

Figure 1. Scematic fractions of street and background for concentrations of Nox and PM in the street canyon.

The topic of this workshop is the street emission of PM, see Figure 1. The contribution to the street emission is exhaust and non-exhaust emissions. The street emissions of PM can be divided into direct emissions and road resuspension. The direct emissions being: exhaust (bigger part in Copenhagen), brakes, clutches (smaller part); and the indirect emissions being: tyre (road) wear and resuspension. We don't know how much different vehicles, velocities etc. affect the resuspension.

The aim is to make a model for using NOx as a tracer. Subtract the background from the street concentrations. A correction factor as sometimes used for TEOM data (e.g. 1.2 or 1.3) is therefore not used here. This depends on the emissions, if the main part is exhaust or other emissions (not road wear).

Again the plots of the emission ratio (dPM/dNOx) show a seasonal variation for Hornsgatan, but not for Jagtvej. Hornsgatan has a springtime peak at 0.17 g/g (dPM2.5/dNOx) as emission ratio, whereas the typical summer emission factor is between 0.02 and 0.05 g/g. These values are true for all the stations.

The emission ratios (PM10/NOx) are typically 0.05-0.15 for Runeberg street and Hornsgatan (except at spring). For Jagtvej dPM10/dNOx is 0.08 and the correlation is good (R^2 about 0.50) and for HCAB this value is about 0.1 and the correlation is much worse. How to explain this? The model can not. Some outliers occur during dry periods but not always! There should be an increase in resuspension during dry periods but this pattern is not always evident. It could be the organic material (leaves from trees etc.) affecting HCAB.

What should be done is to single out the dry periods and analyze these separately.

The German method has given no speed dependence on highways in PM10-non-exhaust emission factors. Higher speed dependence at slow speeds and a strong dependence on traffic situation (stops/acceleration). But in Germany and Denmark there is no use of studded tyres.

A comparison between different methods and the emission factors achieved with these was shown.

A comment on the importance of the exhaust part of the emission factors was made, it is important to make emission factors separating between exhaust and non-exhaust (and perhaps more classes) so that the effects of regulation of exhaust in Denmark (with filters in cars etc.) can be checked through measurements and modelling.

One conclusion is that the road wetness is badly correlated with the emission factors, which should be worked out further.

Questions for the future are the influence of driving speed, rain, bad road surface conditions and why there is a big difference between Jagtvej and HCAB.

Additional information: The summary of the recent Danish report on particle pollution: can be found under: http://www.dmu.dk/Nyheder/ar212.htm

The full report (in Danish) but including an English summary can be downloaded under: http://www.mst.dk/default.asp?Sub=http://www.mst.dk/udgiv/publikationer/2005/87-7614-720-7/html/

The chapter 3.2 on the traffic related particles contains results of the receptor analysis used for quantifying the different particle sources.

Christer Johansson: Dependence of PM10 concentrations in Stockholm on road moisture, studded tyres, vehicle speed, wind speed, dust binding CMA and road cleaning

A conceptual model for PM emission was presented. Instead of resuspension, Christer wants to use the word suspension instead of resuspension. There is a road wear from which there is a direct wet and (mostly) dry emission, but also there are indirect emissions due to deposited material which are mainly wet deposited and other sources such as sanding, brake and tyre material and salting. These are suspended from the road surface depending on the vehicle, wind, whether the road surface is wet or dry and the slope of the road. The emissions evolving in time, having a depot in which material is deposited when the direct emissions are decreasing (wet periods) and during dry periods the indirect emissions deplete the depot (if the conditions are dry long enough).

CMA will be used to keep down the suspension of PM in Stockholm.

Ruwim Berkowicz: Results of PM10 and PM2.5 calculations with OSPM using standard emission factors

Ruwim showed some results from OSPM.

What can be seen is that it is especially difficult to model October-November. A few days with very high measured NOx-values (where the model underpredicts).

The model has a much better resemblance to measurements for Jagtvej than for HCAB, as described by Matthias Ketzel. The reason could be asphalt, biological material or traffic speed or… It is vehicle related since there is a diurnal variation, but not exhaust related.

The share of trucks/lorries could also be of importance, but when comparing to a site in London, the traffic is similar to HCAB, but the modelled and measured data gives a perfect fit. So there is another reason.

The stability is not a parameter in the model OSPM, which should on some occasions cause problems, since a lid could be created on top of the street emissions causing very high concentrations which the model will not capture.

Mervi Haakana:

About Runeberg street measurements and exhaust emissions in congested flow.

The reasoning for this study was that average speed is less important descriptor of emission factors in newer cars. The study was coordinated by TRL (UK) and it was part of the EU/OSCAR project (2002-2005).

At first, driving cycle measurements and characterisation of each link were made. Following, the grouping of links due to descriptors, such as, number of cars per km per lane and average velocity. The characterisation and driving cycle measurements were made using a mobile unit (a car), reporting parameters such as time, rpm, vehicle speed etc.

For each link group, driving cycles for dynamometer emission tests were developed. Different types of cars (LDV) were used in the study, driving through the driving cycles. On the basis of the preliminary results, the average PM emission rate for diesel passenger cars was about 40 mg/km in urban driving (below 50 km/h). With different driving cycles, the PM emission rate typically varied between 20 and 60 mg/km. There was not much difference between the cars, except for one being higher having a stronger engine.

Look at the home page www.eu-oscar.org for further information.

Mia Pohjola: Modelling of emission in a roadside environment

Measurements at different distances to a 3x2-lane road at occasions of wind being perpendicular to the road been made during four days in February 2003. The site is close to the city centre of Helsinki. Measured are meteorology, traffic flow, urban background and exhaust aerosol number concentrations combined to six size modes.

Models have been used to look at the aerosol process during the transport from the emission (street) to the measurement sites. The model used for aerosol processes was MONO32, meteorological parameters were obtained from the meteorological pre-processing model MPP-FMI, and the dilution description used in MM32 runs was obtained from the roadside dispersion model CAR-FMI. Size distribution was modelled with 6 bins (bin limits in accordance with the measurement data). One problem with this is the effect of traffic induced turbulence not being included in the build-up of the road emission over the lanes, only accumulation of emitted particles according to wind speed. Because there is no measurement data on the chemical composition the modelling results regarding this aspect of the particles cannot be validated.

Jari Härkönen: Statistically estimated seasonal PM2.5 emission factors at Vallila

A computational NOx-tracer- method has been used to calculate the emission factors of PM2.5. Measurements of urban background of NOx and modelled background for PM2.5 based on the ionsum method (Karppinen et al. in Scand J Work Environ Health 2004; 30, 2: 47-53) were used. The ratio of PM2.5 to NOx from the road is estimated by a General Linear Model including the interaction term between relative humidity (RH) and stability (L^{-1} = inverse of MO-length). The interaction RH*L^{-1} associates with the contributions of local and LRT background of PM2.5, which are favoured in different humidity-stability conditions.

The test was limited to one-year time-series (2002) grouped into winter, spring, summer and autumn periods. As discussed, the problems of studded tyres and sanding might diminish by adding new variables to the regression: a monthly function for studded tyres and hourly function of temperature with time-lag for sanding. The best correlation was achieved for spring and autumn, when the estimated ratio of non-exhaust to exhaust emission factor was 5-

7. According to the discussion the exhaust part should be larger than the 18 mg/vkm stated in the presentation, which decreases the ratio.

Gunnar Omstedt: Modelling of PM emissions at Hornsgatan, Jagtvej and Runebergkatu

A model was presented for calculation of PM emissions in traffic environments (Omstedt et.al, 2005. Atm. Env. 39, 6088-6097). Input to the model is meteorological- and traffic data. For the summer period a simplified model was used taking into account the wetness of the road. During the winter season a more complicated model was used, taking into account variations in dust loads as function of studded tyres and sanding, wetness of the road and how dust suspension interacts with these processes. In the model the emission factor is divided into a direct and a suspension part. The moisture amount at the road surface is calculated taking into account precipitation, evaporation and run-off.

Good results (when comparing to measurements) are displayed for Hornsgatan both for the year 2000 and for the year 2004. For Jagtvej the results were not better than the results using a constant emission factor. Precipitation and the wetness of the road were not important for Jagtvej but important for Hornsgatan. One explanation could be that wetness of the road is only important for dirty streets and Jagtvej is a rather clean street compare to Hornsgatan. For Runebergskatu the agreement between calculated and measured concentrations was rather good with some exception where the model over predicts the concentrations. The reasons for that were discussed: caused by snow or a result of street cleaning?

There was an objection to the point 3 in the conclusions that the dust reservoirs at edges of streets due to sanding and road wear cause high PM10 concentrations. This is however not well known. They can be important sources for the spring peaks in concentrations.

Sara Janhäll: Size distributed traffic emission factors

Using inverse modelling. A method has been developed to model the emission ratio (ER) for a size distribution. The model is applied to a large dataset (Jagtvej). The NOx tracer method was used. Only one measurement site is needed, since the lowest traffic hours were used as background and the highest traffic hours were used as input data. When the NOx was at its lowest values, the traffic was regarded as low and when the ratio NO/NO2 was at its peak the traffic was regarded as high. The method is not sensitive to the level used, but here 20% of the data was chosen as the limit for both high and low traffic.

The dataset was split into different categories and analysed for differences depending on time of day (no dependence in ER of hour), night (bigger dependence on hour, due to low traffic intensity, other vehicles than during day, to small dataset to distinguish between week days and weekend days = ”taxi effect”, difference in background and traffic being to low), temperature (colder means more particles than at hotter occasions, also a shift towards smaller particles when colder), global radiation, humidity, wind speed,…

One question raised was the effects of differences in geometry causing different downward mixing of ozone from above which could affect the choosing of high versus low traffic occasions. It would be interesting to investigate the dependence in the model of different geometries.

There is always a need to be cautious when dealing with or without background stations. If a forest fire causes high concentrations a background station would notice but on the other hand a nucleation event would cause bad results when having one.

The question of looking at PM10 or PM2.5 instead of number/size distribution is a problem since the relative difference between background and street concentrations is so small.

The importance of placing the measurement equipment at the right distance from the exhaust pipes was stressed, to represent the correct timescales (1/2 to 1 hour).

Dag Tonnesen: Effects on roadside PM10 of a speed reduction results from Oslo.

Does a speed reduction affect the air quality positively close to the road? During one winter season the speed limit was reduced from 80 to 60 km/h (the average speed was reduced from 77 to 67 km/h compared to the reference period). The difference in traffic, and PM, NOx, inorganic fraction and organic fraction was investigated. The result were compared between stations (one speed reduced and several with no speed reduction) for a reference year and the reduction year. For the reference year the number of cars was about 3 % less. The largest reduction was in the coarse fraction of PM, about 30 % less. The monthly average PM was higher for the station than the average of the other stations for the reference year but for the reduction year the opposite was true.

One question was whether this study was scientifically correct? The whole situation could be different for the reduction year than for the reference year. The answer was that the uncertainties such as the use of studded tyres and the climate that could change from year to year would be different for all stations and since the changes were compared only within the year between stations in Oslo, and not from year to year, these effects would be filtered away.

The physical principle behind the results is that the force of the wheels on the ground increases with the square of the speed, which should mean velocity dependence.

It would be interesting to look at the ratio PMcoarse/NOx to see the effect of speed reduction on emissions.

Mats Gustafsson: PM10 from road pavement and winter tyre interaction

Within a laboratory, with no contribution to the levels except from the experiment itself, experiments have taken place running winter tyres on different asphalts.

The aim was to look at physical and chemical properties of the PM, finding factors affecting the formation and to see whether PM is a danger to health.

A remorse was that not more experiments were made varying the tyres and adding sand and washed gravel on soft asphalt. One experiment was made using studded tyres and no adding of sand or gravel on soft asphalt.

Harder asphalt (SMA, quartzite) was used in a number of experiments changing between studded or friction tyres and adding crushed stone or sand or no adding to the pavement.

The velocity was also varied, showing speed dependence, higher speeds causing higher concentrations of PM10, but no shift in maximum of size distribution. Much mineral material was found in the PM, but no material from the tyres, which was somewhat surprising. The soft asphalt gave rise to PM concentration 3 times higher than for the hard pavement. Studded tyres gave higher concentrations than friction tyres, also when using crushed material on the asphalt. However sand gave even higher concentrations, especially when using studded tyres (the worst combination).

Another surprise was the finding of a particle mode at less than 100 nm, for which the maximum had a dependence of velocity. The reason for this is unknown so far, but one suggestion at the workshop was that the reason could be ozone coming from the motor reacting with organic material from the tyres, since the laboratory was isolated this could be an explanation. The motor however did not give rise to the mode was shown through measurement.

Three reports, in Swedish, are available at the homepage of VTI: www.vti.se, the project name being WearTox.

In the future one project is to compare results for different temperatures. Also different asphalt types could have different efficiencies in holding road dust.

A discussion was brought up about the possibility in a seasonal variation in the asphalt surface due to the use of studded tyres in the winter. This could be of importance. Modelling and measurements investigating this would be interesting.

Summary and conclusions

The discussion/summary at the end of the workshop was as follows:

There is a need for modelling PM10 and PM2.5 emissions and measurement of concentration to test the models. There are two main types of situations: using studded tyres or not.

Questions to investigate and try to add in our models (if they aren't already) are: the vehicle speed, studded tyres use, road wear/depot of sand/dust layer. Salting and sanding should also be put into the models, weather data can be used if it is not known to predict when this has occurred (due to temperature and humidity).

We need to continue our work. Soon we will have a dataset from Malmö where there is a lower fraction of studded tyres (40%) which will be interesting to study further and also perhaps some further data from Gothenburg could be added to the Nordic data base.

For finding the reason of the bad model behaviour at HCAB the work will continue. Need to know the actual vehicle speeds and the type of asphalt (which could be taken from the road administration).

There is a need to make an overview over all the results: all the different models on the different datasets and to report or publish this.

There could be a seasonal change in the asphalt where studded tyres are used and this could cause differences in emission factors even during the summer period between Danish and the other streets. The differences in emission factors (especially exhaust) between different models should be looked into.

A common understanding should be reached concerning the PM10 emission factors, as to which are the important factors: exhaust, breaks, road wear etc.

Northern countries should decrease the emissions of particles related to road wear and Denmark put in filters in cars to reduce the exhaust related particles. Perhaps one should also try to decrease the traffic in street canyons which are prone to high concentrations of PM.

The data obtained in Norway should also be used in the analyses of the models, especially for investigation and implementation of velocity dependence in the models. It would be good to have the speed dependence in the models since there will be use of the model when trying to regulate the PM concentrations using lower velocities, to give background material to such political regulation in the future.

Should think about making error estimates of the emission factors. One problem is that there is so much error that it spreads everywhere. But if the most important error is identified that point can be worked on to become more accurate. Also a way to test the emission factors is to try to predict new measured data using a model developed using other data. The models should confirm that the emission factors are correct.

Different types of vehicles: what is the contribution of different sectors to the emission factors? This would be good to know. Trucks/busses/diesel/passenger cars/taxies… To exhaust the composition of traffic is especially important.